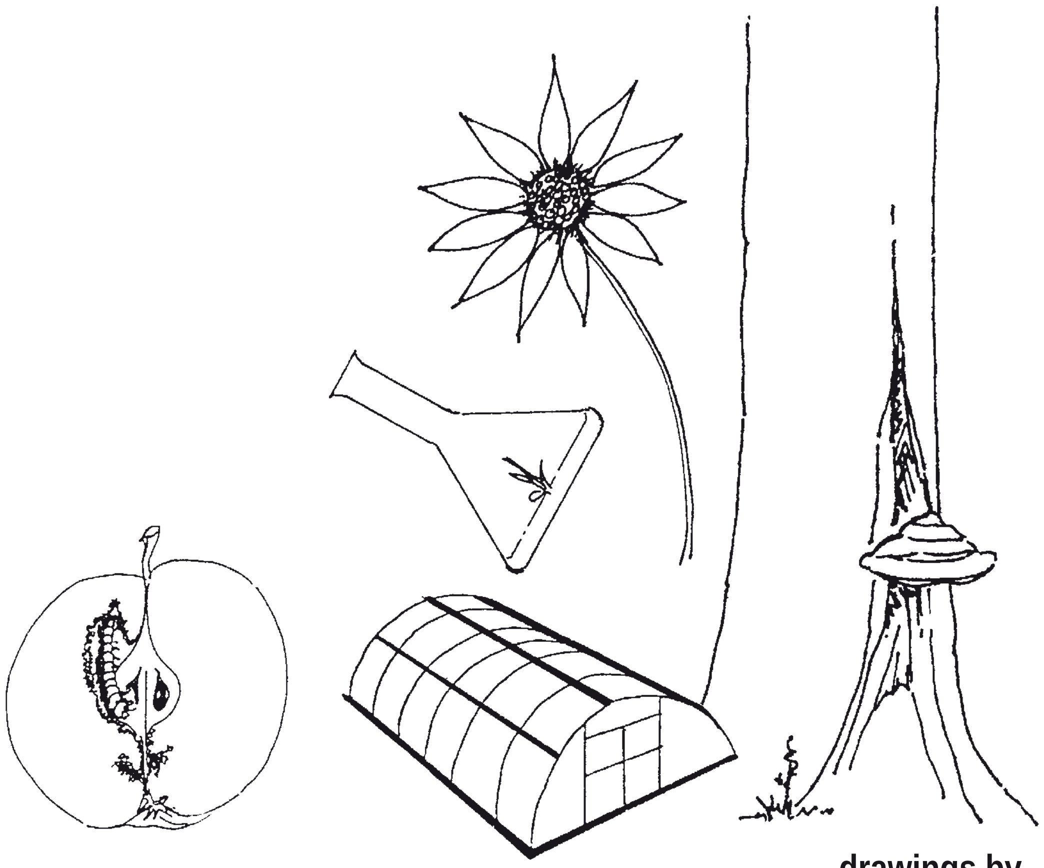
PLANT PROTECTION 3

Selected Ornamentals, Fruit and Vegetables



Ruth M. Kerruish

drawings by
Adrienne L. Walkington

PLANT PROTECTION SERIES

PLANT PROTECTION 1

Pests, Diseases and Weeds.

Pests and Diseases

- Insects and allied pests
- Snails and slugs
- Vertebrate pests
- Nematode diseases
- Virus and virus-like diseases
- Bacterial diseases
- Fungal diseases
- Parasitic flowering plants
- Non-parasitic problems

Weeds

PLANT PROTECTION 2

Methods of control.

- Cultural methods
- Sanitation
- Biological control
- Resistant varieties
- Plant quarantine
- Disease-tested planting material
- Physical and mechanical methods
- Pesticides
- Plant Management
- IPM (Integrated Pest Management)
- Organic standards,
- BMP (Best Management Practice)

PLANT PROTECTION 3

Selected Ornamentals, Fruit and Vegetables.

- Annual and herbaceous perennials
- Bromeliads
- Bulbs, corms, rhizomes and tubers
- Cacti, ferns
- Fruit and nuts
- Orchids, palms, roses
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- Turf grasses
- Vegetables
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PLANT PROTECTION 4

How to Diagnose Plant Problems.

- Step 1. The client's enquiry
- Step 2. Identify affected plant
- Step 3. Examine plant parts for signs and symptoms
- Step 4. Visit site, history, questions
- Step 5. Consult references
- Step 6. Seek expert help
- Step 7. Report the diagnosis

PLANT PROTECTION 3

Selected Ornamentals, Fruit and Vegetables

Ruth M. Kerruish
with original line drawings by
Adrienne L. Walkington

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PLANT PROTECTION 2 : Methods of Control
PLANT PROTECTION 4 : How to Diagnose Plant Problems

Front cover : *Codling moth damage to apple, wood rot fruiting body on a tree trunk.*

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ALWAYS READ AND FOLLOW LABEL INSTRUCTIONS ATTACHED TO THE PESTICIDE CONTAINER AT TIME OF USE

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This book is dedicated to the many students whose interest in Plant Protection ensured the book's completion

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Preface

Plant Protection is a dynamic field and a systematic understanding of the principles involved is necessary to permit constant updating. The systematic approach described below makes the study of Plant Protection easy and fast. It can be used in conjunction with the season-related teaching of pests, diseases and weeds.

BOOKS IN THIS SERIES

A thorough understanding of Plant Protection requires that it is studied, as far as practical, in the following order:

Plant Protection 1 : *Pests, Diseases and Weeds*

These are the causes of most plant problems. ***Some problems*** affect a wide range of plants, others a limited range. ***Diagnosis*** of the cause of a problem precedes effective control.

Plant Protection 2 : *Methods of Control*

All possible methods are considered including preventative and non-chemical methods.

Plant Protection 3 : *Selected Ornamentals, Fruit and Vegetables*

A knowledge of the pests, diseases and weeds of a particular plant allows pest management systems to be followed and plant management programs prepared. ***Most plants*** in a particular region or situation, are only susceptible to a ***few economic diseases and pests***. There are exceptions, eg carnations, some stone fruits and tomatoes. For such plants, ***diagnosis of problems*** can be difficult. ***Most plants included in this book*** are prone to problems or are important commercial and horticultural species . This book is a ***starting point*** for the collection of the type of information needed for the preparation of a plant management program.

WHAT IS IN THIS BOOK?

Plants included in Plant Protection 3:

Annual and Herbaceous Perennials	Palms
Bromeliads	Roses
Bulbs, Corms, Rhizomes and Tubers	Trees, Shrubs and Climbers
Cacti	Turfgrasses
Ferns	Vegetables
Fruit and Nuts	Other Plantings
Orchids	

Information on Each Plant is Presented in a Standard Form:

PESTS AND DISEASES

Parasitic
- Virus and virus-like diseases
- Bacterial diseases
- Fungal diseases
- Parasitic plants
- Nematode diseases
- Insects and allied pests
- Snails and slugs
- Vertebrate pests

Non-parasitic

WEEDS

Weeds are sometimes only presented in the general introductory section of each plant group.

This manual is ***not intended*** to be a comprehensive list of the diseases, pests and weeds affecting a particular plant. ***Criteria for inclusion*** of a pest or disease were based on:

Economic importance
Abundance
Interesting or
Striking appearance

Additional or different problems may occur when a plant is grown out of its natural habitat.

Information on Each Pest, Disease or Weed is Presented in a Standard Prescription Form:

Common name
Scientific name
Host range
Disease/pest cycle
Overwintering
Spread
Conditions favouring
Control
- **Cultural methods**
- **Sanitation**
- **Biological control**
- **Resistant varieties**
- **Plant quarantine**
- **Disease-free planting material**
- **Physical and mechanical methods**
- **Pesticides**
- **Pest management**

Some pests, diseases and weeds are dealt with in more or less detail than others. If the ***common name of a pest or disease*** has the ***common name of the host plant/situation*** then it is described under that ***plant/situation***, eg

Cucumber mosaic under **Cucurbits**
Greenhouse thrips under **Greenhouses**
Oleander scale under **Oleander**

If the common name of the pest does ***not indicate*** the plant, or if the host is not included in this book then the ***index*** must be consulted, eg

Twospotted mite (red spider)

Pesticides are not generally listed in this book as there are many computerised systems available which provide up-to-date information, eg Chemwatch (Melbourne), Infopest (Qld), Peskem (Qld) and the National Registration Authority (Canberra). Some industries, eg the turf industry, publish current recommendations for their particular industry. See Preface xii.

Selected references
Only key references are included.

Management
Selection
Establishment
Maintenance
Postharvest

SUGGESTED STUDY PLAN

Selected plants/situations in this book plus local key plants may be studied in more or less detail. For each plant/situation studied, a management program should be prepared. Students should choose plants/situations of their own choice, preferably to do with their work, following the steps outlined below.

Prepare a Management Program for Each Plant/Situation:

Pests, diseases and weeds of the plant
List and identify by sight, the key pests, diseases and weeds associated with the plant in that particular area. Prepare a standard prescription form (as above) for each problem.

Management of the plant
Selection
Establishment
Maintenance
Postharvest

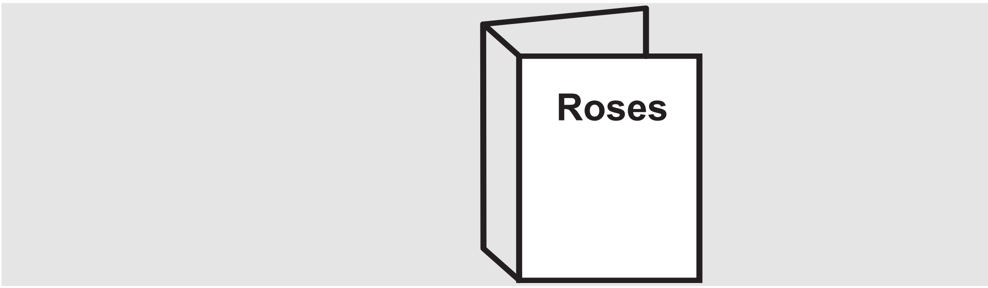
Pesticide supplement

Monthly calendar of activities

Sources of information
Human resources, eg
    Advisory services
    Growers and suppliers
Material resources
    Pest management programs for particular plants
Specific plant product guides, eg chrysanthemum, strawberry
Books, computer management programs

Problem solving
Diagnosis
    Identify the host
    Examine the plant
    Check the history of the plant
    Check reference to confirm identification and obtain information on control
    Seek expert assistance if necessary
Monitor the problem and implement control measures
Evaluate the control measures
Evaluate the management program

Presentation
The project should be held in a folder with a comprehensive index so that further information can be readily added to each section as required.



Further details of these processes can be found in Kerruish, R. M. 1990. *Plant Protection 2 : Methods of Control.* pages N 1-N 16. RootRot Press, Canberra.

PRACTICAL EXERCISE ***Prepare a management program*** for the plant, crop or situation as described above and then ***implement the program***.

Selected References

Diagnostic and Advisory Services

Agfacts, Agnotes, Fact Sheets, Farmnotes, Refnotes, other Leaflets, Books and Bulletins. Catalogues are available on request. Some States and Territories are replacing their information sheets with books and disks on diseases and pests of particular crops, these are available through their bookshops.

Most States and Territories produce books on **home gardening** and fruit and vegetable growing. **Commercial grower** advisory and diagnostic services are offered by some State/Territory Departments of Agriculture or Primary Industry. Some are free, others are cost recovery **(last updated July 2003):**

Australian Capital Territory

Insect Identification and Advice Service
CSIRO Entomology
GPO Box 1700, Canberra, ACT 2601
☎ (02) 6246 4263 **Fax** 6246 4364
email ento-ident@csiro.au
www.ento.csiro.au

New South Wales

Plant Health Diagnostic Service (PHDS)
Elizabeth MacArthur Agriculture Institute
NSW Agriculture
Woodbridge Road, Menangle, NSW 2568
☎ (02) 4640 6428 **Fax** (02) 4640 6415

Plant Pathology
Royal Botanic Gardens
Mrs Macquarie's Road, Sydney, NSW 2000
☎ (02) 9231 8186
www.agric.nsw.gov.au

Northern Territory

Entomology ☎ (08) 8999 2260
Plant Pathology ☎ (08) 8999 2264
Weeds ☎ (08) 8999 2348
Berrimah Agricultural Research Centre
Strath Road, Berrimah, NT 0828
GPO Box 3000, NT 0801
www.nt.gov.au/dpif

Queensland

Grow Help Australia
Centre for Amenity & Environmental Horticulture,
Redlands Research Station,
Queensland Dept. of Primary Industries (Qld DPI)
Cnr Delancey St and Finucane Rd, Cleveland Qld 4163
PO Box 327, Cleveland, Qld 4163
☎ (07) 3824 9526
www.dpi.qld.gov.au

GrowSearch Australia
An Information Service for Producers of Ornamental Plants. GrowSearch, Cleveland, Qld 4163
www.growsearch.net

South Australia

Diagnostic Service
SA Research & Development Institute (SARDI)
Diseases ☎ (08) 8303 9562
Insects ☎ (08) 8303 9540
GPO Box 397, Adelaide, SA 5001
www.sardi.sa.gov.au/horticulture

Tasmania

Diagnostic Services
Dept. of Primary Industries, Water and Environment
St Johns Avenue, Newtown, Tas 7008
☎ (03) 6233 6833
www.piwe.tas.gov.au

Victoria

Crop Health Services
Institute of Horticultural Development
Private Bag 15, South Eastern Mail Centre, Vic 3176
☎ (03) 9210 9356
www.nre.vic.gov.au

Cropwatch
Provides **IPM** services for commercial fruit growers in southern Victoria.
www.nre.vic.gov.au

Western Australia

Plant Laboratories
AGWEST
3 Baron-Hay Court, South Perth, WA 6151
☎ (08) 9368 3721 **Fax** (08) 9474 2658
www.agric.wa.gov.au

Turf Services

Sports Turf Consultants
Consultancy & Laboratory Services
45 Westerfield Drive, Notting Hill, Vic 3168
☎ (03) 9574 9066 **Fax** (03) 9574 9072

Globe Australia - Turf consultants
Offices in every State. Check the White Pages.
☎ (02) 9791 1111

Australian Golf Course Superintendants Assoc. (AGSCAtech)
www.agcsa.com.au/

MAILING SAMPLES FOR DIAGNOSIS

- Consult the advisory service to find out how to sample and send the specimen.
- Samples should be fresh and show early and late stages of damage.
- Insects and fungal fruiting bodies causing damage may be collected.
- For identification of plants/weeds, collect leaves, flowers and seeds where possible.
- If collecting small plants or grasses, collect roots as well.
- Do not wrap specimens in plastic or wet them, specimens rot. Use clean dry paper.

Journals

American Horticulturist
American Nurseryman
Arboricultural Journal
Arborist News
Australian Farm Journal (incl. Rural Research)
Australian Garden Journal
Australian Grapegrower & Winemaker
Australian Horticulture (inc. HortGuide)
Australian House & Garden
Australian National Flower Show (Melbourne)
Australian Nursery Magazine
Australian Orchid Review
Australian Plants
Brooklyn Botanic Gardens Gardening Guides
California Landscaping
Earth Garden
Ecos
Floraculture International
Flower Link
Gardening Australia
Good Fruit & Vegetables
Golf Course Management
Greenhouse Grower
Greenhouse Management and Production
Grounds Maintenance

Growers
GrowerTalks
GrowSearch Australia (Qld DPI, Brisbane)
Horticultural Reviews (American Soc. for Hort. Sci.)
HortScience
International Plant Propagators Society
International Society of Arboriculture
Journal of the American Society of Horticulture Science
Journal of Arboriculture
Journal of Environmental Horticulture
Journal of Horticultural Science
Journal of Garden History
Landscape Australia
Landscape Management
New Plantsman
NSW Nursery News
Nursery Industry Association of Australia (NIAA)
Nursery Industry Trade Register (NIAA, Epping, NSW)
Nursery Management and Production
Nurseryman & Garden Centre
NZ Tree grower
Ornamentals Update for Qld Nurseries
Pacific Horticulture
Parks and Gardens News
Parks, Golf Courses & Sports Grounds
Permaculture International Journal
Plant Disease
Phytopathology
Plant Protection Quarterly
Practical Hydroponics
Professional Horticulture
Sports Turf Bulletin
The Nursery Papers
Turfcraft Australia
TurfNotes (ATRI)
Your Garden

General

ACT Parks and Conservation. *Pest Management Manual.* cur. edn. ACT Parks and Conservation, Canberra.
ACT Parks and Conservation. *City Parks Handbook.* cur. edn. ACT Parks and Conservation, Canberra.
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Non-chemical control methods

Australian Quarantine and Inspection Service AQIS). *Plant Quarantine Leaflets*. AQIS, Department of Primary Industries and Energy, Barton, ACT.
Bodman, K., Hargreaves, J. and Parker, R. 1993. *Pest Control in Ornamental Crops.* Qld Nursery Industry Assoc., PO Box 345, Salisbury, Qld 4107.
Broadley, R. and Thomas, M. 1995. *The Good Bug Book : Beneficial Insects and Mites Commercially Available in Australia for Biological Pest Control.* Australasian Biological Control (ABC)/Qld DPI/RIRDC. Avail. from ABC, Tel. (045) 701 331.
Brough, E. J., Elder, R. J. and Beavis, C. H. S. (eds). 1994. *Managing Insects and Mites in Horticultural Crops.* Qld Dept. of Primary Industries, Brisbane.
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Kerruish, R. M. 1990. *Plant Protection 2 : Methods of Control.* RootRot Press, Canberra.
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Pascoe, S. 1995. *Organics on the Commercial Agenda.* Aust. Hort., Nov.
Raupp, M. J., Van Driesche, R. G. and Davidson, J. A. 1993. *Biological Control of Insect and Mite Pests of Woody Landscape Plants : Concepts, Agents and Methods.* University of Maryland System, Dept. of Environmental Management, University of Massachusetts, USA.

Pesticides

Banks, A. G., Broadley, R. H., Collinge, M. and Middleton, K. M. 1990. *Pesticide Application Manual.* 2nd edn. Qld Dept. of Primary Industries, Brisbane.
British Crop Protection Council (BCPC). *The Pesticide Manual : A World Compendium.* cur. edn. BCPC, Berks, UK.
Kent, J. 1994. *Pesticides in Australia.* Resource Manual. Charles Sturt University, Wagga Wagga, NSW.
Kerruish, R. M. 2001. *Plant Protection 2 : Methods of Control.* 3rd edn. RootRot Press, Canberra.
Pesticide Computer Packages.
ChemWatch. cur. edn. 381-383 Burnley St., Richmond, Vic.
Infopest. cur. edn. Qld Dept. of Primary Industries, Brisbane.
Australian Pesticides & Veterinary Medicines Authority (APVMA). Industry House, National Circuit, Barton, ACT.
Rice, R. P. *Nursery and Landscape Weed Control Manual*. cur. edn. Thomson Pub., Fresno, California.
Thomson, W. T. *Agricultural Chemicals*. cur. edns.
Book 1. *Insecticides*
Book 11. *Herbicides*
Book 111. *Miscellaneous Chemicals, Fumigants, Growth Regulators, Repellents & Rodenticides*
Book 1V. *Fungicides.*
Thomson Pubs., PO Box 9335, Fresno, CA.
Thomson, W. T. *Tree, Turf and Ornamental Pesticide Guide.* cur. edn. Thomson Pub., Fresno, California.
Various pesticide training packages, eg Agsafe, ChemCert, SmartTrain.

Annuals and Herbaceous Perennials

Fig. 1. Tomato spotted wilt virus infection of nasturtium causes irregular whitish blotches or a yellow-green mosaic.

Fig. 2. Tomato big bud phytoplasma (greening) infection of chrysanthemum**.**

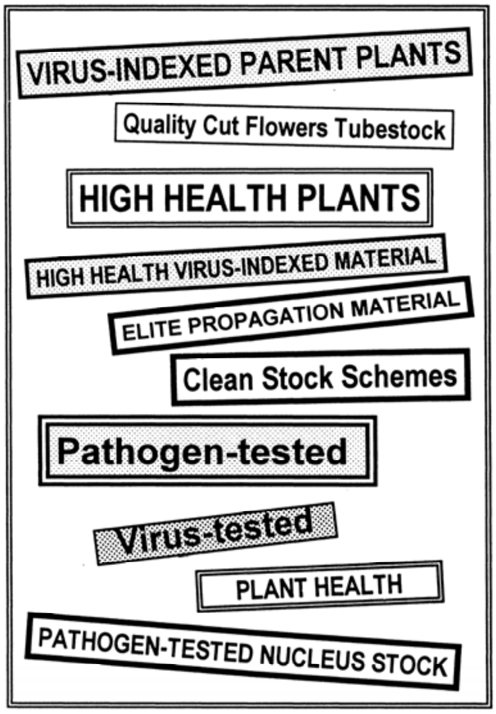

Fig. 3. Disease-tested planting material for a range of flowers is widely advertised.

ANNUALS AND HERBACEOUS PERENNIALS A 1

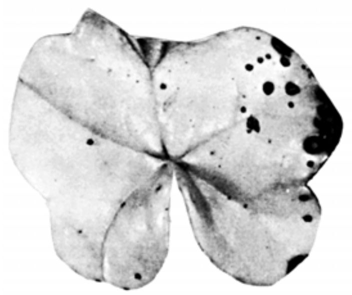

Fig. 4. Bacterial leaf spot and stem rot (*Xanthomonas campestris* pv. *pelargonii*) of ivy-leaved geranium. Dept. of Agric., NSW.

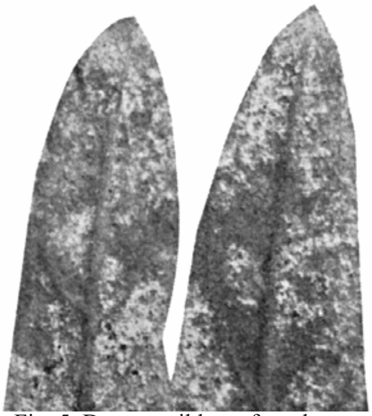

Fig. 5. Downy mildew of stock (*Peronospora parasitica*), patches of greyish mildew on leaf undersurfaces. Dept. of Agric., NSW.

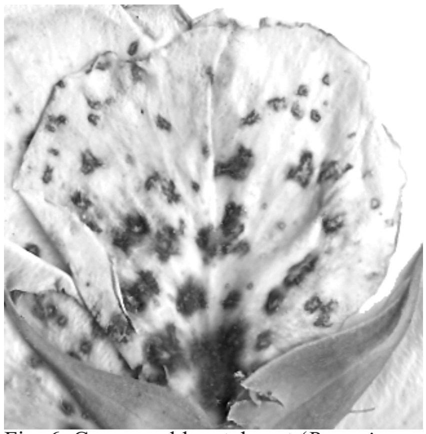

Fig. 6. Grey mould, petal spot (*Botrytis cinerea*) on rose petals, each spot represents where a spore has germinated.

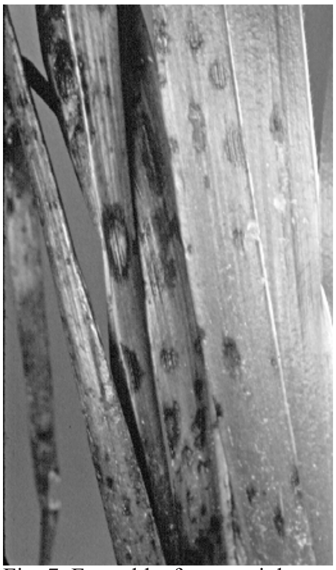

Fig. 7. Fungal leaf spot or ink spot (*Alternaria alternata*) of kangaroo paw.

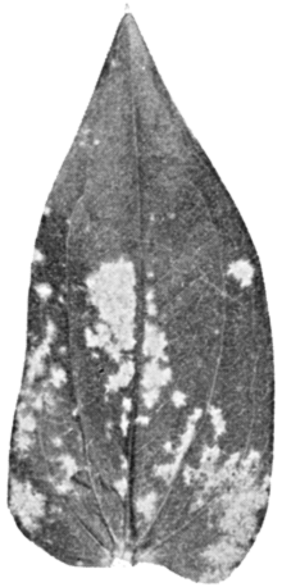

Fig. 8. Powdery mildew (*Oidium* sp.) on zinnia leaves. Dept of Agric., NSW.

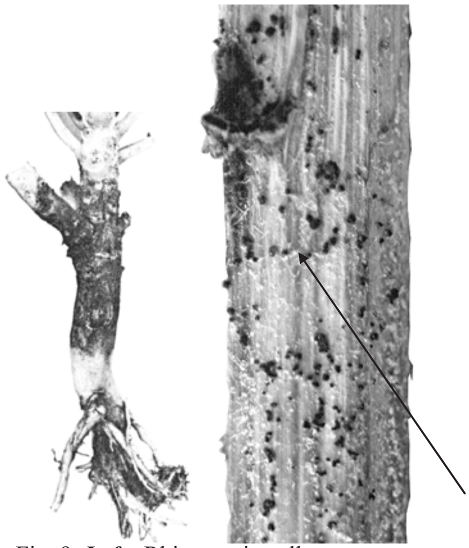

Fig. 9. ***Left :*** Rhizoctonia collar rot (*Rhizoctonia solani*) of stock. Dept. of Agric., NSW. ***Right :*** Sclerotium stem rot (*Sclerotium rolfsii)* of sunflower, note tiny sclerotia**.**

Fig. 10. Rust pustules (*Puccinia malvacearum*) develop on stems as well as on leaves of hollyhock.

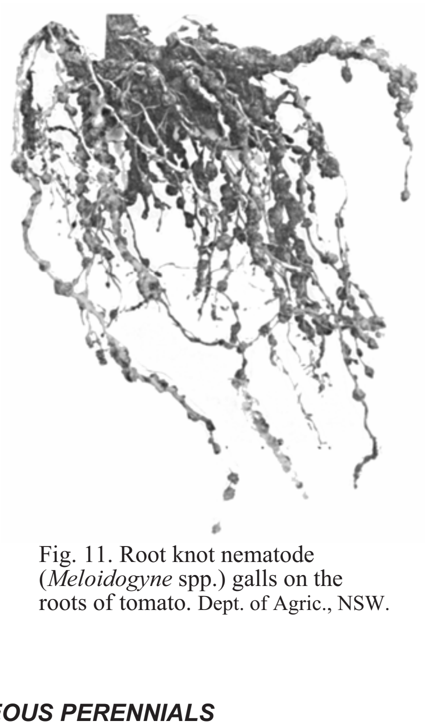

Fig. 11. Root knot nematode (*Meloidogyne* spp.) galls on the roots of tomato. Dept. of Agric., NSW.

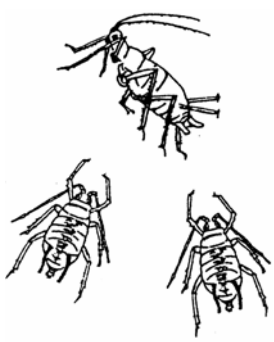

Fig. 12. Aphids (Aphididae) are 1-3 mm long and common pests, they cause distortion of new growth and spread virus diseases.

Fig. 13. Vine hawk moth (*Theretra oldenlandiae*) caterpillars (60 mm long) which are minor grapevine pests, chew impatiens leaves.

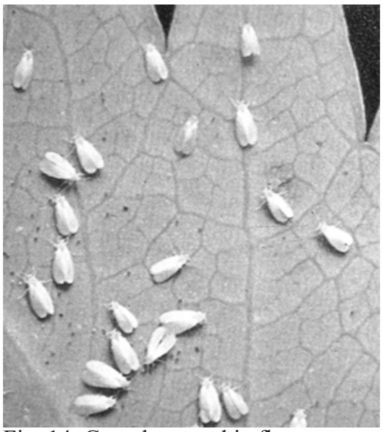

Fig. 14. Greenhouse whitefly (*Trialeurodes vaporariorum*) on leaf undersurfaces.

Fig. 15. Leafhopper injury to marigold (*Tagetes*) leaves, the speckled patterns are the feeding sites of the leafhoppers.

Fig. 16. Cineraria leafminer (*Chromatomyia syngenesiae*) damage to nasturtium leaves.

Fig. 17. Twospotted mite *Tetranychus urticae*) sucks sap from violet leaves causing a light sandy mottle.

Fig. 18. Thrips (Thysanoptera) rasping and sucking plant sap from petals.

Fig. 19. Common garden snail (*Helix aspersa*) damage to kangaroo paw.

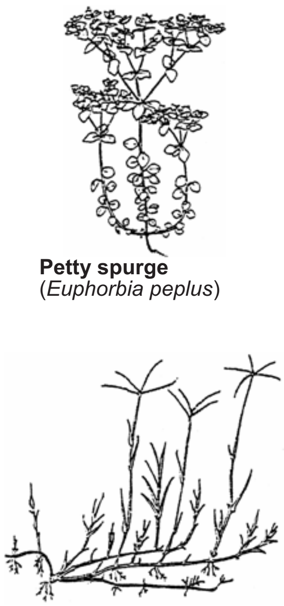

Fig. 20. ***Top :*** Annuals weed.
Lower : Perennial weed.

STEPS IN DIAGNOSIS	
1.	**Identify the plant**
2.	**Examine the plant** externally and internally
3.	**Inspect the problem** in the field **AND/OR** **Discuss the history** of the plant, eg what treatments has it received
4.	**Look up a reference** to confirm diagnosis and find out more about the problem
5.	**Seek specialist help** if the cause of the problem is still uncertain

Fig. 21. Diagnosing plant problems.

Annuals and
Herbaceous Perennials

*Annual and perennial herbaceous ornamental plants are affected by the same types of diseases, pests and weeds as **vegetables**.*

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Host range: Many annuals are ***susceptible*** to at least one or several virus diseases. Some viruses only attack ***one species***, eg carnation mottle virus, while others, eg cucumber mosaic virus and tomato spotted wilt virus ***(TSWV)***, infect ***many species.*** Others, eg tobacco mosaic virus may have ***different strains*** each of which has a different host range. ***Impatiens necrotic spot virus (INSV)*** is closely related to ***TSWV***, has a wide host range but has not been detected in Australia (Hill 1994). With the introduction of ***western flower thrips*** (*Frankliniella occidentalis*) both ***TSWV*** and ***INSV*** may become more important diseases.

Symptoms: Symptoms vary with virus, cultivar, growth stage and temperature and usually appear one to several weeks after infection. Symptoms may be more obvious ***during spring and autumn***. ***Leaves*** develop mosaic patterns, pale yellow, green or brown ring-like markings, straw-coloured spots, or be distorted (Fig. 1). ***Stems*** may develop black streaks. ***Flowers*** may be distorted, green or variegated (Fig. 2). ***Plants*** may be stunted, yellow, have reduced flower quality and yield, but do not usually die. Some grow reasonably if cared for, but may deteriorate and are a source of infection. ***Diagnostic tests*** are available for some species.

Overwintering: Infected hosts, including weeds. Some may be generally seedborne, others may be seedborne only on certain hosts. A few may overwinter in infected crop debris.

Spread: All viruses are spread by ***vegetative propagation*** and grafting from infected plants. Some are also spread by ***sap-sucking insects***, eg aphids, leafhoppers, thrips. More than 20% of virus diseases are ***seedborne*** but in a variable percentage. Some ***spread*** also by ***mechanical transmission*** of plant sap by foliage contact and on hands, clothes and tools during plant handling, eg pruning, flower cutting, and a few also by ***pollen***. Also by ***introduction*** of infected seedlings, cuttings and some by debris from infected plants.

Conditions favouring: Repeated vegetative propagation from infected plants. Weather may favour an increase in vectors. At certain times of the year, especially after hot dry weather, vectors migrate from drying weeds and other hosts where they breed and feed, to ornamentals and other hosts.

Control: As there is no cure for infected plants, the aim is ***to prevent infection***. To minimise losses, plant virus-tested planting material and practice strict hygiene. Insecticides may be necessary to control vectors in commercial crops.

Cultural methods: Rotate crops if the virus overwinters in plant debris, eg tobacco mosaic.

Sanitation: Before planting remove volunteer hosts and weeds. ***After planting*** remove virus-infected plants and weeds in the crop and nearby. If viruses are sapborne, maintain strict hygiene during propagation, pruning, handling and harvesting. Wash hands with hot soapy water, sterilise tools before and after handling particular groups of plants. Work 'clean' areas prior to infected plants. Handle new, less infected younger plants before older, and possibly infected plants. Train staff in how viruses are spread. See Nurseries N 51, N 55.

Biological control: It will be possible to control some vectors biologically in the future.

Resistant varieties: Varieties with ***resistance*** to virus diseases should be used where possible.

Plant quarantine: Isolate susceptible seed and cutting beds and crops from infected hosts.

Disease-free planting material: Plant certified ***virus-tested*** planting material (Fig. 3), otherwise select vegetative propagation material and seeds from symptomless plants. Yields of crops derived from virus-tested planting material are greater than from virus-infected crops. As most viruses infecting annuals have insect vectors, virus-tested planting material needs to be re-purchased regularly. Infected seed may be treated with hot water.

Physical and mechanical methods: Grow where practical in insect-proof greenhouses and control insect vectors inside. If virus is soil-borne (unusual), pasteurise soil.

Pesticides: Insecticides may be applied to control vectors and reduce re-infection of virus-tested stock and spread of virus within commercial crops, seedbeds and especially greenhouses. Some vectors have ***developed resistance*** to some insecticides.

BACTERIAL DISEASES

Bacterial leaf spots
(*Pseudomonas, Xanthomonas*) occasionally occur on annuals, eg carnation, chrysanthemum, delphinium, primrose, viola, and may be angular or circular. ***Foliage*** of older plants is disfigured (Fig. 4) and plant vigour is reduced. Spots may enlarge rapidly on seedlings, leaves and growing tips may die. See Vegetables M 5.

Others: ***Bacterial soft rots*** (*Erwinia* spp.), ***bacterial wilt*** (*Pseudomonas solanacearum*), ***crown gall*** (*Agrobacterium* spp.), ***stem rots*** (*Xanthomonas* spp.).

FUNGAL DISEASES

Damping off
(*Botrytis*, *Colletotrichum*, *Cylindrocladium*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia solani, Sclerotium rolfsii*) may kill cuttings, seedlings and young plants. ***Pre-emergence*** damping off occurs when seeds and seedlings rot before emerging. ***Post-emergence*** damping off occurs after seedlings and cuttings have emerged from the soil causing stem and root rots and aerial damping off. See Seedlings N 66.

Downy mildews

Scientific name: Peronosporaceae, Eumycetes: *Bremia, Peronospora, Plasmopara, Sclerospora*

Host range: ***Ornamentals***, eg stock, ***fruit***, eg grape, ***vegetables***, eg onion, ***field crops***, eg wheat. Generally a particular species of downy mildew is restricted to one host, or group of related hosts, eg one species attacks stock, another zucchini. Strains may occur, the one that attacks stocks may not attack cabbages.

Symptoms: Pale yellow lesions bounded by veins develop on ***leaf uppersurfaces***. Lesions on ***leaf undersurfaces*** produce a downy growth under humid, cool conditions (Fig. 5). As lesions dry out leaves die, plants and small seedlings may be killed. ***Stems, buds, flowers, petals, seed pods and fruit*** may also be attacked. Disease is less important after planting out.

Overwintering: Infected host plants (bulbs, canes, twigs), older infected crops, volunteer plants, host weeds, undecomposed crop debris (leaves, prunings, berries), seed.

Spread: Spores are spread by wind and water splash from infected plants, debris. By vegetative propagation from infected plants. By introduction of infected seedlings, cuttings, plants and seed.

Conditions favouring: Cool, wet weather and hosts growing rapidly. Heavy dew, fog, rain, poor ventilation and drainage. Overcrowded cutting and seedbeds, often minor after transplanting.

Control: Control can be difficult.

Cultural methods: Rotate crops. Avoid overhead irrigation, poor drainage, overcrowding. Regulate temperature and humidity in greenhouses, seed and cutting beds.

Sanitation: ***Deep bury/plough in*** or burn diseased seedlings, infected crops and debris immediately after harvest to reduce inoculum. On woody hosts prune out and chip and deep bury or burn infected shoots. Sanitation measures alone are unlikely to bring about satisfactory control.

Resistant varieties: Varieties differ in ***resistance***.

Disease-free planting material: Plant ***disease-free*** seed (otherwise treat seed) and propagate vegetatively only from disease-free crops.

Physical and mechanical methods: ***Pasteurise*** soil in cutting and seedbeds.

Pesticides: ***Fungicides*** on their own may not control downy mildews. They may be applied at first sign of disease to leaf undersurfaces, repeat applications may be needed in humid weather.

Flower blights, flower rots

Grey mould (*Botrytis cinerea*): ***Blossom blight*** may develop towards the end of the growing season. ***Petals*** of fully-opened flowers, eg petunia, rose, may develop ***small ring-like markings*** (Fig. 6) which are reddish in light-coloured varieties or creamy-white in dark varieties. Each ring-like marking indicates where a spore has germinated. ***Leaves*** may develop brown or grey spots or blotches. ***Stems and crowns*** may rot at ground level and fall over. ***Aerial damping off*** may occur on seedlings. In damp weather, affected areas are covered with furry, grey spores. Field damage is usually slight. ***Postharvest*** losses after cutting may be serious. See Greenhouses N 22.

Rhizopus soft rot (*Rhizopus stolonifer*). See Carnation A 17, Protea K 119.

Others: Ray blight (*Mycosphaerella ligulicola*). See Chrysanthemum A 23.

Fungal leaf spots

Scientific name: Ascomycetes/Imperfect Fungi: *Alternaria*, *Ascochyta*, *Cercospora*, *Curvularia*, *Helminthosporium*, *Mycosphaerella*, *Septoria*

Host range: ***Ornamentals***, eg carnation, gerbera, iris, ***fruit***, eg strawberry, ***vegetables***, eg beet, ***field crops***, eg lucerne. Generally a particular species is restricted to one host, or group of related hosts, eg one species attacks gerbera, another iris.

Symptoms: ***Leaf spots*** are mostly circular, vary in colour and size and may join together (Fig. 7). Leaves may yellow, die and fall, reducing plant vigour, 50% of seedlings may be destroyed. Some only cause minor disfigurement. ***Stems, flower stalks, seeds and fruit*** may develop spots. It may be difficult to distinguish fungal leaf spots from those caused by bacteria and other agents. Tiny, black spore-producing structures may develop within the spots of some species, eg *Septoria*. By the end of the season all the crop may be affected.

Overwintering: Infected host plants (leaves, dead blossoms, bulbs, canes, twigs), older infected crops, volunteer plants, host weeds, undecomposed crop debris on and in the soil, seed.

Spread: Spores are spread by wind, water splash, and insects from infected plants and debris. By vegetative propagation from infected plants. By introduction of infected seedlings, nursery stock, cuttings, plants, soil containing infected crop debris and by seed. Occasionally on workers' clothes, machinery moving through damp crops.

Conditions favouring: Warm, wet, conditions (some exceptions). Overhead irrigation, misting, heavy dews, shady, overcrowded conditions, lush growth. Lack of water and nutrient deficiencies may ***predispose*** plants to infection by weak parasites, eg *Colletotrichum*. ***Leaves damaged*** by sun scorch, drought, insect, mites, mechanical or chemical injury may be colonised by *Pestalotiopsis*.

Control: Leaf spots may not be important.
Cultural methods: Practise a ***3-4 year rotation***. ***Avoid*** overcrowded, humid conditions, overhead irrigation (irrigate in the morning). ***Avoid*** lush soft growth but keep plants growing vigorously by careful irrigation and fertiliser. Do not plant susceptible crops in soil with undecomposed crop residues or near other infected plants. Site plants to minimise environmental leaf damage. ***Ventilate*** greenhouses to regulate humidity.
Sanitation: ***Deep bury/plough in*** or burn infected crops and crop debris immediately after harvest to reduce inoculum. ***Prepare ground early*** to reduce undecomposed plant debris. Do not replant until all residues have decomposed. If only a few leaves or a few plants, remove and destroy affected leaves by hand. Greenhouses may need to be disinfected.
Resistant varieties: Varieties vary in ***resistance***.
Plant quarantine: Prevent contaminated stock entering the nursery. Only purchase plants free from fungal leaf spots. Inspect new purchases.
Disease-free planting material: Only purchase ***certified disease-tested*** seed or vegetative planting material and plant in disease-free soil. Otherwise only save seed or propagate vegetatively from disease-free plants; treatment may be necessary, eg hot water.
Physical and mechanical methods: ***Pasteurise*** soil for seed and cutting beds.
Pesticides: ***Fungicides*** may be applied to young plants of ***susceptible varieties*** during humid weather at the first sign of disease, the need for further applications depends on the weather.

Powdery mildews

Scientific name: Erysiphales, Ascomycetes: *Erysiphe, Podosphaera, Sphaerotheca, Uncinula*

Host range: ***Ornamentals***, eg begonia, calendula, viola, ***fruit***, eg grapevine, ***vegetables***, eg cucurbits, pea. Generally a particular species is restricted to one host, or group of related hosts, eg one species attacks calendula, another grape.

Symptoms: ***Both leaf surfaces and stems*** develop white circular patches which increase in size to cover large areas and become powdery due to the production of spores (Fig. 8). ***Young leaves*** if infected at an early age may be distorted, reduced in size and finally shrivel and die. ***Stems, flowers, petals, buds and seed pods*** may also be attacked. Affected tissue and young plants may die. Defoliation may cause stems (and fruit) to be sunburnt, flower infection causes poor fruit set.

Overwintering: Infected crops (canes, twigs, buds, scales), volunteer hosts, debris from previous and current infected crops and possibly seed. On shoots and buds, under bud scales.

Spread: Spores are spread by wind and air currents from infected crops, crop debris. By vegetative propagation from infected plants. By introduction of infected nursery stock, plants and seed. Also on some hosts by water splash.

Conditions favouring: Warm, moderately humid weather in summer and autumn, moderately dry conditions when dew or periodic irrigation favour spore germination. Some powdery mildews, eg of grapevines, need ***dry atmospheres*** created by microfine droplets of water which evaporate in the air without wetting the plant. Wet or very hot, dry weather is unfavourable for some species.

Control: Control is difficult.
Cultural methods: ***Rotate plantings***. Avoid dew, shaded, crowded and humid sites, overhead irrigation, poor ventilation, lush tender growth. Irrigate early in day (leaves dry quickly). ***Avoid clipping hedges*** of susceptible varieties, eg *Euonymus,* and over-fertilisation which produces lush new growth susceptible to powdery mildew. Heavy rain or overhead irrigation washes spores off leaves onto soil where they bio-degrade.
Sanitation: ***Destroy*** severely infected plants, volunteer plants, leaves and shoots. ***Prune out*** infected shoots on perennial hosts during winter pruning, eg apple. ***Destroy or deep bury*** diseased crop debris.
Biological control: *Verticillium lecanii* may ***parasitise*** powdery mildews (Sunderland 1991).
Resistant varieties: Varieties differ in ***resistance***.
Disease-free planting material: Only plant ***disease-free*** seed (otherwise hot water treat) and propagate vegetatively from disease-free plants.
Pesticides: Powdery mildew is ***difficult to control*** with fungicides once established. ***Protect new growth*** as it develops. Apply fungicides at first sign of disease, the need for repeat applications depends on the weather. As mycelium is 'hard-to-wet', a wetting agent may be recommended.

Root, stem and crown rots

Young and old plants wilt and die. As it may be difficult to recognise the fungus causing the rot from symptoms, it should be identified using a ***diagnostic kit*** or ***isolated by a pathologist***. Soil-borne diseases usually occur in ***patches*** in a crop.

Fusarium (*Fusarium*) causes rotting of ***stem tissue*** of young plants which later yellow, wilt and die. ***Pink spore masses*** may develop on rotted tissue.
Phytophthora root rot (*Phytophthora*) causes plants (often young plants) to yellow, wilt and die. A wet rot of ***roots***, ***stems*** develops causing a brown discolouration of the ***water-conducting tissues***, roots are dead and decayed. Rotting may progress up into the stem. See Trees K 6.
Pythium stem rot (*Pythium*) causes a black, wet rot of tissues that spreads up ***stems*** to leaf petioles and blades. Roots may also rot.
Rhizoctonia root or stem rot (*Rhizoctonia solani*) attacks ***stems*** at ground level causing a brown rot of young plants, wilting and death. Sunken cankers develop at the ***stem base*** (Fig. 9), soil particles adhere to damaged tissue by a fine web of brown fungal threads. Roots decay after plants die.
Sclerotinia (*Sclerotinia*) causes a soft, brown rot of ***stems*** and ***other aerial parts*** of ***mature plants***. A white fungal mycelium grows over the rotted area. White ***sclerotia*** (resting bodies of the fungus) up to about 12 mm in size are produced on rotted area, these later turn black and may also develop in pith cavities.

Sclerotium stem rot (*Sclerotium rolfsii*) attacks ***stems*** of mature plants at ***ground level***. A white mat of fungal mycelium grows over affected parts. Sclerotia (1-2 mm across) form on the surface of mycelium, these later turn brown and may be hard to see (Fig. 9). A brown dry rot develops, plants yellow, wilt and die.
Others: *Cylindrocladium, Thielaviopsis.*

See Vegetables M 7.

Rusts

Scientific name: Uredinales, Basidiomycetes: *Phragmidium, Puccinia*, *Uromyces*

Host range: ***Ornamentals***, eg chrysanthemum, kangaroo paw, snapdragon, ***fruit***, eg stone fruit, ***vegetable***, eg French bean, ***field crops***, eg wheat, ***weeds***, eg mallow. Usually a particular species of rust is restricted to one host, or group of related hosts eg one species attacks calendula, another snapdragon. There may be different races of rust..

Symptoms: ***Leaf uppersurfaces*** are speckled with yellow, patches which may run together. On ***undersurfaces*** there are corresponding orange or rusty brown spore masses. Leaves may die. In severe infections, premature and repeated leaf fall weakens plants. ***Stems*** may be girdled by lesions (Fig. 10), parts above die. ***Seed pods and fruit*** may be attacked. Plants are unsightly and may die.

Overwintering: Infected plants (leaves, twigs) and debris from infected plants. Contaminated seed, fungal spores are carried on the outside of seed pods and other plant debris from infected plants. Also out-of-season and between season crops. Volunteer crop plants.

Spread: Spores are spread by wind, air currents, water splash and irrigation water from infected plants and debris to healthy plant parts. By vegetative propagation from infected plants, infected seed (spores on outside). By introduction of infected nursery stock, plants and plant debris.

Conditions favouring: Some prefer hot, moist weather, others prefer cool and moist conditions.

Control:
Cultural methods: ***Rotate crops***. Do not plant young crops near older diseased crops. ***Avoid*** humid conditions, overhead irrigation, excessive nitrogen, poorly ventilated, shaded and overcrowded seedbeds/plantings. Irrigate, spray plants and foliage fertilise in the morning, leaves will dry before nightfall.
Sanitation: ***Deep bury or destroy*** infected crops and debris immediately after harvest. Prepare ground early to reduce undecomposed infected debris. ***Remove*** and destroy infected leaves in cutting and seedbeds, also infected twigs and plants, weeds and self-sown seedlings. Deep bury or burn infected fallen leaves and prunings.
Biological control: *Verticillium lecanii* ***parasitises*** carnation, wheat and dwarf bean rusts, barley mildew, scales and aphids overseas.
Resistant varieties are the most effective control, even ***partial resistance*** reduces pesticide usage.
Plant quarantine: ***Isolate*** new plant purchases.
Disease-free planting material: Only save seed and propagate from ***rust-free plants***. Plant rust-free propagation material and seed (or treat with fungicides) in rust-free beds. Do not introduce infected plants to rust-free plantings.
Pesticides: Rust can be ***difficult to control*** with fungicides if conditions favour disease. Fungicides may be applied to both leaf surfaces of susceptible varieties at the first sign of disease, repeat applications depends on weather.

Wilts include ***fusarium wilts*** (*Fusarium oxysporum* f. spp.) and ***verticillium wilt*** (*Verticillium dahliae*). Some plants, eg carnations, may be infected by both wilt fungi. Symptoms are similar and on hosts affected by both, diseases can only be identified by laboratory examination. Wilt fungi enter ***roots***, become established in the ***vascular system*** and extend upwards into the ***branches***. Young plants may show a one-sided yellowing and wilt. If stems are cut lengthwise, vascular tissues are brown. In older plants, branches wilt and die one at a time, finally the whole plant dies prematurely. See Vegetables M 9.

NEMATODE DISEASES

Many species of nematodes may be associated with annuals including:

Foliar nematodes (*Aphelenchoides* spp.) infest many plants, eg African violet, chrysanthemum, kangaroo paw. Watersoaked lesions develop on ***leaves***, which later die and fall. Initially, leaf spots tend to be triangular and bordered by veins but not always so. Infestation progresses from lower leaves upwards. ***Flowers*** may be infested and decay, often only on one side. See Ferns E 2.
Root knot nematodes (*Meloidogyne* spp.) penetrate ***roots*** causing ***galls*** up to 25 mm in diameter (Fig. 11). Plants are stunted, yellow and wilted (symptoms similar to nutrient deficiencies or water stress). Fungal and bacterial rots may develop in affected roots, plants die prematurely. Infected seedlings are often more susceptible to water stress. See Vegetables M 10.
Stem and bulb nematode (*Ditylenchus dipsaci*) infests ***young shoots*** causing twisting and spindling. Stems may be swollen near the tops and basal buds stimulated to develop. Plants may be stunted, fail to bloom and die prematurely. See Daffodil C 20.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Cotton aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum euphorbiae*)
Aphids are ***common pests*** of annuals, eg carnation, chrysanthemum, stock. They are slow moving, winged or wingless, plump-bodied, 1-2 mm long, green, yellow, pink or brown depending on species and food plant (Fig. 12). ***Nymphs*** look like adults but are smaller and wingless. ***Nymph skins***, shed as aphids moult, are found on infested plants and are particularly noticeable after winged aphids have left. Nymphs and aphids suck plant sap from ***new shoots, leaves, buds and flowers*** causing distortion, leaves may shrivel. Some species suck sap from roots. Other sucking insects, eg broad mite and cyclamen mite, may also cause distortion of new leaves. Most aphids secrete ***honeydew*** on

which sooty mould grows and which attracts ants. Aphids ***spread many virus diseases*** into and within crops during feeding. Green peach aphid spreads > 100 virus diseases. See Roses J 4.

Bugs (Hemiptera)

Coon bug (*Oxycarenus arctatus*)
Green vegetable bug (*Nezara viridula*)
Harlequin bug (*Dindymus versicolor*)
Metallic shield bug (*Scutiphora pedicellata*)
Leptocoris bug (*Leptocoris mitellatus*)
Many species suck sap, usually from ***new shoots*** which wilt and brown. See Vegetables M 12.

Caterpillars (Lepidoptera):

Most species have a wide host range. Caterpillars and their chewing damage are easily identified (Fig. 13). Droppings are found on plants or underneath.

Budworms, cutworms (Noctuidae): ***Corn earworm*** (*Helicoverpa armigera*) and ***native budworm*** (*H. punctigera*) feed on and inside ***buds*** and ***flowers*** causing them to brown and not open. A small hole in the calyx marks where the caterpillar entered the bud. Petals must be parted to find the young caterpillars in flowers, damage continues after harvest. They are difficult to control, it may be necessary to spray regularly, starting at first sign of damage. See Sweetcorn M 89. ***Cutworms*** (Noctuidae) are smooth-bodied, dark-grey to pinkish caterpillars up to 40 mm long. They hide in the soil by day and feed on the ***base of stems*** of ***young plants at night*** causing them to topple over. See Seedlings N 68. ***Looper caterpillars*** (*Chrysodeixis* spp.) chew ***leaves*** and can cause severe damage in shady situations. See Vegetables M 13.

Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars eat buds and flower segments. See Pome fruits F 112. ***Lucerne leafroller*** (*Merophyas divulsana*).

Loopers (Geometridae) chew leaves. See Avocado F 19.

Others: Cluster caterpillar (*Spodoptera litura*), ***painted apple moth*** (*Teia anartoides*).

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with one or several generations each year.

Overwintering: Usually as cocoons or pupae on host plants, crop debris or in the soil.

Spread: By butterflies and moths flying assisted by wind, caterpillars crawl. Seedlings and cuttings may carry eggs, tiny caterpillars or pupae.

Conditions favouring: Usually warm and moist, above average rainfall will favour some caterpillars, eg cluster caterpillar, but some like it cool. Common during summer and autumn.

Control:

Cultural methods: Minimise host weed growth.

Sanitation: Caterpillars (not irritant hairy ones) may be hand picked or squashed ***in small plantings***, some may be well camouflaged and hard to locate. Infested crops and debris should be destroyed ***as soon as possible after harvest***.

Biological control: Caterpillars are subject to many ***natural enemies*** including parasitic wasps, predatory bugs, birds and diseases which do not usually prevent economic damage (exceptions).

Pesticides/Resistant varieties: The bacterial insecticide, *Bacillus thuringiensis* **(Bt),** may be applied to ***young leafeating caterpillars*** (not usually internal-feeding caterpillars in flower or leaf buds, in fruit or in stems, branches or trunks), and provides economic selective control if applied regularly during the main infestation period. It is slow-acting as it has to be eaten to be effective. Plants ***resistant*** to caterpillars, eg cotton, tomato, are being bred with the ***Bt*** gene in them, eliminating the need for sprays. Chemical insecticides may be applied if caterpillars are large and numerous. Caterpillar numbers and damage should be ***monitored*** before chemical pesticides are applied. See Brassicas M 39.

European earwig (*Forficula auricularia*)

feeds on seedlings, dahlia, zinnia, other plants, also foodstuffs and dead and living insects. ***Adults*** are brown and about 12 mm long with pincers at the end of the abdomen. They seldom fly, and hide during the day in rubbish, flower and fruit clusters. ***Leaves, flowers and petals*** may be damaged by their chewing, and develop a ragged appearance. They also spoil plants with their excrement. See Vegetables M 14.

Greenhouse whitefly (*Trialeurodes vaporariorum*)

is a sporadic pest of annuals during warm humid weather. ***Whiteflies*** are tiny, white insects which fly out in a cloud when plants are disturbed (Fig 14). Adults and nymphs may be found on ***leaf undersurfaces*** where they feed by sucking plant sap causing speckled patterns on leaves. Whiteflies secrete honeydew on which sooty mould fungi grow. Infestation may occur but there may be little damage. See Greenhouses N 24.

Leafhoppers (Cicadellidae, Hemiptera)

Apple leafhopper (*Edwardsiana australis*)
Common brown leafhopper (*Orosius argentatus*)
Vegetable leafhopper (*Austroasca viridigrisea*)
Yellow jassid (*Erythoneura ix*)
Leafhoppers may be abundant and feed on many plants, eg dahlia, marigold, grasses and weeds, and range from very small to medium-sized insects. They pass their whole life cycle on the plant and feed by sucking plant sap. When disturbed they hop away. Their feeding causes ***speckled patterns*** on ***leaves***, each speckle representing a feeding site (Fig. 15). During spring, summer and autumn they migrate from drying weeds, etc. to crops. Control is difficult as damage is not usually noticed until they have flown away. See Vegetables M 15.

Leafminers

are the larvae of flies (Diptera), eg ***cineraria leafminer*** (*Chromatomyia syngenesiae*) or ***moths*** (Lepidoptera), which tunnel inside ***leaves*** spoiling the appearance of foliage (Fig. 16). Generally each leafmining species attacks only one plant family or one species. See Cineraria A 28.

Mealybugs (Pseudococcidae, Hemiptera)

may infest ***stems, leaves and roots***. ***Female mealybugs*** are powdery white 3-4 mm long, oval, slow moving, wingless, flattened. They suck plant sap causing soft-foliaged plants to wilt and eventually die. Economic damage may also be caused by the excreted ***honeydew*** which attracts ants and on which ***sooty mould*** grows rendering plants unsightly. See Greenhouses N 25.

Mites (Acarina) feed by sucking plant sap.

Broad mite (*Polyphagotarsonemus latus*) causes ***malformations*** of ***growing tips and young leaves***. See Greenhouses N 26.

Cyclamen mite (*Phytonemus pallidus*) causes similar damage to that caused by broad mite, damaging ***flower buds and leaves*** of African violet, petunia. Mites cannot be seen with the naked eye and shelter inside buds. See Cyclamen C 16.

Redlegged earth mite (*Halotydeus destructor*) and ***blue oat mite*** (*Penthaleus major*) are blackish in colour, about ***1 mm*** long and have red legs. Nymphs and adults suck sap from the ***leaves*** causing them to turn silvery and sometimes die. Cool, weather during autumn, winter and spring. See Vegetables M 16.

Twospotted mite (*Tetranychus urticae*) infests carnation, hollyhock, marigold and perennial phlox during hot, dry weather. ***Leaves*** become bleached or ***sandy mottled*** (Fig. 17). Mites are about ***0.5 mm*** long. Mites and webbing can be seen on ***leaf under surfaces*** which may yellow and fall. A tiny black mite-eating ladybird (*Stethorus*), its larvae and pupae, are found on infested leaves. See Beans (French) M 29.

Thrips (Thripidae, Thysanoptera)

Plague thrips (*Thrips imaginis*) and other species infest ***flowers*** of most plants. Adult thrips are dark, small, fast-moving elongated about ***1-1.5 mm*** long, nymphs are paler in colour (Fig 18). Thrips are easily seen by shaking them out of flowers onto a white surface. Plague thrips enter opening ***buds and blossoms*** and rasp and suck exuded sap from petals which become silvered (red varieties), streaked or blotched, later turning brown. Dark excreta on light blooms add to their disfigurement. See Roses J 6.

Western flower thrips (WFT) (*Frankliniella occidentalis*) is ***1 mm*** long, yellow-brown, and feeds on herbaceous plants, it is a major vector for tomato spotted wilt virus ***(TSWV)*** and impatiens necrotic spot virus (***WFT*** is the only thrips that can spread this virus). When eggs hatch, nymphs emerge and feed on infected plants and become infected throughout their life cycle which is about 30-45 days. As ***WFT*** spreads in Australia, both these viruses may cause increased crop losses and damage. ***WFT*** may be biologically controlled overseas by ***predatory mites*** (*Amblyseius cucumeris*, *A. barkeri*, *Geoaelaps* sp.) and ***predatory bugs*** (*Anthocoris nemorum, Orius* sp.) (Sunderland 1991). Management strategies and control techniques (biological and chemical) to minimise ***WFT/TSWV*** problems are being researched (Hill 1994). ***A National WFT Management Strategy Group*** has been set up. Thrips management in greenhouses is important for virus control. See Greenhouses N 24, Tomato M 96.

Weevils (Curculionidae, Coleoptera)

Black vine weevil (*Otiorhynchus sulcatus*) larvae chew on the ***fine root hairs*** of plants during summer and autumn. See Grapevine F 63.

Others: ***Garden weevil*** (*Phlyctinus callosus*) chews scalloped holes from centres and margins of ***leaves***. See Trees K 17. ***Vegetable weevil*** (*Listroderes difficilis*) and its larva chew winter growing flowers, eg stock. See Vegetables M 17.

Others: ***Locusts, grasshoppers, crickets***

(Orthoptera) chew young shoots, soft leaves and flowers. Larvae of ***scarab beetles*** (Scarabaeidae) and ***wireworms*** (Elateridae) damage roots.

SNAILS AND SLUGS

Snails and slugs may damage seedlings and perennial borders (Fig. 19). Fleshy plants, eg gazania, may be skeletonised. See Seedlings N 70.

VERTEBRATE PESTS

Birds, eg parrots, may tear off flowers when seeking soft green plant tissue. See Fruit F 13.

Non-parasitic

Chemical injury: ***Herbicides*** may injure plants by drift, vapours and excessive rates. Seedlings may be injured by planting too soon in ***treated soil***. ***Sulphur*** may damage some plants in greenhouses, test prior to large scale use. ***Over-application of wetting agents*** used to retain water in media, improve aeration and nutrient availability may reduce shoot and root growth of geranium, impatiens, poinsettia and possibly other plants.

Environment: Flowering may be affected by insufficient ***light***. Flowers generally are more susceptible to ***frost*** than foliage, eg chrysanthemum flowers are damaged by frost but not the foliage. Both flowers and foliage of some plants, eg marigold, nasturtium are damaged by frost. Flowers and leaves may be ***sun scorched***. Annuals may suffer from ***drought*** or ***too much water***. Tall plants may need staking to prevent ***wind*** damage.

Genetic abnormalities: Many varieties have variegated leaves or flowers. ***Sports*** of variegated parts may occur on normal green varieties and vice versa. Flattened ***fasciated stems*** may develop.

Nutrient deficiencies and toxicities: Mistakes may occur during media preparation. Excessive rates may cause reduced growth and pollution. ***Soil and leaf analyses*** are available for most commercial crops. See Citrus F 43.

Others: The spiny legs of ***nectar scarabs*** (*Phyllotocus* spp.) damage petals. ***Plague soldier beetle*** (*Chauliognathus lugubris*) weighs down flowers. ***Sooty mould*** grows on honeydew secreted by sucking insects, ***slime moulds*** grow on leaves close to soil, ***dogs and cats*** may damage flowers.

WEEDS

Weed control is important, especially during the first year. ***Emerged annual and perennial weeds*** (Figs. 20, 21) should be controlled prior to planting either by cultivation or by post-emergence herbicides. ***After planting***, weed mats or weed-free mulches of various types prevent moisture loss, keep roots cool and discourage annual weeds. Cultivation to control weeds after planting may injure roots. Beds may be carefully hand weeded. ***Pre-emergence herbicides*** may be applied after planting and at regular intervals thereafter in perennial beds to control seeds of grass and broadleaved weeds.

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State/Territory Departments of Agriculture/Primary Industry eg

NSW Agdex/Agnotes
Getting Started in Cut Flower Growing
Major Flower Grower-Sellers & Exporters in NSW
National Flower Wholesalers
Ornamental Horticulture Associations in NSW
Poinsettia Whitefly (Bemesia tabaci type B)
Potential Cut Flower & Foliage Crops
Suggested Publications for Floriculture
Suppliers of Cut Flower Planting Materials
The NSW Cut Flower Industry
Watchout for Western Flower Thrips

NSW Agfacts
Availability and Price of Cut Flowers
Foliar Nematode Diseases of Ornamental Plants
Fungicides for Ornamentals in NSW
Native Flowers as Cut Flowers
Nectar Scarab Beetles
Powdery Mildews of Ornamentals

SA Information Sheets
Cut-flower Production in SA (SA Fact Sheet)
Suggested Booklist for Floriculture

Sydney Market Authority
Fresh Flowers Handling and Care

Tas Farmnotes
Extending the Shelf & Vase Life of Cut Flowers
Handling & Storing Cut Flowers

Vic Agnotes
Aphids as Pests of Ornamental Plants
Availability & Price of Cut Flowers
Cut Flower Growing
Domestic Market for Cut Flowers
Export Market for Cut Flowers
Importing Ornamental Plants as Tissue Culture
Post Harvest Treatments for Cut Flower
Powdery Mildews of Ornamentals
Quar. Requirements for Importing Ornamental Plants
Scale Insects & Mealybugs on Ornamentals
The Ornamentals Improvement Program for Cut Flowers
Twospotted Mite on Ornamental Plants

WA Farmnotes
Bleaching Plant Foliage
Chlorination in Postharvest Horticulture
Cooling Cut Flowers and Foliage
Drying Cut Flowers and Foliage,
Dyeing Cut Flowers and Foliage
Floriculture : A Blooming Business (WA Agric)
Post-harvest Insect Disinfestation Treatments for Cut Flowers and Foliage
Post-harvest Management of Hort. Produce in the Market
Scale Insects, Mealybugs and Whiteflies
Soilborne Diseases in Horticulture
Storage Conditions for Ornamental Crops
The Garden Weevil
Tomato Spotted Wilt & Impatiens Necrotic Ringspot : Viruses Spread by Thrips

Associations, Journals etc.
Australian Flower and Protea Grower's Assoc. (AF&PGA)
Australian Flower Grower's Council (AFGC)
Australian National Flower Show (Melbourne)
Flower Link
Floriculture Conferences
FloraCulture International
Flower Export Council of Australia (FECA)
GrowSearch (database Qld DPI)
IPM Ornamentals, Institute of Hort. Dev., Knoxfield, Vic.
National Flower Centre, Melbourne
Nursery Industry Association of Australia (NIAA)
State/Territory Flower Grower's Groups
Supermarket Flora
Tasmanian Floricultural Association
Victorian Farmers Federation Flower Grower's Group

See Preface xii, Australian native plants N 9, Bulbs C 9, Greenhouses N 28, Nurseries N 56

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: An overview of the industry is presented by Coombs (1995). Select species as ***required*** for colour, height, cost, market, flowering dates, quality, yield and need for maintenance.

Resistant varieties: Choose species or varieties which are relatively ***problem-free***. If particular problems occur, select species or varieties with some resistance to them. Choose proven hardy varieties.

Disease-free planting material: Always plant disease-free seed, budwood and rootstock in disease-free soil. Crop Health Services (Crop Hygiene) in the Institute for Horticultural Development, Agriculture Victoria, supplies the cut flower industry with ***propagating material*** of some species, eg carnation, chrysanthemum, which is free from viruses and other diseases. Purchase ***disease-free planting material*** (High Health Plants) from specialist propagators, (Fig. 3) otherwise propagate vegetatively and save seed only from disease and pest-free plants. Seed may need to be treated with steam, hot water or chemicals.

Establishment

Propagation: By seed, cuttings, tissue culture.

Cultural methods: Select growing areas, site layout and practices which will ***minimise disease development***. Select species to suit ***sites*** to be planted, eg need for shade, sun, soil, drainage. Site plants according to their ***cultural needs***. Do not plant susceptible species where soilborne problems occur. Avoid overcrowded seed and cutting beds as these encourage diseases. Rotate crops to avoid build up of disease inoculum. Regularly rotate annuals; many perennials should be lifted/divided regularly for maximum productivity. Flowering plants are more ***sensitive to temperature*** than foliage plants.

Sanitation: Remove/destroy/deep bury crop or burn residues ***immediately after harvest*** to reduce inoculum. Remove all old plant material from packing sheds. Hygiene procedures prevents infection of later crops.

Biological control: Use biological methods if available and appropriate.

Plant quarantine: Inspect new stock and keep separate until disease and pest freedom is assured. Keep new plantings separate from older and possibly diseased plantings.

Physical and mechanical methods/Pesticides: ***Pre-plant*** pasteurise, fumigate or solarise media for seed or cutting beds for high value crops in small areas to control diseases and weeds. ***Post-plant*** mulch (must be weed-free) or apply pre-emergence herbicides to control weeds. Control snails, cutworms, damping off and other problems that affect susceptible seedlings and cuttings as required.

Maintenance

Cultural methods: ***Ensure appropriate*** light, temperature, humidity, irrigation regimes as these ***affect vase life***, eg temperatures that vary from optimal may shorten vase life; ***excessive*** nitrogen, chlorine, salinity and pollution, ***decrease vase life*** and ***increase susceptibility*** to diseases, eg grey mould (*Botrytis cinerea*).

Sanitation: Remove old flower heads, diseased plant parts and weeds regularly.

Biological control: Use biological methods if available and appropriate.

Physical and mechanical methods: Flower-bearing stems may bend under the weight of flowers and may need to be ***staked*** to avoid difficulty in arranging curved stems in vases.

Pesticides: ***Control diseases, pests and weeds*** if necessary. Plants may be treated with plant growth regulators. Pre-market treatments may be required. Vase life may be reduced by fungal diseases.

Pest management: Check to see if such a program is available for a particular crop. Accurate ***diagnosis*** and ***monitoring*** of likely and potential problems are essential (Fig. 21).

Postharvest

Cut flower crops are among the ***most perishable*** *of horticultural produce and will only have a useful vase life if harvest, transport and storage procedures have been properly carried out. Handle cut flowers speedily. Avoid mechanical injury to flowers as they may be more sensitive to Botrytis and other fungi. Quality standards are available in Australia for some cut flowers and overseas for many more and also for potted plants, eg there are US standards for carnation, chrysanthemum, gladiolus, rose, snapdragon. Export flowers may need special treatments to eradicate insects and prevent propagation.*

Harvest flowers with a sharp knife at correct growth stage for the crop and the intended market. Generally flowers are picked during cool temperatures (early morning) and quickly placed in clean water containing a bactericide. Some flower species are sensitive to ***ethylene gas*** which is a naturally occurring plant hormone which comes from vehicle exhausts, damaged or dying flowers and foliage, ripening fruit, cigarette smoke and flowers themselves (Jones and Moody 1993). Ethylene accelerates ageing of harvested flowers and leaves. Flowers won't open and petals may shatter. ***The effects of ethylene can be minimised*** by reducing temperatures, eliminating ethylene sources and treating sensitive flowers with anti-ethylene chemicals.

Storage/Transport: Flowers are graded, bunched, packaged for transport, and usually ***rapidly cooled*** to 0-2^{o}C and kept at this temperature during shipment until sale to reduce water loss, maintain flower quality, inhibit bacteria and fungal infections, retard flower growth and senescing processes and extend storage life. Cooling is not suitable for all flowers (Jones and Moody 1993), some may suffer chilling injury, eg minimum storage temperature for alstroemeria is 4^{o}C and for orchids 8-12^{o}C. High relative ***humidity*** prevents drying out but favours *Botrytis*. ***Potted plants*** may need appropriate lighting, conditioning and hardening. Some cut flowers are affected by ***light*** (phototropism) or ***gravity*** (geotropism). Modified-atmosphere packaging ***(MAP)*** techniques with controlled temperatures are used for overseas markets. See Postharvest N 61.

Vase life decline is due to inability of stems to absorb water, excessive water loss from the cut flower, a short supply of carbohydrate to support respiration, the presence of diseases and ethylene gas. ***Maximise vase life***, which varies with the species and may be extended by ***pulsing*** (placing lower portions of flower stems in solutions containing a disinfectant and food, eg sugar, for several hours to 2 days); by ***growth regulators*** and by ***floral preservatives*** which usually contain a ***disinfectant*** (germicide, biocide), eg chlorine, to prevent blockage of xylem vessels with microoganisms; ***nutrients***, eg sucrose to extend vase life and an ***acidifier***, eg citric acid or vinegar to help flowers take up more solution and discourage bacteria which may plug xylem vessels. Floral preservatives can be made up or purchased. ***Bud opening*** solutions contain nutrients, acidifiers, disinfectants and hormones. If stems have been out of water for a while trim stem ends under water (if cut out of water, ***air bubbles*** are drawn up into the sap blocking stems). Salt may reduce vase life.

African violet

Saintpaulia ionantha
Family Gesneriaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt causes ***leaf mottles and ringspots***. Overseas tobacco mosaic virus also infects *Saintpaulia* sp. ***Destroy*** plants with symptoms, do not propagate from them. See Annuals A 4, Tomato M 96.

BACTERIAL DISEASES

Overseas *Pseudomonas marginalis* may cause black leaf rot during propagation and *Erwinia chrysanthemi* may cause a soft rot of roots, crowns and petioles. Both bacteria occur in Australia.

FUNGAL DISEASES

Damping off (probably *Phytophthora*, *Pythium*, *Rhizoctonia*). See Seedlings N 66.

Grey mould (*Botrytis cinerea*) may cause ***leaves and flowers*** to brown and a grey, furry mould may grow on them. See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) develops on the pedicels and calyces of ***flowers*** in warm humid conditions, eg in bathrooms. Although the white mealy growth occurs extensively on ***leaves*** it is not always damaging. See Annuals A 6.

Root, crown and stem rots (*Phytophthora,* and probably *Pythium, Rhizoctonia*) may cause ***leaves*** to become limp, ***whole plants*** may collapse. Do not confuse these fungal rots with petiole rots due to salts. See Annuals A 6, Vegetables M 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) may attack African violets causing watersoaked lesions on ***leaves***. Infested leaves die and fall. Varieties vary in their resistance. See Ferns E 2.

Others: ***Root knot*** (*Meloidogyne javanica*).

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) occasionally attack ***soft tender leaves*** and the ***flowers***. See Annuals A 7, Roses J 4.

Mealybugs (Pseudococcidae, Hemiptera)
African violet mealybug (*Rhizoecus dianthi*)
Citrus mealybug (*Planococcus citri*)
Longtailed mealybug (*Pseudococcus longispinus*)
Mealybugs feed in ***leaf axils and leaf undersurfaces*** and may cause ***serious damage*** if not treated promptly. They may also feed on ***roots*** making control difficult. See Greenhouses N 25.

Mites (Tarsonemidae, Acarina): ***Broad mite*** (*Polyphagotarsonemus latus*) causes ***leaves*** to develop a glassy appearance. See Greenhouses N 26. ***Cyclamen mite*** (*Phytonemus pallidus*) causes distortion of ***stems and leaves***. Leaves in the crown appear curled, dwarfed and very hairy. Flowers may also be dwarfed. ***Plants may die***. Control is difficult. See Cyclamen C 16.

Non-parasitic

Crowns: A mature African violet plant should have only ***one crown*** (rosette of leaves). Additional crowns that develop should be gently twisted out as they appear, this will encourage more flowers.

Environment: ***Bud drop:*** Buds may shrivel, turn brown, and drop prematurely. Causes include low temperatures, low humidity, overwatering and extreme fluctuations in soil moisture, temperature and light intensity. ***Water rings*** or patches develop on leaves if they are splashed with water which is ***cooler or warmer*** (by 8^{o}C or more) than the leaves (Larson 1992). Cell walls in the leaf palisade layer collapse and chlorophyll is damaged. Water drops on leaves in ***bright light*** may cause similar symptoms. Water pots from below using wick, tube or mat watering systems or use a narrow spouted watering can.

Nutrient deficiencies, toxicities: ***Petiole rot*** occurs if the petiole touches the rim of a porous pot which has absorbed fertiliser salts. An aluminium strip placed over the rim prevents contact. Do not confuse with bacterial or fungal root, stem or crown rots. ***Salt toxicity:*** African violets are sensitive to high salt levels (Larson 1992). Symptoms include poor growth, leaf yellowing, marginal leaf burn, death of growing points and dark limp roots. Hard water which contains bicarbonates and carbonates that make the growing media more alkaline may cause ***white spots and patches on leaves*** of sensitive varieties.

Pesticide dusts are difficult if not impossible to remove from ***hairy leaves***. Avoid using them.

Others: Algae, springtails and fungus gnats may occur in ***overwet pots*** (see House plants N 37). Some varieties have ***variegated leaves***, do not confuse with water rings.

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State/Territory Departments of Agriculture/Primary Industry eg

Nematodes on African Violets (Vic Agnote)

Propagation of African Violets by Tissue Culture (Vic Agnote)

The Foliar Nematode in Ornamental Plants other than Ferns (Vic Agnote)

Associations, Journals etc.

GrowSearch (database Qld DPI)

State/Territory African Violet Socs.

See Annuals and herbaceous perennials A 10, Containers N 20, House plants N 37

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: African violets are popular hobby plants or 'disposable' flowering pot plants which flower for 3 months and then may be thrown away. They usually cease flowering and growing during winter.

Resistant varieties: Cultivars vary in susceptibility to *Phytophthora* (Strider 1985).

Disease-free planting material: Purchase plants free from diseases and pests from reputable sources.

Establishment and Maintenance

Propagation is usually by leaf petiole cuttings from mature firm green leaves, rooting hormones promote rapid root formation, also by tissue culture and by seed (few cultivars come true from seed).

Cultural methods: Root systems are ***shallow*** so use shallow pots, when pot bound plants will produce flowers. Use a prescribed African violet mix ***free from soilborne diseases*** or treat the medium. ***Fertilise*** with prescribed African violet fertilisers or recommended alternatives. Keep plants in fairly bright ***light*** but not in direct sun (leaves may burn if water is left on them). Artificial light extends the hours of exposure and markedly increases flowering performance. Plants in window sills should be turned 1/4 every day to prevent a lean towards light. As plants are sensitive to chilling at < 10°C, purchase when ***weather is mild.*** Unlike most plants, African violets grow best with a warmer night temperature and a cooler day temperature. Night temperatures of 20-23°C and a day temperature of 14°C produce good growth (Larson 1992). African violets generally flourish in temperatures of 18-21°C. The main difference in the care of African violets from season to season is the amount of water required. ***Do not overwater***, soil should be kept moist without getting water on foliage. During the colder months of the year water with warm water or water at room temperature and water sparingly, ie when the soil feels dry to touch and plants will often survive in low temperatures. ***Provide good air circulation*** by adequate spacing of plants. Conditions in bathrooms are ideal for powdery mildew and *Botrytis*. Keep foliage free from ***dust*** by bathing regularly. Plants are sensitive to ***drafts***.

Sanitation: Remove any dead flowers and leaves promptly to prevent *Botrytis* from growing on them and spreading to other flowers and leaf stalks.

Plant quarantine: Plants taken to shows and brought back may bring back cyclamen mite and other pests. These pests may also be introduced to established collections by the purchase of infested plants.

Pesticides: On indoor plants only use pesticides ***registered for indoor plant use***, otherwise take plants outdoors for treatment and comply with label requirements.

Postharvest

Harvest: Pots should be sold at the beginning of flowering. There are no obligatory International Standards but many countries or societies have established standards governing their sorting and size.

Transport and storage: Water plants before packing. ***Avoid breaking foliage*** during handling, eg pack pots in sleeves of paper or other material. On arrival, unpack plants immediately, place under artificial lights to keep flowers in good condition until sold. Plants ***do not store well***, they withstand a maximum of 1 day in darkness, at 10°C and relative humidity of 90%, flowers are sensitive to ethylene so may be treated with anti-ethylene chemicals by the grower (Nowak and Rudnicki 1990).

Pot life: To keep plants growing and flowering, water and fertilise as recommended and provide adequate natural light or use artificial light.

Calendula

English marigold, pot marigold

Calendula officinalis
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Several viruses have been recorded on calendula but none appear to be serious.
Cucumber mosaic virus
Lettuce necrotic yellows virus
Tomato big bud mycoplasma (greening)
Tomato spotted wilt virus
Some are ***spread*** by insects and are ***seedborne***. See Annuals A 4.

FUNGAL DISEASES

Grey mould, *Botrytis*, flower blight (*Botrytis cinerea*) may occur sporadically during moist weather. See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) is common. Whitish mycelium covers ***leaves*** of plants grown under excessively moist conditions. Circular spots 2-5 mm across first appear irregularly scattered over leaves. Later the whole plant is affected and may finally ***wither and die***. See Annuals A 6.

Root, stem and collar rots
Ashy stem blight, charcoal rot, base rot (*Macrophomina phaseolina*)
Rhizoctonia (*Rhizoctonia solani*)
Sclerotium (*Sclerotium rolfsii)*
Sclerotinia rot (*Sclerotinia sclerotiorum*)
See Annuals A 6, Vegetables M 7.

Rust (*Puccinia lagenophorae*) is a native rust and a ***serious disease*** of Asteraceae, ie ***native plants,*** eg *Lagenophorae* spp., *Senecio* spp., *Erichtites* spp., ***exotic plants***, eg calendula, cineraria, English daisy (*Bellis perennis*), ***exotic weeds***, eg groundsel (*Senecio vulgaris*), and self-sown plants. Pale yellow-green spots may develop on ***leaves, stems and flower stalks*** (Fig. 22) during warm humid weather. Clusters of minute orange cup-like structures (aecia) later develop on these spots (Fig. 23). Masses of black spores (teliospores) may be produced amongst the aecia. ***Both leaf surfaces*** look as if they are covered with a yellow dust (rust spores) and may shrivel up. See Annuals A 7.

Smut, fungal leaf spot (*Entyloma calendulae,* Ustilaginales, Basidiomycetes) causes pale yellow ***leaf spots*** about 5 mm across, which later turn brown to black. Occasionally other fungi may also cause leaf spots on calendula. See Annuals A 5, Dahlia C 24.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* spp.) has been recorded on *C. officinalis* and other *Calendula* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Marigold aphid (*Neotoxoptera oliveri*)
These aphids infest ***new growth*** of calendula and a range of other plants. They may damage calendula during humid conditions in spring and autumn. See Roses J 4.

Caterpillars (Lepidoptera)
Cabbage white butterfly (*Pieris rapae*)
Cluster caterpillar (*Spodoptera litura*)
Cutworms (*Agrotis* spp.) attack seedlings
Native budworm (*Helicoverpa punctigera*)
See Annuals A 8.

Others: ***Earth mites*** (Penthaleidae) may feed on leaves, ***greenhouse whitefly*** (*Trialeurodes vaporariorum*) may infest leaf undersurfaces, ***leafhoppers*** (Cicadellidae) may feed on leaves. ***Mealybugs*** (*Pseudococcus* sp.) feed on stems and leaves. ***Plague thrips*** (*Thrips imaginis*) infests flowers, ***vegetable weevil*** (*Listroderes difficilis*) and other weevil larvae may feed on foliage.

Non-parasitic

Hen and chickens marigold (*C. officinalis prolifera*) has an unusual form (Fig. 24). ***Nectar scarabs*** (*Phyllotocus* spp.) and the ***mottled flower scarab*** (*Protaetia fusca*) may damage ***petals*** with their spiny legs. See Roses J 8.

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Pirone, P. P. 1978. *Diseases & Pests of Ornamental Plants*. 5th edn. John Wiley & Sons, NY.
State/Territory Departments of Agriculture/Primary Industry eg
Rust of Calendula, Cineraria and English Daisy (NSW Agfact, Vic Agnote)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural qualities: There is a wide range of cultivars to choose from, eg dwarf and semi-dwarf.

Resistant varieties: Varieties are continually being developed to ***improve quality***, eg flower colour and size, vigour and ***resistance to disease***, eg powdery mildew and rust.

Disease-free planting material: Some diseases are ***seedborne***, eg rust.

Establishment and Maintenance

Propagation: By seed. In warm climates, seed is usually sown in autumn or early winter and in cold districts in autumn and spring. Seedlings can be transplanted when they are large enough to be handled easily.

Cultural methods: Calendula perform well in any soil with good drainage but full sun is essential. ***Remove self-sown plants*** unless they are to be cared for with the rest of the crop. Do not plant new crops near older diseased crops. Calendula are shallow rooted so require regular watering in dry weather. A mulch of compost or leaf mould will prevent moisture loss, keep roots cool and control annual weeds.

Sanitation: Remove spent flower heads to prolong flowering and severely rust-affected plants to prevent further spread.

Pesticides: If it is considered necessary to apply a fungicide to control rust on ***susceptible varieties***, it should be applied at the first sign of disease.

Postharvest

Flowers for direct sale should be cut when flowers are fully open. If flowers are cut at too early a stage of development they will not develop properly even in an opening solution, or else their development will be prolonged and the quality of the flowers that finally appear will be poor. Cut flowers wilt rapidly and should be placed immediately after harvest in water or moisture-retentive boxes (Nowak and Rudnicki 1990).

Storage: No more than 3-6 days in water at 4-5^{o}C.

Vase life: Use a floral preservative. Remove leaves below the waterline and change water frequently.

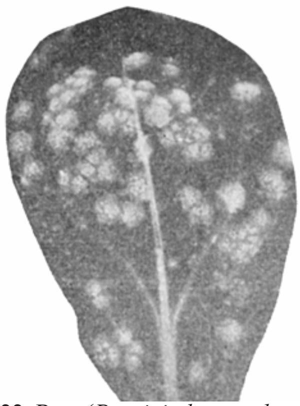

Fig. 22. Rust (*Puccinia lagenophorae*) on calendula leaves. Dept. of Agric., NSW.

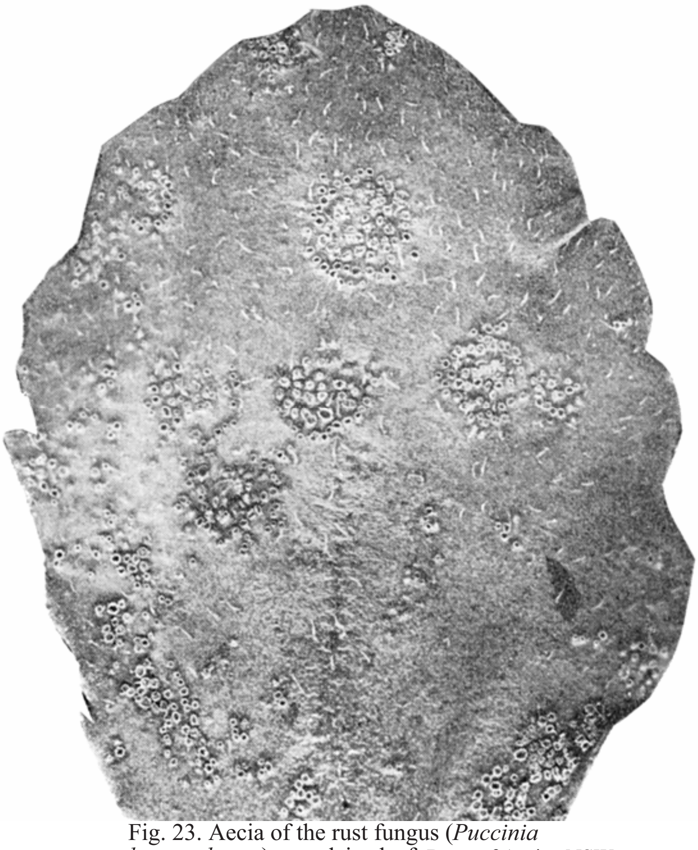

Fig. 23. Aecia of the rust fungus (*Puccinia lagenophorae*) on a daisy leaf. Dept. of Agric., NSW.

Fig. 24. Hen and chickens marigold (*Calendula officinalis prolifera*).

Carnation

Dianthus spp.
Family Caryophyllaceae (carnation family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot
- **Fungal diseases**
  - Anther smut
  - Damping off
  - Downy mildew
  - Fungal leaf spots
  - Fusarium blight and bud rots
  - Fusarium wilt
  - Grey mould
  - Rhizopus soft rot
  - Root and stem rots
  - Rust
- **Nematode diseases**
  - Cyst nematode
  - Root knot nematodes
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Mites
  - Thrips
- **Snails and slugs**

Non-parasitic
- Calyx splitting
- Environment
- Nutrient deficiency, toxicity
- Pesticide injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Most ***commercial carnation crops*** are affected by virus diseases, most of which are restricted to carnations. Plants may be infected with more than one virus. Virus diseases are ***important***, reducing flower quality and yield by as much as ***40-50%.*** Some cultivars infected with virus make reasonable growth if well cared for, but tend to deteriorate and are a source of infection for other plants. Symptoms vary with the virus(es) involved, the cultivar, stage of growth and climate. Their presence can only be confirmed by viral diagnostic tests. ***Leaves and stems*** may show mottling, streaking and other symptoms. ***Flowers*** may have an increased incidence of colour breaks and calyx splitting. ***All carnation viruses*** are ***spread*** by vegetative propagation from infected plants, by grafting, but usually not by seed, some also by insects and by sap.

Carnation mottle virus (***CarMV***) is the ***most common virus*** of carnations in Australia. Infected plants are mostly symptomless but some cultivars may show leaf mottling and a variable colour intensity in petals. ***CarMV*** is ***also spread*** by sap transmission during handling, by contact between plants (roots or foliage contact), there is no vector.

Carnation etched ring (***CERV***), ***carnation latent virus*** (***CarLV***), ***carnation necrotic fleck virus*** (***CarNFV***) ***carnation vein mottle*** (***CarVM***), may cause necrotic rings, flecks, spots and mottles on ***leaves and flower breaks***, but often there are ***no symptoms***. Multiple infections of these viruses can make symptoms more obvious. ***CERV*** is ***also spread*** by aphids, by mechanical inoculation, not by contact between plants; ***CarLV*** also by aphids, eg green peach aphid (*Myzus persicae*), by mechanical inoculation, not by contact between plants; ***CarNFV*** also by aphids, by mechanical inoculation with difficulty, not by contact between plants; ***CRSV*** also by mechanical inoculation, by contact between plants, not by a vector; ***CarVM*** also by aphids, mechanical inoculation, not by contact.

Others: Many more viruses occur in Australia and overseas, eg tomato big bud mycoplasma (Fig. 25).

See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot, bacterial leaf and flower blight (*Pseudomonas andropogonis = P. woodsii*) is a ***common and serious disease*** in cooler areas. Some strains are more virulent than others. ***Ornamentals***, eg carnation, statice, gypsophila, bougainvillea, *Ceratonia siliqua*, *Cicer arietinum*, *Mucuna deeringiana*, ***field crops***, eg *Sorghum* spp., *Trifolium* spp., *Vicia* spp., red and white clover, chick pea. Some strains are more virulent than others. Initially ***leaf spots*** are watersoaked and dark green, later centres become pale brown and have a purplish margin. Spots are up to 10 mm in diameter and may join together to form irregular dead patches, leaves may die. ***Calyx infection*** may result in damage to the flower and stems may be girdled. Old foliage, stems and flower buds are severely affected, severely infected plants die. ***Favoured*** by wet weather, warm temperatures (20-25^{o}C) and by wounding. ***Avoid*** growing carnation with statice, gypsophila or bougainvillea. Plant cultivars with some ***resistance***, many new Mediterranean cultivars are susceptible (Trujillo and Nagata 1994). Effective bactericides are not available. See Vegetables M 5.

Others: ***Bacterial wilt*** (*Pseudomonas caryophylli*) was introduced on plants imported from an approved overseas source. ***Fasciation*** (*Corynebacterium*) causes a proliferation of short spindly branches that arise from nodes of the main stem. ***Spread*** by water splash and favoured by moist conditions. Remove and destroy all affected plants, select disease-free planting material (Richardson and Merriman 1986). Also ***crown gall*** (*Agrobacterium* sp.).

FUNGAL DISEASES

Anther smut (*Ustilago violacea*) was detected in Qld in 1987 on a carnation crop grown from planting material obtained from an approved source overseas. Anther smut is an uncommon disease of modern cultivars partly because very few produce anthers. The disease has been ***eradicated*** (Bodman et al. 1996). The fungus is systemic and affected plants are stunted, often producing excessive numbers of side shoots. Purplish-black fungal spores replace the pollen in ***anthers***, flowers look dirty. Young plants are very susceptible, infection can take place in buds, cut stems and cuttings. Spores are ***spread*** by air currents, water splash or by handling infected material. Remove and burn infected plants (Com. of Aust. 1991, Fletcher 1984).

Damping off (*Pythium, Rhizoctonia solani*) in cuttings is ***common*** and may cause ***serious losses***. **Young plants** wilt and die. *Pythium* causes a wet root rot of roots and stems, *Rhizoctonia* causes a brown, dry rot of tissues around the crown of the plant. See Seedlings N 66.

Downy mildew (*Peronospora dianthicola*) has been recorded on pinks and dwarf carnation hybrids and some other cultivars. See Annuals A 5.

Fungal leaf spots may attack leaves, stems and flowers causing ***serious losses*** (Fig. 26).

Alternaria leaf spots (*Alternaria dianthicola, A. dianthi*) are ***common*** and cause ***serious losses***. Small, purple spots (0.5-1 mm in diameter) develop on ***leaves, stems*** and occasionally ***flowers*** in ***cool, wet conditions***. Spots enlarge, develop a yellow halo and grey centres and become covered with black spores. Leaves may die prematurely and stem infections may girdle stems killing branches. Infected flower buds may fail to open properly.

Cladosporium echinulatum is less common and less damaging than *Alternaria* and *Septoria*. Conspicuous pale brown spots, often with reddish-purple margins, about 5 mm in diameter, develop on ***leaves, stems and calyces*** in ***cool and wet conditions***. Rings of pin-point fruiting bodies develop within the leaf spots.

Septoria dianthi causes light-brown to grey spots, generally with purplish margins on ***leaves or young stems*** during ***warm and wet weather***. Pinpoint, black, fruiting bodies (pycnidia) which produce spores occur within older spots.

Others: Shot-hole (*Heteropatella valtellinensis*).

See Annuals A 5.

Fusarium blight and bud rots

Fusarium branch blight (*Fusarium culmorum, F. roseum*) causes branches to wilt. Stem tissues may rot usually at the ***axils of branches*** and are often pinkish. ***Spread*** by water splash from the soil surface. ***Favoured*** by wet weather, overhead irrigation. Avoid ragged wounds when removing flowers or cuttings. See Turfgrasses L 5.

Fusarium bud rot (*F. poae*) affects ***young buds*** which fail to develop, when cut open the petals are moist, brown and rotted. ***Large buds*** may open unevenly and have a lop-sided appearance and may be moist and spongy at the base. White cottony mycelium and a ***white oval mite*** (*Pediculopsis graminum*) which spreads the fungus from bud to bud, is usually seen inside affected buds. Mite infestations should be controlled.

Fusarium stem and branch rot, branch blight (*F. avenaceum = Gibberella avenacea*) is ***spread*** by aerial spores and infected cuttings and soil or mix causing ***basal stem rots and branch rot***. Under humid conditions white fungal threads and often orange spore masses form on rotted areas.

Fusarium stem rot, wilt and basal rot (*F. graminearum*) affects carnations grown in ***old pasture*** and is not as aggressive as fusarium wilt (*F. oxysporum* f.sp. *dianthi*), plants often grow out of the disease. Affected areas may have a ***red pigmentation***. See Turfgrasses L 5.

Fusarium diseases are ***spread*** by infested soil and by taking cuttings from infected plants. See Vegetables M 7.

Fusarium wilt (*Fusarium oxysporum* f. sp. *dianthi*) is probably the ***most serious disease affecting carnations*** throughout the world (Ibarbia 1996). Probably ***all 6 known strains occur in Australia,*** some strains are particularly virulent to young plants. Other species of *Fusarium* (see above) and other wilt fungi (*Verticillium* sp.) can also attack carnations. Symptoms of *Fusarium* wilt usually occur after flowering but may appear at any stage. Infected plants may not show symptoms for many months. ***Young plants*** show a one-sided yellowing and finally leaves wilt. ***Woody tissue in*** the stem beneath the affected leaves is ***discoloured***. This browning can take place before the plant begins to collapse. Symptoms gradually extend to the growing point. Plants may appear bleached and dried out. When the disease is well advanced, roots rot and the whole plant may be pale green and completely wilted, bark rots and disintegrates. Most infections occur near the soil level. ***Older plants:*** Flower stems yellow and wilt. Often one side of a plant wilts and dies, then the whole plant dies. Lower stem tissues are rotted and brown or straw coloured. Brown rotted streaks are seen in the ***water conducting tissue*** above the rotted areas. Usually no fungal growth develops on rotted areas (unlike stem rot caused by another *Fusarium* fungus). ***Phialophora wilt*** (*Phialophora cinerescens*) is not known to occur in Australia. See Vegetables M 9.

Grey mould (*Botrytis cinerea*) is of minor importance. Initially tan coloured flecks develop on ***petals, later flowers and stems rot*** and a ***grey fluffy mould*** may develop on the affected parts during moist conditions. Petals and stems of cut flowers are also affected by grey mould, especially when ***stored***. See Greenhouses N 22.

Rhizopus soft rot (*Rhizopus stolonifer*) is a minor disease in greenhouse crops. ***Petals*** collapse with a wet rot which extends into the heart of the flower. ***Black fungal spores*** develop on the rotted tissue. *Rhizopus* is commonly present in decaying plant material in soil. The fungus may grow readily on packing material and invade flowers through injuries. Inoculum builds up on ***trimmings from flowers*** if these are left in or around packing sheds. Avoid injury and keep flowers dry. Ensure good hygiene in packing sheds. See Vegetables M 6, Fruit F 6.

Root and stem rots

Fusarium blights and bud rots (*Fusarium* spp.) (see above)
Phytophthora rots (*Phytophthora* spp. and *P. nicotianae* var. *parasitica*)
Rhizoctonia stem rot (*Rhizoctonia solani*)
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 6, Vegetables M 7.

Rust (*Uromyces dianthi*) is ***common and serious*** during humid weather, warm days and cool nights. Rust may attack any stage of growth. Pale greyish areas appear on ***leaves, stems and calyces of flowers***. These erupt to expose reddish-brown spore masses. A ***ring of secondary pustules*** may develop around the first pustule. Heavy infection causes curling and death of leaves, stunting of plants and unsaleable flowers. As symptoms may take up to 1 month to develop after infection, rust may be ***transferred*** on ***cuttings***. Spores germinate on foliage if free water is present for 9-12 hours. A ***fungus*** (*Verticillium lecanii*) ***parasitises*** carnation and other rusts, eg dwarf bean rust, barley mildew, scales and aphids under natural conditions overseas. See Annuals A 7.

NEMATODE DISEASES

Cyst nematode (*Heterodera trifolii*) feeds on roots causing plants to be stunted. ***Roots*** are ***brown and branched*** with ***small white pinhead cysts*** which later brown (Minchinton et al. 1992).

Root knot nematodes (*Meloidogyne* spp.) may be damaging in some areas causing ***galls*** on ***roots***. See Vegetables M 10.

Others: ***Foliar nematode*** (*Aphelenchus avenae*), ***pin nematode*** (*Paratylenchus nainianus*), ***spiral nematodes*** (*Helicotylenchus* spp., *Rotylenchus brevicaudatus*), also *Filenchus exiguus, Macroposthonia rustica, Paratrichodorus, Scutellonema brachyurum, Tylenchorhynchus capitatus.*

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Aphids are ***common and serious pests*** in some areas, causing ***unsightly flowers and distorted foliage*** (Fig. 27). Most aphids infesting carnations have a wide host range and many ***transmit virus diseases***. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)

Corn earworm (*Helicoverpa armigera*) and native budworm (*H. punctigera*) are ***serious pests*** in warm humid areas (Fig. 28). Caterpillars feed ***inside flower buds and within flowers*** so that damage is often concealed; a small hole in the calyx may be the only indication of where the caterpillar has entered the bud. Petals must be parted to find the young caterpillar in the flower. Damage continues ***postharvest***. See Sweetcorn M 89.
Other caterpillars may also infest ***flower buds*** and ***flowers***.

See Annuals A 8.

Mites (Acarina)

Carnation shoot mite (*Eriophyes paradianthi*, Eriophyidae) lives between ***leaf bases and stems*** particularly of the lower portions of plants. They also feed ***under sepals***. Plants become pale and sometimes stunted and distorted.
Twospotted mite (*Tetranychus urticae*) may be a ***serious pest*** in warm conditions infesting ***leaves*** causing them to appear bleached or silvery, older leaves may die (Fig. 27). Growth is severely retarded. See Annuals A 9, Beans (French) M 29.

Thrips: ***Plague thrips*** (*Thrips imaginis*) may be a ***serious pest*** of ***flowers*** during warm humid weather. ***Gladiolus thrips*** (*Taeniothrips simplex*) and ***onion thrips*** (*Thrips tabaci*) may also infest carnations. Thrips (Fig. 27) feed in ***developing buds*** (preventing normal opening of flowers), on ***flowers*** causing petals to silver (particularly red or crimson cultivars) or brown, and ***anthers*** which may brown and shrivel. They may also feed on ***young leaves***. Egg-laying 'shot-holes' may be seen on the young leaves. Thrips re-infest crops from nearby vegetation drying out in spring. ***Insecticide applications*** may be necessary. See Gladiolus C 31, Onion M 68, Roses J 6.

SNAILS AND SLUGS

Snails and slugs may eat ***young plants*** in wet weather. See Seedlings N 70.

Non-parasitic

Calyx splitting is ***serious and common*** and occurs when the calyx cannot grow enough to accommodate the expanding petals and is due to sudden and/or great ***fluctuations in temperature***:

Rapid falls in temperature (6^{o}C per hour) when the bud is about 3-6 mm diameter, resulting in a larger than usual number of petals.
Long periods of low night temperatures (below 10^{o}C) causing a large number of petals.
Day temperatures of 6-9^{o}C above that of the previous day, 2-6 days after the calyx has begun to open. This occurs when petal numbers are already high. Low nitrogen and boron accentuate the problem but do not cause it.

Control:
Cultural methods: Optimum temperatures for production are 12.5^{o}C (night) and 19^{o}C (day). Day temperatures > 21^{o}C reduce petal numbers providing less substantial flowers and stems.
Resistant varieties: Some cultivars have a higher incidence of splits than others.
Physical and mechanical methods: Most split flowers are marketed using ***calyx clips*** applied after picking and before bunching of blooms.

Environment: ***Extremes*** in winter and summer temperatures reduce flower production and quality (see calyx splitting). ***High temperatures*** reduce flower and stem size. ***Frost*** or unseasonably low temperatures, damage leaves and flowers. Leaves may be twisted (Fig. 29). Near freezing temperatures (< 2^{o}C) cause circular white lesions on stems, leaf undersurfaces and on petals of coloured varieties, and pink to red lesions on petals of white varieties. Where temperatures are < 10^{o}C for long periods, large circular buds which fail to open ('bull-heads' or 'blindness') are more common. Although growth is normal, petals do not develop, buds do not open. ***Hail*** can cause severe losses. ***Rain*** and ***overhead irrigation*** increase disease. ***Wind*** may cause mechanical injury. Sim carnations break at the joints usually at the 2nd joint.

Nutrient deficiency, toxicity: In commercial production deficiencies of nitrogen, phosphorus, potassium, calcium, magnesium and boron may occur. ***Leaf analyses standards are available*** (Salinger 1985). ***Boron deficiency*** is common, causing shortening and thickening of

leaves, death of terminal buds and ***excessive shoot production*** high on stems. It is difficult to diagnose and a leaf analysis is required for confirmation. ***Calcium deficiency*** combined with direct sunlight is thought to cause ***tip burn of leaves*** of carnations propagated in glasshouses and watered with misters. Excess water may be supplied and some nutrients, particularly calcium, may be leached.

Pesticide injury: ***Methyl bromide*** may cause bleaching of foliage in bands; young flower buds may be affected. Soil is usually aerated for 7-10 days prior to planting but some plants, eg carnations, are sensitive to the small quantities which remain after 5 weeks or more. Retention is favoured by high soil moisture, clay content and organic matter. Leach fumigated beds well before planting and delay planting for at least 5 weeks; ensure good drainage. Methyl bromide is to be deregistered. ***Hypochlorite injury*** causes bleaching of leaf tips and new growth of cuttings. This may be due to being dipped in a solution which is too strong or for too long. Some cultivars, eg Gipsy, Diana and Chinesini are ***very susceptible***. Plants usually recover.

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State/Territory Departments of Agriculture/Primary Industry eg

NSW Agfacts

Diseases of Carnations
Heliothis Caterpillars
Prolonging the Vase-life of Carnations

Vic Agnotes

Fungal and Bacterial Diseases of Carnations
Ornamental Horticulture Kit
Pests of Carnations
Propagation of Chrysanthemums/Carnations by Tissue Culture
Virus Diseases of Carnations

Associations, Journals etc.

Flower Growers' Groups
Flower Link
Greenhouse Grower
GrowerTalks
GrowSearch (database Qld DPI)
Victorian Farmers' Federation

See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: There is a wide range of types, eg spray cultivars, standard.
Resistant varieties: If a particular problem recurs, check to see if ***resistant cultivars*** are available.
Disease-free planting material: Purchase and plant ***pathogen and virus-tested cuttings*** which are also free from other diseases, eg *Fusarium* wilt, which are carried in cuttings taken from diseased parent stock.

Establishment and Maintenance

Propagation: By cuttings, by tissue culture.
Culture: Plant ***virus-tested cuttings*** in ***disease-free soil***. Avoid planting areas where *Fusarium* or other soil-borne diseases are present. If this is unavoidable, media should be treated; plant in boxes. Plants are usually trellised. Plant cuttings at the depth grown in the nursery and in well drained soils with a pH of 6-7. Avoid overhead irrigation to reduce foliage and flower diseases. Fertilise as recommended. Carnations may also be grown in ***hydroponic systems.*** Cultivation ***temperatures*** that vary from the optimal ***shorten vase life***, eg carnations grown at 25^{o}C have a shorter vase life than those grown at 20^{o}C. Avoid conditions favourable to calyx-splitting and major changes/fluctuations in temperature in greenhouses to reduce leaf drop and malformed flowers. Pinch (removal of terminal growth to encourage bushy plants) and disbud (removal of terminal and other buds depending on type to improve size and appearance) as recommended.
Sanitation: Remove dead or dying leaves and buds as soon as they appear.
Pesticides: Pesticides are ***registered*** for disease, pest and weed control. Control aphids to reduce re-infection and spread of virus diseases within plantings. ***Growth regulators*** are used for rooting cuttings.
Pest management: Programs are available for some pests, eg twospotted mite.

Postharvest

Harvest: When flowers of standard cultivars are almost fully open, or at 'paint brush' stage with half-open flowers. Harvest spray cultivars with 2 fully open flowers on the stem. After harvest grade flowers according to bud size and stem length and bunch according to ***prescribed standards***. Tighter buds may be opened later with either preservative or bud opening solutions depending on the stage of development. As flowers are sensitive to ethylene, growers may treat flowers with anti-ethylene chemicals immediately after harvest to extend or double vase life. Avoid sunlight, draughts, keep flowers dry (Nowak and Rudnicki 1990). Avoid damaging flowers and maintain ***strict hygiene*** in the packing shed. See Postharvest N 62. A Melbourne-based company (Florigene®) has developed an *Agrobacterium*-mediated gene transfer system for inserting ***anti-ethylene genes*** into any carnation cultivar. This will extend vase life and reduce the need for anti-ethylene treatments to extend vase life and preservatives (Moody 1994).

Storage/Transport: Flowers can be kept for ***short periods*** in a cool room in preservative and wrapped in plastic (Jones and Moody 1993). Overseas fully open flowers may be stored at 3-4^{o}C in preservative solution for up to 2 weeks, at paint brush stage store dry in moisture-retentive boxes at about 0^{o}C for 3-4 weeks (Nowak and Rudnicki 1990). Buds may also be stored.

Vase life: Recut stems and place in warm water with biocide for a few hours. Allow flowers to rehydrate for a few hours before putting in sugar solutions, eg floral preservative. Remove dying flowers and damaged buds regularly, remove foliage below the water line. Replace vase water regularly (Jones and Moody 1993). Salt concentrations of 200 ppm decreases vase life of carnations and chrysanthemums.

Potted plants: Potted plants are ready for sale when flowers begin to open; plants require bright indirect light, a temperature of 18-20^{o}C and moderate watering (Larson 1992).

Fig. 25. Tomato big bud phytoplasma (greening) on *Dianthus* sp.

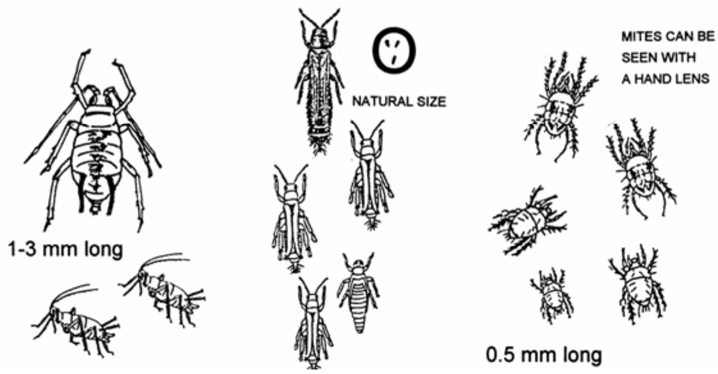

Fig. 27. ***Left :*** Aphids, commonly green peach aphid (*Myzus persicae*). ***Centre :*** Thrips (various species) feed on leaves, buds, flowers. ***Right :*** Twospotted mite (*Tetranychus urticae*).

Fig. 26. Fungal leaf spots (several species of fungi).

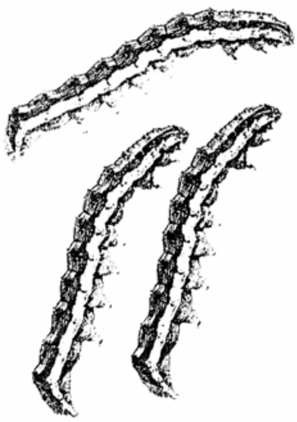

Fig. 28. Corn earworm (*Helicoverpa armigera*) feeds in buds and flowers. NSW Dept. of Agric.

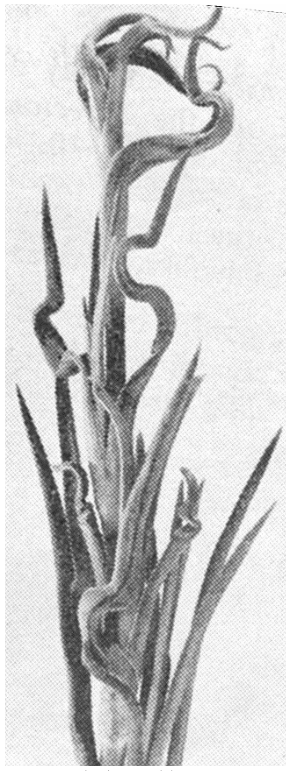

Fig. 29. Twisting of leaves caused by low temperatures. NSW Dept. of Agric.

China aster

Callistephus chinensis
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Fungal diseases
Damping off
Fusarium wilt
Grey mould
Root and stem rots
Nematode diseases
Root knot nematode
Insects and allied pests
Aphids
Caterpillars
Twospotted mite
Snails and slugs
Non-parasitic
Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases include tomato big bud mycoplasma (greening) and tomato spotted wilt virus. See Annuals A 4.

FUNGAL DISEASES

Damping off (*Pythium, Rhizoctonia solani*) may cause ***seedlings*** to die before, or soon after emergence. *Rhizoctonia* attacks plants at ground level and they collapse as stem tissue is destroyed. *Pythium* invades the young shoots, so that all below ground parts are rotted and the seedlings wilt and die. See Seedlings N 66.

Fusarium wilt (*Fusarium oxysporum* f.sp. *callistephi*) is the ***most important disease*** causing losses as high as ***20-30%.*** Young plants collapse and die. Older plants are stunted and wilt, older leaves yellow, stems are brown or black. The ***water conducting tissues*** of the ***stem and root*** are ***discoloured*** well in advance of obvious damage. See Vegetables M 9.

Grey mould, petal blight (*Botrytis cinerea*) is usually only a minor marketing problem. ***Petals, flowers or stems*** may be attacked. The tissue is at first watersoaked but later develops a grey mould over the surface. If stems are attacked, they wilt and older leaves yellow. If plants rot at ground level, ***they fall over***. See Greenhouses N 22.

Root and stem rots
Phytophthora root rots (*Phytophthora cryptogea, P. nicotiana* var. *parasitica*)
Rhizoctonia rot (*Rhizoctonia solani*)
Sclerotinia rot (*Sclerotinia sclerotiorum)*
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 6, Vegetables M 7.

Others: ***White blister rust*** (*Albugo tragopogonis*) may affect China aster but is uncommon. See Gerbera A 37.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) may cause small ***galls*** on ***roots***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest ***new shoots***. See Roses J 4.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.) are the ***most important insect pests*** affecting China asters. Eggs are laid on flower buds and the caterpillars feed inside the ***flowers***. Caterpillar faecal pellets discolour blooms and petals may fall. See Sweetcorn M 89.
Leafrolling moths (Tortricidae) caterpillars also damage ***flowers*** but usually feed on terminals and leaves. ***Leaves*** are rolled and webbed. See Pome fruits F 112.

See Annuals A 8.

Twospotted mite (*Tetranychus urticae*) and other spider mites (*Tetranychus* spp.) may damage ***leaves***. They can breed rapidly and their feeding causes silvering and russetting of the leaves which is followed by unthriftiness and leaf fall. See Beans (French) M 29.

SNAILS AND SLUGS

Snails and slugs may feed on China aster. See Seedlings N 70.

Non-parasitic

Environment: ***Temperature:*** Flowers, foliage and stems may be damaged by ***frost***. Flowers are also damaged by ***night temperatures*** in summer $> 23\ ^{o}C$ which reduce stem strength and flower size. When $23^{o}C$ is exceeded the neck of the flower stretches and the flower often ***bends at the neck*** after picking. ***Irrigation*** is essential to produce flowers of marketable quality. Well drained soils prevent serious soilborne diseases. A ***suitable pH*** is within the range of 5.5-6.5 (medium acid) (McKay et al. 1984).

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See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: China aster is an annual and not suitable for very cold climates. Select cultivars with firm petals and separate colours.

Resistant varieties: Cultivars vary in their ***resistance*** to *Fusarium* wilt.

Disease-free planting material: Seed is generally disease-free.

Establishment and Maintenance

Propagation: By seed which must be of good quality and stored correctly (McKay et al. 1984).

Cultural methods: ***Rotate crops*** to prevent a build up of soilborne diseases. Prepare ground early to facilitate the breakdown of organic matter. It may be necessary to ***pre-plant*** pasteurise the seedling mix, fumigate soil or use fungicides to control soil diseases. Choose a sunny position, sandy loam with organic matter with good drainage. Mulch to decrease water loss and to keep roots cool. Water and fertilise regularly. Asters can be flowered the year round when the night temperature can be kept at 10^{o}C (Larson 1992). Pinching is not essential to obtain good quality flowers. The decision on whether or not to pinch a crop depends on the daylength and temperature under which the crop is being grown and on when the crop is to be marketed. China asters are usually trellised. ***Avoid injury*** to roots during weed control.

Sanitation: Isolate infected plants and practise nursery hygiene. See Nurseries N 51. Ensure that water supply is free from possible ***waterborne diseases***.

Pesticides: Pesticides ***are registered*** for various diseases, pests and weeds. ***Growth regulators*** are used to control flower promotion and height.

Postharvest

Harvest: Fully open flowers with unblemished petals, otherwise they will not develop properly even in opening solution, or development will be prolonged and eventual flower quality poor (Nowak and Rudnicki 1991). Leaves are usually stripped off the lower 1/3 to 1/2 of the stem and placed in water with floral preservative preferably in a cool room at 5-8^{o}C to remove field heat. Avoid injury to flower heads by appropriate packaging (McKay et al. 1984).

Storage: Usually in clean water containing preservative ***(no sugar)*** at 1^{o}C at high relative humidity (Jones and Moody 1993). Fully open flowers may be stored at 0-4^{o}C for 1-2 weeks in water with floral preservatives, prior to shipment and sale. Flowers should be conditioned for 15-20 hours at room temperature in special solutions. Flowers should be ***transported*** in water at 4-5^{o}C (Nowak and Rudnicki 1990).

Vase life: Recut stems under water to prevent air from entering water vessels in the stems and ***remove all leaves below the water line***. Place stem ends in shallow water (30-100 mm) to minimise decay (submerged parts of the stem decay faster than upper parts). Every 1-2 days recut stem ends 20-30 mm from the bottom and replace vase water with fresh water with floral preservative, preferably at room temperature (Nowak and Rudnicki 1990). Avoid direct sunlight, drafts and sugar.

Chrysanthemum

Florists' chrysanthemum

Chrysanthemum x *morifolium*
= Chrysanthemum sinense
= Dendranthema x morifolium
Family Asteraceae

PESTS AND DISEASES

Parasitic

- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Damping off
  - Fungal leaf spots
  - Grey mould
  - Powdery mildew
  - Ray blight
  - Ray speck
  - Root and stem rots
  - Rusts
  - Wilts
- **Nematode diseases**
  - Foliar nematode
- **Insects and allied pests**
  - Aphids
  - Caterpillars,
  - Chrysanthemum gall midge
  - Leafminers
  - Mites
  - Thrips

Non-parasitic

- Environment
- Nutrient deficiencies, excesses
- Pesticide injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Many virus diseases may affect chrysanthemum and can be difficult to identify. Symptoms may not be expressed (latent viruses), may only be expressed after the first year of infection, or may only occur on some cultivars. Most viruses which infect chrysanthemum can only infect chrysanthemum, but others, eg tomato spotted wilt virus, can attack a wide range of herbaceous plants, vegetables, field crops, weeds. ***All virus diseases*** affecting chrysanthemum are ***spread*** by vegetative propagation from infected plants, some are also spread by insects, eg aphids and thrips, and/or by sap.

Chrysanthemum virus B (CVB): Mild ***leaf mottling***, brown streaks on ***florets***. ***CVB*** is ***also spread*** by aphids, eg potato aphid (*Macrosiphum euphorbiae*), foxglove aphid (*Aulacorthum solani*), chrysanthemum aphid (*Macrosiphoniella sanborni*), by mechanical inoculation, not by contact between plants, not by seed.

Chrysanthemum stunt viroid (CSV): On susceptible cultivars plants may be stunted, flower earlier; ***flowers*** may be small, distorted and bleached; leaves may have white spots (measles). ***CSV*** is ***also spread*** in sap from infected plants coming in contact with healthy plants via root or leaf contact. Sap may also be carried on tools, hands and workers' clothes. Where ***CSV*** is a problem, virus-tested planting material should be planted in treated soil or in soil where chrysanthemums have not been grown before.

Tomato aspermy virus (TAV) causes stunting of plants, ***flower breaking and distortion.*** ***TAV*** is ***also spread*** by aphids.

Tomato spotted wilt virus(TSWV) causes faint mottling, ring and line patterns, brown areas between ***leaf veins and vein yellowing***. In some cultivars flowers are of poor quality and distorted. ***TSWV*** is ***also spread*** by onion thrips (*Thrips tabaci*) and other thrips species. See Tomato M 96.

Others: Chrysanthemum chlorotic mottle viroid, chrysanthemum vein mottle, tomato big bud mycoplasma. See Annuals A 1 (Fig. 2). Overseas many more viruses may affect chrysanthemum.

See Annuals A 4.

BACTERIAL DISEASES

Bacterial blight (*Erwinia chrysanthemi*) may rot ***leaves, stems***. Also ***bacterial leaf spot*** (*Pseudomonas cichorii*) and ***crown gall*** (*Agrobacterium tumefaciens*).

FUNGAL DISEASES

Damping off (*Pythium, Rhizoctonia solani*) may kill ***cuttings*** and ***younger plants***. *Pythium* causes a wet rot of roots and lower stems. *Rhizoctonia solani* attacks the stem at ground level causing a dry rot. Propagate from tip cuttings that have no contact with soil. See Seedlings N 66.

Fungal leaf spots (*Septoria* spp). Dark brown spots (10-20 mm in diameter) develop on ***leaves*** (Fig. 30). These are usually circular at first, but may extend to involve all or a large part of the leaf. Small, black spots which are the fruiting bodies (pycnidia) of the fungus which produce the spores, appear on the dead areas. Younger leaves are infected as soon they emerge; spots often develop on leaf edges. Losses can be ***common and serious***. ***Ray blight*** (*Mycosphaerella ligulicola*) may also cause leaf spots. See Annuals A 5.

Grey mould (*Botrytis cinerea*) may occur in ***greenhouses*** or after other diseases or bruising outdoors. A grey furry fungal growth develops on affected areas during cool moist weather. See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) mainly occurs on ***greenhouse*** or ***neglected crops***. ***Leaves, flower buds and young stems*** become covered with a whitish, ash-grey, powdery growth. Leaves may be deformed or stunted and foliage sunburnt. Affected foliage withers. See Annuals A 6.

Ray blight (*Mycosphaerella ligulicola*) may affect chrysanthemums causing economic loss. ***Petals*** develop small pink spots which spread causing petals to brown and rot. Infection usually starts on one side of blooms but may later spread to all florets. Flowers apparently healthy when harvested may be unfit for sale when they reach the market. ***Leaf spots*** are large irregular, dark and often zoned, but usually only a few develop.

The fungus ***overwinters*** in infected plants and plant debris and is ***spread*** by wind-blown spores and by propagation from infected plants. ***Favoured*** by warm, humid weather, rain followed by warm conditions and an early autumn. ***Cultural methods:*** Avoid excessive moisture and nitrogen fertilisers which encourage lush vegetative growth which is difficult to spray. ***Sanitation:*** Cut off and burn all diseased flower stalks. Destroy diseased crops and debris immediately after harvest. ***Disease-free planting material:*** Do not take cuttings from infected plants, otherwise remove all but youngest leaves. ***Pesticides:*** If ray blight is a problem, fungicides may be applied to flower buds, leaves and stems. Use a wetting agent.

Ray speck

Ray speck (*Alternaria* spp., *Stemphylium* sp.) cause tiny dark spots on ***petals***, flowers look as if covered with dust (Bodman et al. 1996).

Root and stem rots

Root and stem rots are not usually of economic importance.
Phytophthora root rot (*Phytophthora* sp.)
Pythium stem rot (*Pythium* spp.)
Rhizoctonia stem rot (*Rhizoctonia solani*)
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 6, Vegetable M 7.

Rusts (Uredinales, Basidiomycetes)

Rust (*Puccinia chrysanthemi*) is ***common, serious*** and affects ***leaves, stems and branches***. Initially, light-coloured raised spots develop mainly on leaf undersurfaces which later break open and shed ***dark dusty spores***. Leaves may wither prematurely, reducing plant vigour. Disease is favoured by crowded cutting beds and moist weather in early autumn. See Annuals A 7.

White rust (*Puccinia horiana*) may cause ***complete crop loss***. Overseas, two strains of the fungus (83 and 84) exist, the situation in Australia is not yet known. Pustules develop mainly on ***leaves*** but may also develop on ***bracts and stems***. Leaves become susceptible with age. Initially pale green to yellow spots develop on ***leaf uppersurfaces***, centres turn brown. On ***leaf undersurfaces***, raised, pinkish, waxy pustules develop (Fig. 31), these become whitish and prominent (these white pustules on the undersides of leaves distinguish white rust from *P. chrysanthemi*). Under humid conditions leaves may wither before many pustules are present. Occasionally pustules develop on both surfaces of ***petals***, flowers brown and dry at tips. Spores are ***spread*** by wind (up to 700 m). Optimum temperature for spore dispersal and infection is ***17°C*** in spring and autumn. High relative humidity and a film of water on the leaf surface are required for sporidia to germinate on the leaf, infected leaves display symptoms 7-10 days after infection. ***Sanitation:*** Remove old unwanted crops and all crop debris, control weeds to reduce crop humidity. ***Resistant varieties:*** Most cultivars of florists' chrysanthemum (*C. sinense*) are susceptible, but they vary in susceptibility. Accent, Dark Lapana, Lipoma, Purple Bounty, Resilient and Smiles are resistant to ***race 84.*** Beatrix is resistant to ***race 83***. Bright Eye, Jane Rowe, Neil Zwager and Rosita to ***races 83 and 84.*** ***Other susceptible species*** include *C. indicum*, *C. japonese*, *C. makinoi*, *C. makinoi* var. *wakasaense*, *C morifolium* var. *sinsense*, *C.shiwogiku*, *C. shiwogiku* var. *kinokuniense*, *C. yezoense*, *C. koreanum*. ***Resistant species*** include the annual chrysanthemum (*C. carinatum*), shasta daisy (*C. maximum*), garden pyrethrum (*C. coccineum*) (Com. of Aust. 1984). ***Plant quarantine:*** Attempts to eradicate white rust in Australia have been unsuccessful and its quarantine status is under review. ***Fungicides*** may be applied to the foliage of affected plants at the first sign of disease. Myclobutanil is being researched as a dip for chrysanthemum cuttings prior to planting (Bonde et al. 1995).

See Annuals A 7.

Wilts

Fusarium wilt (*Fusarium oxysporum*) may occur in warm areas but is of minor importance.

Verticillium wilt (*Verticillium dahliae*) causes plants to become stunted. Lower leaves develop a pinkish or purplish tinge, wither and hang limply against the stem, younger leaves are yellower than normal. Eventually plants wilt. If the stem above ground level is scraped, wood is brown. Purchase ***Verticillium-free plants*** and plant in *Verticillium*-free soil or in infested soil which has been treated prior to planting. Otherwise propagate only from healthy plants in beds that are wilt-free and not adjacent to diseased plants and plant in *Verticillium*-free soil. *Verticillium*-free cuttings can also be obtained by taking tip cuttings from shoots 300-450 mm high (the fungus does not extend up the stem right to the tip) and discarding any infected cuttings as soon as infection is evident.

See Vegetables M 9.

NEMATODE DISEASES

Foliar nematode

Foliar nematode (*Aphelenchoides ritzembosi*) damages ***leaves and flowers***. Initially, ***leaf spots*** form which later may become triangular and bordered by veins (Fig. 32). Disease progresses from lower leaves upwards and in a severe attack, leaves may hang withered against the stem. Infested flowers become brown and decayed often only on one side. ***Prune out*** and destroy infested leaves and stems and other affected portions of plants. Varieties vary in ***resistance***. Avoid ***propagating*** from infected plants. If this is unavoidable, then either take tip cuttings from the tops of long vigorous shoots or treat infected setts in hot water (some plant damage may occur). Keep infested plants separate from healthy ones. Treated setts and tip cuttings must be planted in ***nematode-free soil***. As soon as leaf spots appear on susceptible cultivars, apply a ***nematicide*** to the foliage, repeat applications may be necessary in wet weather. Prune out affected parts before spraying. See Ferns E 2.

Others: ***Root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* sp., *Rotylenchus reniformis*), *Basiria graminophila, Paratrichodorus sp., Paratylenchus nainianus.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Chrysanthemum aphid (*Macrosiphoniella sanborni*)
Pale chrysanthemum aphid (*Coloradoa rufomaculata*)

Cotton aphid, melon aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Leafcurl plum aphid (*Brachycaudus helichrysi*)
Foxglove aphid (*Aulacorthum solani*)
Aphids are ***major pests*** (Fig. 33), they distort ***new foliage*** and spread ***virus diseases***. See Roses J 4.

Caterpillars (Lepidoptera) may be pests of the ***foliage and flowers*** in warm, moist conditions. ***Budworms*** (*Helicoverpa* spp.) feed on petals of buds and flowers causing ***serious losses*** often without proper identification. ***Leafrolling moths*** (Tortricidae), eg ***lucerne leafroller*** (*Merophyas divulsana*) and other species. ***Others: Cabbage white butterfly*** (*Pieris rapae*), ***cutworms*** (Noctuidae), ***looper caterpillars*** (*Chrysodeixis* spp.), ***woollybear caterpillar*** (*Spilosoma glatignyi*). See Annuals A 8.

Chrysanthemum gall midge

Scientific name: Cecidomyiidae, Diptera: Chrysanthemum gall midge (*Rhopalomyia chrysanthemi*)

Host range: Chrysanthemum (occasional pest).

Description and damage: ***Flies*** are frail, small, long-legged, orange and about 1-2 mm long. ***Tiny maggots*** feed inside plant tissue causing small, ugly thorny ***galls*** on ***leaves and stems*** (Fig. 34). ***Foliage*** may be distorted and unmarketable.

Pest cycle: Complete metamorphosis (egg, maggot, pupa, adult) with many generations each year. Females lay eggs on new foliage. Eggs hatch in 3-4 days and maggots enter leaves and other tissue, galls develop, when mature the maggots pupate in the gall. After flies emerge, the empty pupal skin protrudes from the gall.

Overwintering: Infested leaves, stems, debris.

Spread: By adults flying, propagation from infested plants, and introduction of infested plants.

Conditions favouring: Warm, moist conditions especially greenhouse chrysanthemums.

Control:
Sanitation: ***Remove*** and destroy (burn/deep bury) all infested foliage and severely infested plants.
Resistant varieties: Florist's chrysanthemum (*Chrysanthemum* x *morifolium*) is ***susceptible***. Cultivars with light green foliage are reputed to be more susceptible.
Plant quarantine: ***New plants*** should be carefully ***inspected***, infested plants should be destroyed.
Disease-free planting material: ***Do not propagate*** from infested plants.
Pesticides: Maggots inside leaves are difficult to kill so ***insecticide treatments*** are aimed at killing adult midges. In a home garden situation, spraying is not usually necessary and sanitation will provide satisfactory control.

Leafminers (Diptera)

Cineraria leafminer (*Chromatomyia syngenesiae*) maggots tunnel between ***upper and lower leaf surfaces*** during cool weather in late winter and spring (Fig. 35). Flower crops may not be affected. Occasional infested shoots may be pruned off and destroyed. ***Very susceptible varieties*** include Marguerite daisies (*Chrysanthemum frutescens*) and shasta daisy (*C. maximum*). See Cineraria A 28.
Other fly leafminers infesting chrysanthemums and related plants overseas have the potential to cause ***multi-million dollar crops losses*** in the flower and vegetable industries (Com. of Aust. 1996).

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) causes malformations of ***growing tips, young leaves***. See Greenhouses N 26.
Cyclamen mite (*Phytonemus pallidus*) causes similar damage as broad mite. See Cyclamen C 16.
Earth mites (Penthalidae) may suck sap from ***leaves*** near the ground during winter. See Vegetables M 16.
Twospotted mite (*Tetranychus urticae*) can be damage ***leaves*** in hot dry conditions. See Annuals A 9, Beans (French) M 29.

Thrips (Thripidae, Thysanoptera)

Plague thrips (*Thrips imaginis*) and other species are very small, fast-moving insects which cause streaking and browning of ***petals***. Dark excreta produced by thrips on light coloured blooms causes disfigurement. See Roses J 6.
Greenhouse thrips (*Heliothrips haemorrhoidalis*) causes ***leaf silvering***. See Greenhouses N 24.

Others: ***European earwig*** (*Forficula auricularia*) may damage ***petals***. ***Also greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***flower beetles*** (*Protaetia* spp.), ***leaf hoppers*** (Cicadellidae), ***mealybugs*** (Pseudococcidae).

Non-parasitic

Environment: ***Frost*** will damage flowers. ***Low temperatures*** may cause leaves of some varieties to become pinkish.

Nutrient deficiencies, toxicities: It may be difficult to recognise ***deficiencies***; effects often depend on the stage of plant growth and are usually due to a shortage of a particular element and not to its complete absence. Common deficiencies include ***iron*** (interveinal yellowing of the new leaves), ***magnesium*** (interveinal yellowing of the older leaves), ***nitrogen*** (slow growth, stunted growth and pale leaves), and ***potassium*** (thin shoots and dead or yellow margins of older leaves). ***Salt toxicity and excess fertiliser*** may be harmful. Deficiencies and toxicities are mainly found in ***container-grown*** chrysanthemums.

Pesticide injury to flowers is common and is favoured by ***high temperatures***; if foliage and flowers remain ***wet*** for extended periods after application, during ***moisture stress***; using ***incompatible pesticides*** and ***exceeding recommended rates*** for wetting agents and pesticides. ***Emulsifiable concentrates*** are more phytotoxic than wettable powders which may leave visible residues on flowers and foliage. ***Hormone herbicides*** may distort new growth and cup leaves.

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State/Territory Departments of Agriculture/Primary Industry eg

NSW Agfacts

Cineraria leafminer (Insect Pest Bull. 87, 1976)
Diseases of Chrysanthemum

Tas Service Sheets

White Rust of Chrysanthemum and its Control

Vic Agnotes

Application of Fungicides for Control of Chrysanthemum White Rust
Chrysanthemums All Year Round
Chrysanthemum Foliar Nematode
Chrysanthemums for Cut Flowers
Chrysanthemum Stunt
Control of White Rust of Chrysanthemums
Fungal Diseases of Chrysanthemum in Victoria
Pests of Chrysanthemums
Potted Chrysanthemums
Propagation of Chrysanthemums/Carnations by Tissue Culture
Virus Diseases of Chrysanthemum
White Rust of Chrysanthemums

Associations, Journals etc.

Flower Link
GrowSearch (database Qld DPI)
National Chrysanthemum Soc. (Handbook on Chrysanthemum Classification)
State/Territory Horticultural/Flower Socs.

See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural varieties: Perennial florists' chrysanthemum is the most widely grown type of chrysanthemum; there are many different cultivars.

Resistant varieties: Where problems occur, consider using resistant varieties, eg white rust, ray blight. Diagnose any problem correctly. Salinger (1985) has prepared a key to assist with the diagnosis of disorders.

Plant quarantine: Many diseases of chrysanthemum are not yet present in Australia.

Disease-free planting material: Purchase ***pathogen and virus-tested chrysanthemums*** (high health, elite planting material) from reputable suppliers or propagate only from disease and pest-free plants. As many pests and diseases are introduced on cuttings, inspect all planting material for white rust, gall midge and other pests and diseases. Tip cutting should have no contact with soil.

Establishment and Maintenance

Propagation: By cuttings or tissue culture. Named varieties must be propagated by root divisions, cuttings or tissue culture. When taking cuttings remove all but the younger healthy leaves; older leaves are more likely to carry symptomless disease (leaf spots, ray blight, rust). Also by seed.

Cultural methods: Rotate crops to avoid build up of inoculum. Do not plant clean stock in contaminated areas or soil. Plant in well drained soil (pH 6.2-6.7). Do not plant cuttings too deeply and avoid excess fertiliser. Irrigate well but avoid wetting foliage for long periods, water in the morning to reduce foliage diseases. Provide shade in hot climates and protect from wind, rain and frost, choose an open sunny position unless the climate is very hot. The habit of growth is determined by the number of flower stems and the size and quality of the flowers. ***Stopping or pinching*** (removal of the growth tip) promotes the development of 3-4 lateral stems and disbudding (removal of buds) influences the size and quality of flowers. ***Support flower-bearing stems*** to prevent them bending under the weight of the flowers. Avoid excess nitrogen as lush growth is difficult to spray.

Sanitation: Remove and destroy residues from previous crops to make leaf and flower diseases and insect pests, eg gall midge, less likely. Even a few small infected plants are a source of infection. Practice nursery hygiene. Remove and destroy severely diseased plants in otherwise healthy crops. See Nurseries N 51.

Physical and mechanical methods: Pasteurise soil for cutting beds before planting or treat in some manner to ensure that residues from previous crops are destroyed.

Pesticides: ***Growth regulators*** are used to promote flowering and dwarf plants. Where necessary protect foliage from fungal diseases and insect pests with pesticides. It is recommended that a comprehensive disease and pest control program be prepared. ***Monitor*** diseases and pests regularly.

Postharvest

Harvest: Harvest standard cultivars when outer petals are fully elongated, others at different stages (Jones and Moody 1993, Nowak and Rudnicki 1990). There are US guidelines for harvesting standards, sprays, singles, pompoms, decoratives. Remove the hard and woody base which hinders water uptake (100 mm above the base). They can also be ***picked tight, transported or stored and opened*** with correct opening solution (Jones and Moody 1993).

Storage/Transported: Before prolonged storage and transport, flowers must be protected against grey mould and conditioned. Overseas flowers may be held in moisture retentive boxes at -0.5-0^{O}C (Nowak and Rudnicki 1990). To revive flowers slightly wilted after transport, stems may be placed in warm water for 60 seconds (Nowak and Rudnicki 1990).

Vase life: Choose clean undamaged flowers and foliage, remove foliage that would be below the water and woody basal part of stem, use a floral preservative. Recut stems under water (Jones and Moody 1993).

Potted plants for direct sale are ready when coloured flowers begin to appear. If plants are to be ***transported*** for 1-2 days and kept at low light levels then do so when 3/4 of the flowers are fully developed. During ***storage***, potted plants require bright indirect light, at temperatures of 8-12^{O}C, flowers preserve a fresh appearance for a long time (Nowak and Rudnicki 1990).

Fig. 30. Fungal leaf spots (*Septoria* spp.).

Fig. 31. White rust pustules (*Puccinia horiana*) on leaf undersurfaces. Min. of Agric., NZ.

Fig, 32. Foliar nematode damage (*Aphelenchoides ritzembosi*).

Fig. 33. Many species of aphids (Aphididae) infest new chrysanthemum growth and spread virus diseases.

Fig. 34. Chrysanthemum gall midge damage (*Rhopalomyia chrysanthemi*)

Fig. 35. Cineraria leafminer damage (*Chromatomyia syngenesiae*).

Cineraria

Senecio hybrida
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases recorded on cineraria include cucumber mosaic virus and tomato spotted wilt virus. See Annuals A 4.

BACTERIAL DISEASES

Bacterial wilt (*Pseudomonas solanacearum*). See Vegetables M 6, Tomato M 98.

FUNGAL DISEASES

Damping off (*Pythium* spp.). See Seedlings N 66.

Fungal leaf spots (*Alternaria cinerariae, Cercospora* sp.). See Annuals A 5.

Grey mould (*Botrytis cinerea*) may affect ***young plants*** grown under high humidity and low light intensity. See Greenhouses N 22.

Powdery mildew (*Oidium* sp.) may attack ***leaves, stems and flower buds*** covering them with a whitish, powdery growth causing stunting. See Annuals A 6.

Root and stem rots, wilts
Fusarium (*Fusarium* spp.)
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Phytophthora root rot (*Phytophthora cryptogea*)
Rhizoctonia stem rot (*Rhizoctonia solani*)
Verticillium wilt (*Verticillium dahliae*)
See Annuals A 6, Vegetables M 7.

Rust (*Puccinia lagenophorae*) may attack many native and exotic Asteraceae including cineraria. Pale yellow-green spots develop on ***leaves, stems and flower stalks*** during warm humid weather. See Annuals A 7, Calendula A 15 (Fig. 22).

White blister rust (*Albugo tragopogonis*) occurs on cineraria, other *Senecio* spp. and other Asteraceae. Light yellow areas develop on ***leaves***; later dome-like swellings burst to expose white chalky spores. Foliage may die. See Gerbera A 37.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) and ***root lesion nematode*** (*Pratylenchus* sp.) have occurred on *Senecio* spp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cotton, melon aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Leafcurl plum aphid (*Brachycaudus helichrysi*) is pale to dark green or reddish brown.
Potato aphid (*Macrosiphum euphorbiae*)
Aphids may feed on ***new shoots***. See Roses J 4.

Caterpillars (Lepidoptera)

Cineraria moth**,* senecio moth, magpie moth (*Nyctemera amica*, Arctiidae) caterpillars feed openly ***during the day on cinerarias (*Senecio* spp.) and groundsels (*Senecio* spp.). They are ***20-30 mm*** long, hairy black with ***2 tufts of hair*** projecting from the head, with orange or occasionally blue stripes along its back. They pupate on ***foliage*** in thin loosely woven cocoons incorporating body hairs (Common 1990).

Looper caterpillars (*Chrysodeixis* spp.) may feed on ***foliage*** of cineraria and many other plants. See Vegetables M 13.

See Annuals A 8.

Cineraria leafminer

Scientific name: Agromyzidae, Diptera:
Cineraria leafminer (*Chromatomyia syngenesiae*)

Host range: Asteraceae, ***ornamentals***, eg chrysanthemum, cineraria, everlastings (*Helichrysum*), gazania, nasturtium, ***vegetables***, eg lettuce, ***weeds***, eg sow or milk thistle, cape weed, prickly lettuce.

Description and damage: ***Flies*** are grey, 3 mm long and walk over leaves of hosts during winter and spring. ***Larvae*** or maggots are creamy-white and about 4-5 mm long when fully-grown. ***Pupae*** are elongate, about 2.5 mm long and can be seen through the epidermis on ***leaf undersurfaces***. A single leaf may contain several pupae. Maggots tunnel between ***upper and lower leaf surfaces.*** Initially mines appear as pale, narrow, thread-like lines but as the maggots grow, mines become more conspicuous and may reach 1.5 mm in diameter (Fig. 36). In heavily infested cinerarias, growth may be retarded or plants may die after most of the leaves are destroyed. ***Foliage is spoilt***.

Pest cycle: Complete metamorphosis (egg, maggot, pupa, adult) with several generations each season. Female flies lay eggs within the leaf tissues and puncture marks or 'stings' may be seen as small scars on the surface. Eggs hatch in about 4-5 days and the tiny maggots feed between the upper and lower epidermis. When fully grown, they pupate within the leaf. Adults emerge 10 days later. The life cycle is completed in 3-4 weeks.

Overwintering: On host plants, pupae may be seen in the tunnels on the undersurface of the leaf.

Spread: By adults flying, propagation (cuttings etc) from infested plants and the movement of infested plants and plant parts.

Conditions favouring: Cool humid weather during ***late winter, spring and early autumn***.

Control:

Sanitation: Occasional shoots which are infested may be **pruned off** and burnt. All prunings from infested plants should be destroyed/burnt.

Biological control: Overseas, **parasitic wasps** may control cineraria leafminer on chrysanthemum.

Resistant varieties: Varieties vary in **resistance**.

Disease-free planting material: **Avoid** taking cuttings from infested plants. If unavoidable, select ones which are apparently damage-free.

Pesticides: If damage in previous years was severe on susceptible varieties, **systemic insecticides** may be applied as soon as mines appear in late winter and early spring. Repeat applications may be necessary if larvae are still active and further infestations occur, ie in late winter and early spring if weather is cool and wet. If ***pupae can be seen*** when held up to the light it is too late to spray. If non-systemic insecticides are used, spray both sides of leaves thoroughly.

Others: ***European earwig*** (*Forficula auricularia*), ***greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***twospotted mite*** (*Tetranychus urticae*).

SNAILS AND SLUGS

Various species may damage **leaves and stems** of cinerarias. See Seedlings N 70.

Non-parasitic

Environment: Cinerarias may be damaged by **frost** or **strong sun** and require **abundant water** and high humidity because their large leaves accelerate water loss and wilting, but avoid overwatering. **Winds** which are drying accelerate water loss. Plants are sensitive to direct drafts.

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State/Territory Departments of Agriculture/Primary Industry eg

Cineraria Leafminer (NSW Insect Pest Bull. 87, 1976)

Rust of Calendula, Cineraria and English Daisy (NSW Agfact)

See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Cinerarias can be grown in the open or in pots for moving indoors when flowering starts. There are many different types, eg tall and dwarf, compact dwarf types are suited for pots. ***Propagation:*** By sowing disease-free seed in late summer and autumn for flowering in late winter and early spring. Some diseases, eg *Fusarium* sp., may be seedborne. Cinerarias are ***not suitable for very hot or very cold climates.*** They prefer semi-shade and can be grown in shady sites in the open garden and in greenhouses. It may be necessary to apply insecticides to control aphids and cineraria leafminer. ***Potted plants are sold*** when 1/4 to 1/3rd flowers are open. Do not market flowers with yellow pollen showing (they are too old). Cineraria is very sensitive to grey mould (plants may need to be sprayed prior to sale) and has low sensitivity to ethylene. ***During storage/transport*** keep at a cool temperature of 10-12^{o}C. At higher temperatures they are short-lived, flower buds develop faster, senescence is accelerated and plants lose their decorative value. Store or transport a maximum of 3 days in darkness at 5^{o}C and relative humidity of 90%. Plants grow at low temperatures (12- 17^{o}C) and may be used to decorate relatively cool areas, eg halls (Nowak and Rudnicki 1990).

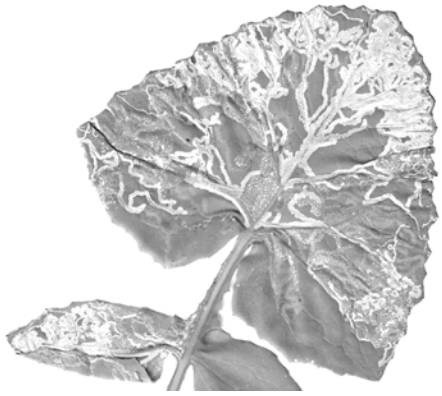

Fig. 36. Mines or tunnels in leaves made by the larvae (maggots) of the cineraria leafminer (*Chromatomyia syngenesiae*). ***Left :*** Cineraria. Dept. of Agric., NSW. ***Right :*** Sowthistle (*Sonchus oleraceus*).

Delphinium

Larkspur

Delphinium grandiflorum
Family Ranunculaceae (crowfoot family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus, tomato spotted wilt virus and tomato big bud mycoplasma (greening). See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot, black leaf spot (*Pseudomonas syringae* pv. *delphinii*) is a minor disease. On ***leaf uppersurfaces*** spots are black, shiny and irregular in shape and size; on leaf undersurfaces they are brown. Symptoms also occur on ***stems, leaf stalks and flowers***. They begin on lower parts of plants. See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf and stem spots
Anthracnose, stem canker (*Colletotrichum acutatum*)
Fungal leaf spot, crown rot (*Diplodina delphinii*)
See Annuals A 5

Powdery mildew (*Oidium* sp.) affects leaves. See Annuals A 6.

Root and stem rots
Damping off (*Pythium*, *Rhizoctonia solani*)
Grey mould (*Botrytis cinerea*)
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Rhizoctonia root rot (*Rhizoctonia* solani)
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 5, A 6, Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* sp.) has been recorded on *Delphinium cultorum*. See Annuals A 7.

INSECTS AND ALLIED PESTS

Aphids (Aphididae): ***Green peach aphid*** (*Myzus persicae*) may infest ***shoots***. See Roses J 4.

Mites (Acarina): ***Twospotted mite*** (*Tetranychus urticae*) may cause ***whitish leaf speckling***. ***Broad mite*** (*Polyphagotarsonemus latus*) and ***cyclamen mite*** (*Phytonemus pallidus*) may also infest delphinium. See Annuals A 9.

Others: ***Caterpillars*** (Lepidoptera), ***leafhoppers*** (Cicadellidae), ***root mealybug*** (*Rhizoecus falcifer*).

SNAILS AND SLUGS

Protect delphiniums from ***snails and slugs*** in spring. See Seedlings N 70.

Non-parasitic

Seedlings are ***frost*** sensitive, established plants are tolerant. Tall varieties need ***staking*** and/or ***wind protection***. Delphiniums contain ***poisonous substances*** (Frohne and Pfander 1983).

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See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Delphinium is a tall, stately and hardy perennial flower. It is best treated as an annual but in cold climates plants will last for several years if summers are mild. They prefer an open sunny position and well drained fertile soil. ***Propagated*** by seed, cuttings or by division. ***Harvest*** cut flowers for direct sale when florets are 1/2 open. Growers may treat flowers with an anti-ethylene agent as they are sensitive to ethylene and florets drop easily or 'shatter'. Keep flowers cool (Jones and Moody 1993). Flowers may be ***stored*** in preservative solution for 1-3 days in water. Spikes must be transported in an upright position as they bend upwards (geotropism) when kept horizontal (Nowak and Rudnicki 1990). Cut stems underwater and add a preservative.

Everlastings

Native daisies, paper daisies, strawflowers
Helichrysum bracteatum (*Bracteantha bracteata*)
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato big bud mycoplasma (greening) affects *Helichrysum* spp. (Fig. 37). See Annuals A 4, Tomato M 97.

FUNGAL DISEASES

Damping off, root and stem rots: ***Phytophthora root rot*** (*Phytophthora cinnamomi*) on *H. diotrophyllum* and *H. obcordatum*, and ***P. cryptogea*** on *H. bracteatum* and *H. diosmifolium*. ***Also sclerotium stem rot*** (*Sclerotium rolfsii*), ***fusarium wilt*** (*Fusarium*), ***verticillium wilt*** (*Verticillium*). See Annuals A 6, Seedlings N 66, Vegetables M 6, M 7.

Downy mildew (*Bremia lactucae*) may damage ***leaves*** of *H. bracteatum*. See Annuals A 5.

Powdery mildew (*Oidium* spp.) may also occur on ***leaves*** of *Helichrysum* spp. See Annuals A 6.

Rust (*Puccinia lagenophorae*) may occur on *Helichrysum* ***leaves*** in bush areas. See Annuals A 7, Cineraria A 28.

White blister rust (*Albugo tragopogonis*) causes soft white rust-like pustules to develop on ***leaves***. See Cineraria A 28, Gerbera A 37.

NEMATODE DISEASES

Foliar nematodes (*Aphelenchoides* spp.) infest *Helichrysum* sp. and ***root knot nematode*** (*Meloidogyne hapla*) occurs on *H. bracteatum.* Root knot may limit production of *Ozothamnus diosmifolis* (Boucher 1995). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest ***new shoots***. See Roses J 4.

Bugs (Hemiptera): ***Crusader bug*** (*Mictis profana*) and ***Rutherglen bug*** (*Nysius vinitor*) may suck sap from succulent ***new growth***. See Vegetables M 12.

Caterpillars (Lepidoptera)

Australian painted lady (*Vanessa kershawi*, Nymphalidae) caterpillars feed on Asteraceae, ***ornamentals,*** eg everlastings (*Helichrysum* spp.), *Helipterum roseum*, *Artemisia*, cudweed, lavender and ***weeds***, eg *Ammobium alatum,* capeweed, Scotch thistle. Between late August and early November a great southerly migration often takes place along the east coast of Australia from south Qld. ***Mature caterpillars*** are ***20-30 mm*** long, usually ***brown*** but sometimes ***yellowish green***. They feed at night and shelter during the day (young caterpillars in ***curled leaves*** of the food plant and older caterpillars beneath the food plant or near the ground (Common and Waterhouse 1981).

Leafroller moths (Tortricidae) include caterpillars of ***Tebenna micalis*** which feed on the foliage of Asteraceae, ***ornamentals,*** eg *H. bracteatum,* and ***weeds***, eg spear thistle, Scotch thistle and capeweed in eastern and southern Australia. ***Caterpillars*** are green, and live under a web incorporating faecal pellets, eating the ***lower leaf surface*** (Fig. 38). They pupate in a silk cocoon in the ***web***. A chalcid wasp (*Brachymeria phya*) ***parasitises*** the caterpillars. ***Caterpillars of a related moth*** (*Asterivora lampadias*) also feed on foliage of *Helichrysum* and other herbaceous Asteraceae and have similar habits to those of *Tebenna micalis* (Common 1990). See Pome fruits F 112.

Native budworm (*Helicoverpa punctigera*) caterpillars feed on everlastings (*Helichrysum* spp.). ***Indian weed caterpillar*** (*Heliothis rubrescens*) commonly feeds on Indian weed (*Sigesbeckia orientalis*) but may also feed on flowers of *H. bracteatum.* See Sweetcorn M 89.

See Annuals A 8, Vegetables M 13.

Cineraria leafminer (*Chromatomyia syngenesiae*) may disfigure ***leaves*** (Fig 39). See Cineraria A 28.

Fruit-tree borer (Oecophoridae, Lepidoptera) larvae may tunnel in the ***bark and sapwood*** of ***shrubby*** *Helichrysum* spp. and cover their tunnels with a mass of brown chewed wood fragments and webbing. See Fruit F 10, Trees K 12.

SNAILS AND SLUGS

Various ***snails and slugs*** may damage ***foliage and flowers***. See Seedlings N 70.

Non-parasitic

Environment: ***Good drainage*** is essential to prevent *Phytophthora* root rots. Leaves may become black and slimy (***sweating***) due to waterlogging. See Australian Native Plants N 8.

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State/Territory Departments of Agriculture/Primary Industry eg

WA Farmnotes

Wildflower Production : Everlasting Daisies

Wildflower Production : Getting Started

Wildflower Production : Industry Contacts

Associations, Journals etc.

Australian Flora and Protea Growers Assoc. (AFPGA)

Australian Plants

GrowSearch (database Qld DPI)

Society for Growing Australian Plants (Australian Daisy Study Group, Newsletter)

See Annuals and herbaceous perennials A 10, Australian native plants N 9.

Remember, always check for recent references

MANAGEMENT

H. bracteatum is a perennial but is usually grown as an annual and may reach 1 m in height. There is a wide colour range. ***Propagated*** by cuttings or by seed ***from disease and pest-free plants***. Sow seeds in autumn or spring, transplant when 50-70 mm high (in areas with little frost sow seed in late summer, but sow in spring where winters are colder). Everlastings require a ***warm sunny position*** and grow well in most garden soils with the addition of fertilisers. They tolerate harsh conditions better than most garden annuals but need regular irrigation in dry weather. Plant should not be pruned back below the leaves as they fail to regrow. If bushes have become overgrown it is better to propagate new plants. ***Harvest:*** No quality standards have been defined yet for everlastings. Harvest blooms when the bracts first start to open, a bloom of 30 mm should be expected from both *H. bracteatum* and *H. roseum*, while stem length for *H. roseum* should have in excess of 400 mm; stem length for *H. bracteatum* is not critical as most blooms are wired. Wiring the flower heads is appropriate for a number of species especially those with weak stems and large blooms (Sharman et al. 1989c). For dried flowers cut when flowers are half open, tie in bunches and hang head downwards in a cool place for drying, dried flowers will last for many months. Blooms of *H. roseum* have a ***vase life*** of 2 weeks in water after which stems weaken and flowers begin to nod. Vase life may be extended by using a floral preservative, removing leaves below the water line and changing vase water frequently. *H. bracteatum* may also be suitable as a ***compact, flowering pot plant***; pinching the apical shoot when the inflorescence bud first appears results in numerous short lateral shoots each with numerous blooms (Sharman et al. 1989b).

Fig. 37. Tomato big bud (greening) on *Helichrysum bracteatum.*

Fig. 38. Chewing damage to leaves by caterpillars of *Tebenna micalis*

Fig. 39. Tunnels caused by maggots of the cineraria leafminer (Chromatomyia *syngenesiae*).

Gazania

Gazania spp.
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Fungal diseases
Root and crown rots
White blister rust
Insects and allied pests
Cineraria leafminer
Snails and slugs

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato big bud mycoplasma (greening) affects gazania. (Fig. 40). See Annuals A 4, Tomato M 97.

FUNGAL DISEASES

Root and crown rots: ***Sclerotinia rot*** (*Sclerotinia* sp.) and probably also ***rhizoctonia stem rot*** (*Rhizoctonia solani*) (Horst 1990). See Annuals A 6, Vegetables M 7.

White blister rust (*Albugo tragopogonis*) causes light yellow areas on ***leaves***. The epidermis is forced into domelike swellings which burst open to expose a chalky mass of spore-producing sporangia. Foliage may die; plants are dwarfed. ***Overwinters*** in infected hosts and infected crop debris. Fruiting bodies (sporangia containing spores) are ***spread*** by wind to moist surfaces and by the movement of infected plants. ***Favoured*** by cool wet weather. ***Clean up*** all dead plant debris at the end of the season. Spraying is impractical. See Gerbera A 37.

INSECTS AND ALLIED PESTS

Cineraria leafminer (*Chromatomyia syngenesiae*) is a small fly, the female lays its eggs into ***leaf undersurfaces*** and when the maggots hatch out they ***tunnel*** between the upper and lower epidermis of the leaf. Initially silvery wandering lines on ***leaves*** are formed. Later these increase in width as the maggot grows bigger. Usually infestation is only slight so that control measures are not necessary. See Cineraria A 28.

SNAILS AND SLUGS

Gazania leaves may be ***severely damaged*** by snails, including the ***common garden snail*** (*Helix aspersa*), grazing on the surface of the leaves (Fig. 41). Damaged leaves shrivel and die. Snail damage to gazania is often misdiagnosed because it is not typical damage;the snails feed at night and hide under the plants during the day. Large populations may build up so that it is difficult to control them. See Seedlings N 70.

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Associations, Journals etc.

GrowSearch (database Qld DPI)

See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Gazanias are excellent for borders, banks, rockeries and hanging baskets. ***Propagation*** is by division after flowering in spring and summer; they are best replanted every few years. Gazanias revel in sunlight and do well in dry situations.

Fig. 40. Green gazania flowers caused by tomato big bud mycoplasma (greening).

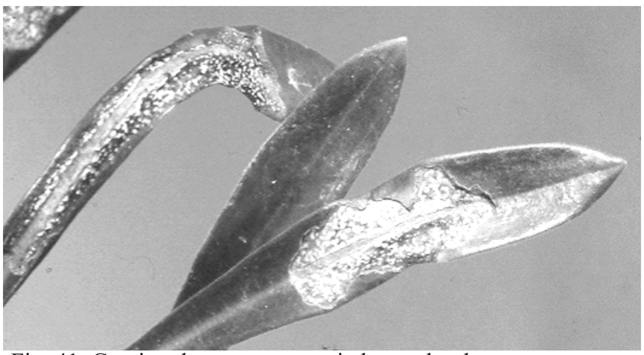

Fig. 41. Grazing damage to gazania leaves by the common garden snail (*Helix aspersa*).

Geranium

Pelargonium

Pelargonium spp.
Family Geraniaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus may cause mottled light green and dark green areas on ***leaves***. Interveinal areas tend to be lighter with darker areas along the vein. Leaves are usually smaller than normal and plants are dwarfed. Symptoms may be masked in warm weather, or variable, or may not be obviously detrimental to the plant. See Cucurbits M 50.

Pelargonium leaf curl virus (unconfirmed) affects *Pelargonium* causing irregular to circular yellow areas on ***leaves*** which may crinkle. Brown elongated corky areas may be formed on ***leaf petioles and stems***. Symptoms are masked in warm weather. This disease is considered to be transmitted by the ***pelargonium aphid*** (*Macrosiphum pelargonii*).

Tomato big bud mycoplasma (greening) causes a greening of the ***floral parts***. See Tomato M 97.

Yellow net vein virus (unconfirmed) is the most striking and ornamental disease symptom of the ivy-leafed geranium White mesh. The only symptom is the ***yellow vein patterns on the leaves***. There are no other symptoms and it is perpetuated by taking cuttings from affected plants.

Others: In Australia there are probably more virus diseases of geraniums (Fig. 42). There are certainly many more overseas (Strider 1985). ***Pelargonium flower break virus (PFBV)*** has become an important disease in greenhouses in Western Europe and is spread by circulating nutrient solutions, ***western flower thrips*** (*Frankliniella occidentalis*) and pollen, but mainly by mechanical transfer (Krczal et al. 1995). ***Thrips management*** may be important for control of viruses in greenhouse crops.

Infected plants should be ***destroyed*** when symptoms are observed in cool weather. Plant only ***virus-tested planting material***, do not propagate from infected plants. See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot and stem rot (*Xanthomonas campestris* pv. *pelargonii*) may affect pelargoniums during humid weather. Irregular sunken, circular, watery brown spots develop on ***leaves*** which may later yellow and fall. Ivy-types are susceptible to leaf symptoms. Brown rotting of ***stems*** (especially cuttings) develop either from the base upwards or from the tip downwards. Where isolated branches are affected, ***prune*** 30-50 mm below the discoloured area. All plants with basal stem rot should be removed and destroyed. ***Sterilise secateurs*** between cuts. ***Do not take cuttings*** from infected plants. If leaf spot is a problem, a ***bactericide*** may be applied but only after diseased branches have been removed and cultural conditions corrected. See Annuals A 2 (Fig. 4), Vegetables M 5.

Others: ***Crown gall*** (*Agrobacterium* sp.).

FUNGAL DISEASES

Fungal leaf spots (*Cercospora* sp., *Botrytis cinerea*, *Septoria pelargonii*). See Annuals A 5.

Grey mould (*Botrytis cinerea*) may be a problem on ***stock plants***. Dead areas develop on ***leaves, flower petals and stems***. During humid condition a grey, furry fungal growth develops. Flower heads rot, ***double flowers*** are more susceptible. Grey mould may be a ***serious disease on greenhouse crops*** (Hausbeck 1996). See Greenhouses N 22.

Root rots, wilts

Pythium black stem rot (*Pythium* spp., Eumycetes) causes blackening, withering and rotting of ***stems*** starting at the base of plants and ***cuttings***, progressing upwards. Infected plants wilt and die. ***Overwinters*** in infested soil and plant debris. ***Spread*** by movement of contaminated soil, drainage water or infected plants. ***Favoured*** by prolonged wet soil. Once plants are infected little can done, the aim is ***to prevent infection***. Remove and destroy infected plants. Do not overwater or propagate from infected plants, take cuttings from uppermost branches, farthest from infected bases. For cutting beds use pasteurised soil. Dip cuttings in fungicide before replanting contaminated areas.

Others: ***Damping off*** (*Botrytis cinerea*, *Fusarium*, *Pythium*, *Rhizopus*), ***phytophthora root rot*** (*Phytophthora cryptogea* on *Pelargonium zonale*), ***rhizoctonia stem rot*** (*Rhizoctonia* sp.), ***verticillium wilt*** (*Verticillium dahliae*).

See Annuals A 6, Vegetables M 7.

Rusts (Uredinales, Basidiomycetes)

Rust (*Puccinia pelargonii-zonalis*) is a ***serious disease*** of cultivated zonal species. Small green spots develop on ***leaf uppersurfaces***, powdery pustules develop on ***leaf undersurfaces***. ***Concentric rings of pustules*** develop (Fig. 43). Leaves yellow but infected areas remain green. Avoid excessive nitrogen.

Rust (*P. morrisonii*) is a native rust which affects native *Pelargonium* spp.

See Annuals A 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.) may cause stunting of plants, yellowing of leaves. Bead-like swellings develop on **roots**. Also **foliar nematode** (*Aphelenchoides fragariae*). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Pelargonium aphid (*Acyrthosiphon malvae*) is thought to spread pelargonium leaf curl virus.
Aphids are sap-sucking insects which cluster around **buds and new shoots** causing curling and distortion of leaves and flowers. Aphids produce **honeydew** on which sooty mould grows and spread **virus diseases**. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)
Cabbage moth (*Plutella xylostella*)
Cabbage white butterfly (*Pieris rapae*)
Looper caterpillars (*Chrysodeixis* spp.)
Lucerne leafroller (*Merophyas divulsana)*
Painted apple moth (*Teia anartoides*)
Painted pine moth (*Orgyia australis*)
Twig looper (*Ectropis excursaria*)
Caterpillars chew holes in **leaves, flower buds and flowers**, they leave dark balls of excrement on the soil surface, on lower leaves or on the floor. Do not confuse caterpillar damage with snail and slug damage. Some caterpillars feed **inside flowers buds** preventing flowering (Fig. 44). **Moth** (*Sphenarches anisodactylus,* Epermeniidae) caterpillars feed on flowers and buds of *Pelargonium* and butter beans (Fabaceae). See Annuals A 8.

Leafhoppers (Cicadellidae, Hemiptera): **Yellow leafhopper** (*Zygina zealandica*) sucks sap from **leaves** of native (*P. australe*) and other plants. See Annuals A 8, Australian native plants N 11 (Fig. 380), Vegetables M 15.

Mealybugs (Pseudococcidae) are very small, sap sucking insects which resemble tiny pieces of cotton wool. They are usually found near **leaf axils, along leaf midribs** or around **flower buds**. They produce **honeydew**. See Greenhouses N 25.

Mites (Acarina)
Broad mite (*Polyphagotarsonemus latus*)
Cyclamen mite (*Phytonemus pallidus*)
Twospotted mite (*Tetranychus urticae*)
See Annuals A 9.

Whiteflies (Aleyrodidae): **Greenhouse whitefly** (*Trialeuroides vaporariorum*) is mainly a pest of **regal geraniums** (*P. domesticum*) but can be a pest of other types. See Greenhouses N 24.

Others: **Black scale** (*Saissetia oleae*).

SNAILS AND SLUGS

Snails and slugs may chew **leaves**, do not confuse with leafeating caterpillar damage to leaves. See Seedlings N 70.

Non-parasitic

Environment

Oedema is **common** on ivy-leafed geranium and is caused by roots of plants taking up more moisture than is lost through the leaves. **Small blisters** develop on **leaf undersurfaces** especially those closest to the ground, and stems. The blisters enlarge, become corky, leaves may yellow and fall. Oedema detracts from the plant's appearance. **Prevent by:**
- Not overwatering soil particularly during extended periods of cloudy weather, provide good drainage, water in the morning with container saucers removed
- Reducing humidity in glasshouses and outdoors, space plants to allow good ventilation
- Maintaining light intensity at recommended levels to encourage leaf development and stoma opening
- Maintaining pH between 4.5-5.5
- Keeping nitrogen and iron levels high

Spindly growth: Insufficient light, excessive fertilising, overwatering and overcrowding may cause spindly growth and poor to no flowering.

Temperature: Older foliage of some varieties turns **red** during winter, if the plants are grown too cool or too dry. Optimum night temperatures are 15-18^{o}C, day temperatures 21-24^{o}C higher.

Senescence: Most geraniums shed their older leaves in late summer/early autumn, so during that period some natural leaf yellowing and leaf fall occur.

Others: Excessive applications of **wetting agents** (applied to retain water in the media and to improve aeration and nutrient availability), may reduce **shoot and root growth** of geranium and other plants, eg impatiens and poinsettia.

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State/Territory Departments of Agriculture/Primary Industry eg
Geranium Oil (NSW Agfact)
Geraniums (NSW Agfact)
Association, Journals etc.
Australian Geranium Society
GrowSearch (database Qld DPI)
State/Territory/Regional Geranium & Pelargonium Socs.
See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: Geraniums are ideal plants for sunny garden situations and make excellent pot plants. Commonly cultivated varieties include zonal pelargoniums (popular garden geraniums) (*P. x hortorum*), regal or show geraniums (*P. domesticum*), ivy geraniums (*P. peltatum*) suitable for hanging baskets, and scented geraniums (*P. tomentosum*). The parent plant of all *Pelargonium* varieties and strains used for commercial production of geranium oil is thought to be *P. graveolens*. Citrosa (African Geranium x Citronella or Grass of China) releases a continuous stream of citronella fragrance into air and is reputed to repel mosquitoes and some other biting insects. ***Resistant varieties:*** Cultivar selection is important as some lose flowers too readily. The double flowers of some cultivars are more susceptible to ***grey mould***. Zonal pelargoniums are subject to ***rust***. ***Disease-free planting material:*** To avoid major systemic geranium diseases, commercial growers should purchase ***virus-indexed plants*** each year from a specialist propagator. All geraniums from the previous year should be discarded before arrival of clean stock (Larson 1992).

Establishment and Maintenance

Propagation: Pelargoniums are usually propagated by cuttings but some may also be propagated by seed. Plants propagated from ***seed*** may produce single flowers and suffer shattering of flower heads. ***Cuttings*** may be affected by pythium black stem rot and grey mould. Unrooted herbaceous cuttings may be stored dry at -0.5^{o}C for 4-6 weeks, under normal refrigeration conditions for 5-10 days or at low pressure storage ***(LPS)*** conditions for 21-28 days (Nowak and Rudnicki 1990). ***Cultural methods:*** Geraniums like warm sunny sites but will grow in almost any soil providing drainage is good; ***do not overwater*** (it is better to underwater than overwater them). Space plants to provide good air circulation. Overwatering, overhead irrigation or watering late in the day means that plants remain wet for a long time and ***leaf, stem and flower diseases***, eg grey mould, rust, pythium black stem rot and bacterial leaf spot, are more likely. Stock plants tend to produce very large leaves which should be removed to allow better air circulation and more light to new growth. Keep ***hanging baskets*** of ivy geranium (*P. peltatum*) away from the upper part of the greenhouse to avoid excessive heat. ***Geranium trees*** (pelargonium cultivars that grow upright) are easily trained into trees or standards. ***Hard prune*** in autumn in warm areas (spring in colder areas) and pinch-prune tips continually while plants are actively growing to keep bushes compact, and increase flowering potential. Make a cut immediately above the node of an outward-pointing leaf or leaf bud. It depends on the cultivar and growing program whether plants may or may not be pinched. ***Sanitation:*** Clean pots before re-use. Keep secateurs sharp. Disinfect tools after pruning diseased plants and before pruning healthy plants. All flower heads should be removed from stock plants as they develop. ***Pesticides*** are registered for diseases and pests. ***Growth regulators*** are used for compactness or elongating stems (tree geraniums). ***Monitor diseases and pests*** regularly.

Postharvest

Potted plants: Sell at the beginning of flowering. Potted plants grow well in full sun or dispersed light. In summer, they need a temperature of 20-25^{o}C and frequent watering. In winter, they need bright light, a minimum temperature of 6-10^{o}C but limited watering. ***Ethylene*** causes petal drop; plants may be treated with an anti-ethylene chemical by the grower. *P. zonale* has low sensitivity to ethylene (Nowak and Rudnicki 1990).

Fig. 42. Yellow ringspotting on geranium leaves (probably viral).

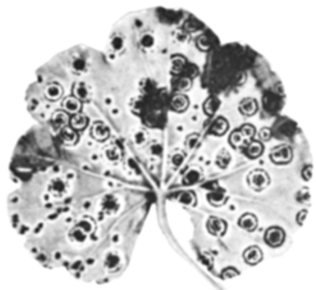

Fig 43. Rust on geranium leaves (*Puccinia pelargonii-zonalis*). Dept. of Agric., NSW.

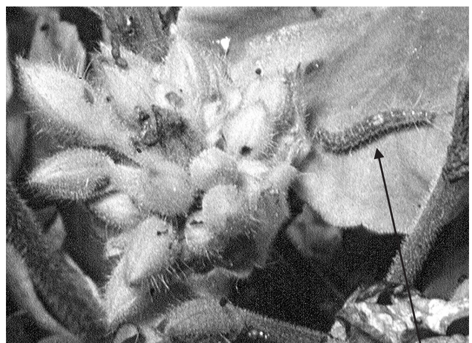

Fig. 44. Tiny caterpillar feeding in flower buds (note holes in buds).

Gerbera

South African daisy
Transvaal daisy
Gerbera jamesonii
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases, eg tomato big bud mycoplasma (greening), tomato spotted wilt virus (TSWV) and cucumber mosaic virus (CMV), may affect gerbera. Overseas ***impatiens necrotic spot virus*** (INSV) spread by western flower thrips (*Frankliniella occidentalis*), may be a serious disease of gerbera (Anon. 1996). See Annuals A 4.

FUNGAL DISEASES

Damping off (*Pythium, Phytophthora*) predominantly affects ***young plants***. Good drainage is essential and plants should be positioned with their crowns above the soil surface to avoid root and crown rots. See Seedlings N 66.

Fungal leaf spots (*Alternaria*, *Ascochyta*, *Cercospora*, *Septoria gerberae*) may be ***quite conspicuous*** during late summer and autumn on older leaves (Fig. 45). See Annuals A 5.

Grey mould (*Botrytis cinerea*) may attack ***lower stems or crowns***, damaged ***leaves*** and ***flowers*** in damp conditions. Avoid leaving snags during de-leaving and flower picking as these become sites for *Botrytis* and other fungal infections. Stems and crowns may ***rot*** at ground level and fall over. See Greenhouses N 22.

Powdery mildew (*Oidium* sp.) is favoured by humid conditions. Improve the environment and if necessary, apply a fungicide. See Annuals A 6.

Root, crown and stem rots

Phytophthora crown and root rot (*Phytophthora cryptogea*) is a ***common and serious disease*** of gerberas of all ages. Plants wilt and collapse suddenly and may die in 14-16 days. ***Leaves*** often become pinkish-purple. Infection usually takes place at or just below ground level and root tissue near the crown is also affected. ***Crowns*** become soft and mushy and are easily pulled away from other plant parts. When diseased plants are removed from the media, the outer part of the ***root*** usually sloughs off, exposing a dark central core. ***Good drainage*** and planting in individual containers, helps limit spread of disease. Plants grown in a moist soil without ever becoming waterlogged or dry and without high salt levels are less susceptible. Clones of gerberas vary in their ***susceptibility*** and by careful hybridisation breeders may obtain more tolerant plants. *Phytophthora* may occur after ***soil sterilisation*** (as will some other soil diseases) and prefers soil temperatures of < 20^{o}C. Infected plants should be ***removed*** followed by soil fungicidal drenches. It is possible to reduce *Phytophthora* attacks considerably without fungicides by adjusting the ***watering frequency and electrical conductivity values*** in ebb and flow systems with recirculating nutrient solutions (Thinggaard and Andersen 1995). See Trees K 6.

Others: Rhizoctonia stem rot (*Rhizoctonia solani*), ***sclerotinia crown rot*** (*Sclerotinia* spp.) and ***sclerotium stem rot*** (*Sclerotium rolfsii*) mainly occur on older plants. Also *Fusarium*, *Pythium,* ***verticillium wilt*** (*Verticillium dahliae*).

See Annuals A 6, Vegetables M 7.

White blister rust

Scientific name: Peronosporales, Eumycetes: White rust (*Albugo tragopogonis*)

Host range: Asteraceae, eg cineraria, gerbera, gazania, *Senecio* spp., overseas also *Artemisia*, *Centaurea*, salsify, sunflower, others.

Symptoms: Soft white rust-like pustules develop on ***leaf undersurfaces***, with corresponding pale green-yellow blotches on ***uppersurfaces*** which darken with age, foliage may die, plants dwarfed.

Overwintering: On infected hosts and debris.

Spread: Fruiting bodies (sporangia containing spores) are spread by wind, rain and insects, and by the introduction or movement of infected plants.

Conditions favouring: Cool, wet weather during winter and spring.

Control:

Cultural methods: Practise a ***crop rotation*** of 3-4 years with unrelated plants. Avoid ***excessive nitrogen*** as this increases disease susceptibility. ***Do not plant*** new crops near infected ones. Keep area around crops free from ***weed hosts***.

Sanitation: ***Remove*** and destroy infected leaves. Destroy all diseased ***crop debris*** after harvest. Ensure all crop residues are thoroughly decomposed before sowing.

Resistant varieties: Varieties differ in ***resistance***.

Pesticides: If white blister rust is a problem, apply ***fungicides*** in late winter before symptoms appear. Remove as much dead and infested material from plants as possible before spraying both leaf surfaces thoroughly at high pressure.

Wilts

Fusarium wilt (*Fusarium* spp.) causes many plants to collapse. Fusarium wilt spreads ***rapidly*** among plants and is most active in warm soils.
Verticillium wilt (*Verticillium dahliae*) develops ***more slowly*** in the plant than *Fusarium* or *P. cryptogea*. Initially, individual outer leaves may wilt and brown.

See Vegetables M 9.

NEMATODE DISEASES

Burrowing nematode (*Radopholus* sp.), ***dagger nematode*** (*Xiphinema* sp.), ***root knot nematodes*** (*Meloidogyne* spp.), ***spiral nematodes*** (*Helicotylenchus* spp.). *Ditylenchus* sp. and *Paratrichodorus* sp. may also infest gerbera. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest new ***shoots***. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)
Leafroller moths (Tortricidae)
Looper caterpillars (*Chrysodeixis* spp.)
See Annuals A 8.

Cineraria leafminer (*Chromatomyia syngenesiae*) disfigures ***leaves***. See Cineraria A 28.

Greenhouse whitefly (*Trialeurodes vaporariorum*) infests ***leaves***. See Greenhouses M 24.

Mites (Acarina)
Broad mite (*Polyphagotarsonemus latus*)
Cyclamen mite (*Phytonemus pallidus*)
Privet mite (*Brevipalpus* sp.)
Twospotted mite (*Tetranychus urticae*)
See Annuals A 9.

Thrips (Thysanoptera): ***Plague thrips*** (*Thrips imaginis*) may infest flowers. Also ***western flower thrips*** (*Frankliniella occidentalis*). See Roses J 6.

Others: ***Common brown leafhopper*** (*Orosius argentatus*) spreads tomato big bud (greening), ***green vegetable bug*** (*Nezara viridula*) sucks sap from shoots. ***Root mealybug*** (*Rhizoecus falcifer*) may infest gerbera in NZ (Salinger 1985).

Non-parasitic

Environment: ***Temperature:*** Gerberas are sensitive to ***frost*** and need a night temperature of 15-17°C and a day temperature of 21-24°C for optimum growth, flower initiation and development. Year round production is possible if night temperatures are > 13°C. Once temperatures fall below 9°C plants become dormant. With consistent high temperatures (> 29°C) flower quality and number may be adversely affected (Gerbera Growing for Cut Flowers, Vic Agnote). ***Sudden changes*** in temperature and humidity can cause plants to wilt. ***Irrigation:*** Gerberas need plenty of water during active growth. ***To avoid crown rot***, the irrigation system should be a low level drip with the dripper a little way from the centre of the plant. Or water early in the day so that plants dry out by evening. If overhead watering, lower the temperature or, to maintain humidity, a very low level of water should be applied as a fine mist. Water infrequently in autumn and winter.

Nutrient deficiencies, toxicities: ***Salt*** levels should not be allowed to build up in the rooting medium. Some cultivars may be sensitive to ***fluoride*** in tap water (fluoride at 0.5-1 ppm may be injurious). Fluoride injury may be a ***postharvest concern*** as damaged areas may be colonised by ***grey mould*** (*Botrytis*) (Anon. 1996).

Pesticide toxicity: Gerberas may be injured by some insecticides, spray trial areas first. Open gerbera flowers may be injured.

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State/Territory Departments of Agriculture/Primary Industry eg
Gerbera Growing for Cut Flowers (Vic Agnote)
Phytophthora cryptogea and other Soil-borne Fungi in Gerbera (Vic Agnote)
The Hydroponic Production of Gerberas for Cut Flowers (Vic Technical Report)
Associations, Journals etc.
Biotech Plants
Flower Power
GrowSearch (database Qld DPI)
See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: Select cultivars which are high yielding, have a good vase life, a stem length of 500 mm after trimming and head diameter of about 100 mm.

Resistant varieties: Cultivars vary in resistance to fluoride and *Phytophthora cryptogea*.

Disease-free planting material: ***Diseases may limit gerbera production***. As plants showing no symptoms may carry fungal diseases, treat cuttings with a fungicide. Preferably use healthy planting material, derived from uncontaminated tissue culture or healthy stock plants. The major source of clonal material is from tissue culture which is relatively free from diseases and pests and possesses a uniform set of genetic characteristics. Top quality cultivars known as the ***Knoxfield collection*** were available from the Ornamentals Improvement Program, Agriculture Victoria (now Crop Health Services (Crop Hygiene), Institute of Horticultural Development, Knoxfield, Agriculture Victoria).

Establishment and Maintenance

Propagation: By tissue culture and divisions with 1-2 growing points which give more uniform plants. Gerberas started from seed are not of uniform quality, ie they may close at night. Well managed gerbera stock may last for 2-3 years before replanting is required.

Cultural methods: Pasteurise soil or sterilise it with chemicals before planting or use a medium free from soil diseases. Plants are ***very sensitive to waterlogging***, plant crowns high so that they are exposed and relatively dry to avoid root and crown rots. Plant in well drained and well aerated slightly acid soil, possibly in raised beds; grow in soil or in hydroponic systems; gerbera is sensitive to salt. Allow soil to dry out between irrigations (continuously wet soil promotes disease). Keep soil rather dry during winter and in cold weather when plants are inactive. ***Provide correct temperatures*** for optimum growth, flower initiation and development. At night temperatures of < 16^{o}C gerbera will not flower and with high temperatures consistently > 29 ^{o}C flower qality and number may be adversely affected. See Gerbera A 38. ***Minimise soil fungal diseases*** by appropriate water management or by hydroponic culture. ***Minimise leaf diseases*** by providing adequate ventilation and avoiding undue moisture on foliage. ***If replanting areas***, fumigate, sterilise or pasteurise soil, or treat soil with chemicals.

Sanitation: Practice nursery hygiene consistently. See Nurseries N 51. ***Minimise leaf and flower diseases*** by regularly removing old and diseased plant material.

Pesticides: Fungicides and insecticides are ***registered*** for the control of soil diseases and insect pests. ***Growth regulators*** are used for cuttings.

Postharvest

Harvest: Handle flowers with care are they are delicate and ***easily damaged***. Harvest in the cool of early morning. ***For direct sale*** cut flowers when outer 1-2 rows of disc florets show pollen, otherwise flowers have a poor vase life, may wilt, close at night and not develop properly. Work flowers loose, rather than cutting them from the plant, to avoid stem stumps which may be invaded by fungi. Cut off the brown base of the stem and ***immediately*** place in fluoride-free water (rain water or de-ionised water) containing a flower preservative. In the packing shed suspend in netting or other support over preservative solution to help ***keep stems straight***. Grade stems for length and quality and pack as recommended to avoid damage and bending towards light (phototropism).

Storage: Gerberas can be ***difficult to store*** as they must be protected against grey mould and bending towards light. Store only as fully open flowers or large buds. Flowers correctly treated can be ***transported*** dry for 24 hours. Do not store for any length of time (even 1 week at 2^{o}C will reduce vase life of some cultivars). After pulsing to improve vase life, grade for stem length and quality (Jones and Moody 1993, Nowak and Rudnicki 1990).

Vase life: Recut stems (20-30 mm) and place in fluoride-free water containing preservative. Replace water regularly, turn vase regularly or avoid strong light as flowers will bend towards it. Because gerberas bend towards strong light, they must be ***wired to retain their position*** in an arrangement. Cooler temperatures, low light intensity and short days of winter decrease ***vase life*** of cut gerberas in comparison with the warm long days of summer. Immature cut gerberas develop ***bent-neck*** due to lack of maturity and hardening of the vascular tissues. ***Ethylene*** causes a slight hastening of senescence.

Potted plants: Sell potted plants when at least 1 flower is open. Plants need bright indirect light, a day temperature of 21^{o}C, a night temperature of 16^{o}C and moderate watering.

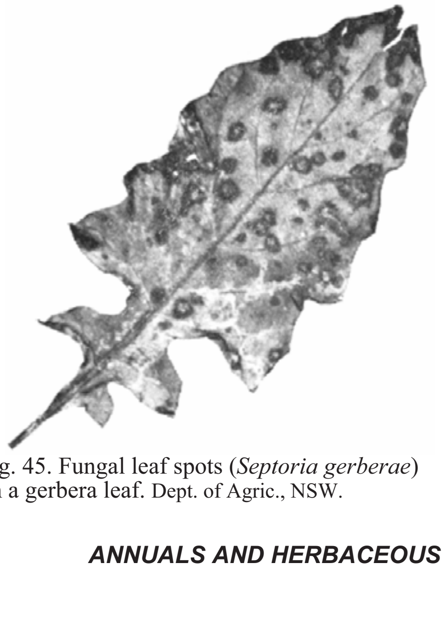

Fig. 45. Fungal leaf spots (*Septoria gerberae*) on a gerbera leaf. Dept. of Agric., NSW.

Gypsophila

Baby's Breath (*Gypsophila paniculata*)
Family Caryophyllaceae (carnation family)

Diseases and pests of gypsophila are not well documented for Australia.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato big bud (greening). See Annuals A 4, Tomato M 97.

BACTERIAL DISEASES

Bacterial leaf spot and blight (*Pseudomonas andropogonis*) may affect gypsophila ***during wet conditions***. See Carnation A 16, Vegetables M 5.

Crown gall (*Agrobacterium* sp.) has been recorded on gypsophila in NZ. See Stone fruits F 125.

FUNGAL DISEASES

Fungal leaf spot (*Alternaria* sp.) is a ***major disease*** of gypsophila. See Annuals A 5.

Grey mould (*Botrytis cinerea*) causes dead lesions to develop on ***seedlings, leaves, flower petals and flower stems***. Flower heads rot during wet weather. Under humid conditions a grey, furry fungal growth develops on affected areas. Leaves become infected when diseased petals fall onto them. ***Space plants*** well, so they get plenty of sun and air, and do not water late in the day. ***Remove*** and burn infected flowers. If disease is a problem, appropriate ***fungicides*** may be applied. See Greenhouses N 22.

Root and crown rots, damping off
Pythium aphanidermatum
Phytophthora cactorum, P. cryptogea
Phytophthora nicotiana var. *parasitica*
Rhizoctonia crown rot (*Rhizoctonia* sp.)
Sclerotium crown rot (*Sclerotium rolfsii*)
See Annuals A 6, Seedlings N 66, Vegetables M 7.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may feed on ***shoots***. See Roses J 4.

Caterpillars (Lepidoptera): ***Budworms*** (*Helicoverpa* spp.) feed on ***foliage and flowers***. See Annuals A 8, Sweetcorn M 89.

Leafminer (unidentified) damages ***leaves*** in NZ (Salinger 1985).

Thrips (Thysanoptera): ***Plague thrips*** (*Thrips imaginis*) may infest ***flowers*** causing them to brown. See Roses J 6.

Twospotted mite (*Tetranychus urticae*) may be a ***serious pest*** (Fig. 46). See Annuals A 9, Beans (French) M 29.

SNAILS AND SLUGS

Snails and slugs may be a problem in ***neglected plantings***. See Seedlings N 70.

Non-parasitic

Environment: ***Flowers*** will brown and shrivel quickly if subject to intense ***sunlight, water stress*** or ***hot dry*** winds. Gypsophila plants are fairly ***frost tolerant*** and can be grown successfully in areas where chrysanthemums are grown. Gypsophila require ***good drainage*** and will collapse and die quickly in wet soil. Cultivars vary in the ***day length*** required for flowering.

Nutrient deficiencies: ***Excessive fertiliser*** results in thin poor quality ***stems***.

WEEDS

Black weed mat suppresses weed growth and warms the soil so that crops can be advanced. Most weeds can be effectively controlled using ***pre-emergence herbicides*** after planting. See Annuals A 9.

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Costs and Returns for Gypsophila in Central Australia (NT Agdex)
Gypsophila : Commercial Production (Qld Farmnote)
Gypsophila as a Cut Flower (Vic Agnote)
Gypsophila for Cut Flower Production (SA Fact Sheet)
Gypsophila for Cut Flowers (NZ Aglink)
Associations, Journals etc.
Biotech Plants
GrowSearch (databae Qld DPI)
See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: Perennial gypsophila (*G. paniculata*) is commonly grown as a cut flower to be used as a filler in floral arrangements. Treat as an annual. Popular cultivars include the white Bristol Fairy and Perfecta, the pink Flamingo and strains of these. There is also annual gypsophila (*G. elegans*) which is mainly used as a garden flower.

Disease-free planting material: Use pathogen-tested planting material to ensure that only plants free from soilborne diseases are transplanted.

Establishment and Maintenance

Propagation: By cutting and grafting, or by tissue culture (Strider 1985).

Cultural methods: Gypsophila grows best on dry, calcareous gravelly soils. The name 'gypsophila' literally means 'gypsum-loving'. The desirable pH range is 6.5-7.5, if soil is acid an application of lime is recommended. Plants need well drained and well prepared sites. Prepare soil with organic matter and mixed fertiliser added. Select a sunny but sheltered spot. Plants should be trellised to keep them off the ground, for better pest and disease control, and for more erect marketable stems.

Sanitation: Pruning established plants hard once per year, cutting back to ground level; time of pruning will depend on when flowers are most needed.

Pesticides: If land is being replanted with gypsophila it is advisable to ***pre-plant*** treat the soil to reduce the possibility of soilborne diseases.

Postharvest

Harvest: Individual flowers do not open simultaneously, the top flowers open first and must be picked separately before the entire inflorescence opens. Harvest when at least 30-50% flowers are open but not too mature. As flowers are sensitive to ***sunlight, draughts and drying*** immediately after cutting, they should be placed in water, under refrigeration at high humidity. As flowers are sensitive to ethylene growers may treat them with an anti-ethylene chemical and sugar pulse (to promote even opening, avoiding the first flowers being dead before the last flowers have opened). It is possible to harvest gypsophila in the bud stage with 20% of buds open if they are conditioned to stimulate further opening. Stems harvested at the tight bud stage without flower colour showing, or with 5% of the flowers open, may also successfully be opened in various bud opening solutions (Nowak and Rudnicki 1990).

Storage: Store at 0-2^{o}C in water with floral preservative at high relative humidity (Jones and Moody 1993).

Vase life: Do not mist, as this encourages grey mould (*Botrytis*). Pinch off dead heads to reduce ethylene damage and ***replace vase water*** (with preservative) every day or two. Flowers are sensitive to water deficiency and intense sunlight and will brown and shrivel if subjected to stress conditions, eg hot dry winds.

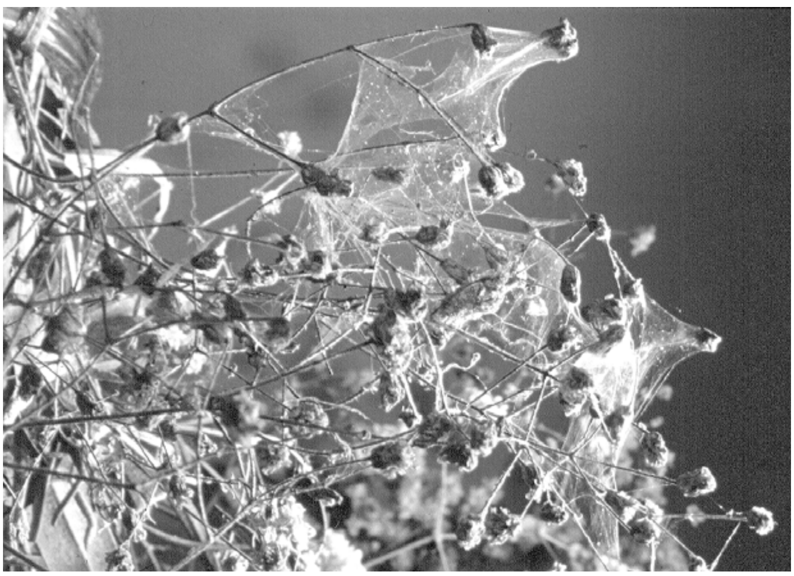

Fig. 46. Severe infestation of gypsophila by twospotted mite (*Tetranychus urticae*), observe mites crawling over webbing.

Hollyhock

Alcea rosea (= *Althaea rosea*)
Family Malvaceae (mallow family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Fungal leaf spots
  - Powdery mildew
  - Root and stem rots
  - Rust
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Metallic flea beetles
  - Twospotted mite
- **Snails and slugs**

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots

Anthracnose (*Colletotrichum malvarum*) may attack all parts of ***seedlings*** and cause large losses. See Fruit F 5.
Fungal leaf spot (*Phoma exigua var. exigua*) is a very common fungus, has a wide host range and may cause ***leaf spots*** on hollyhock.
Fungal leaf spot (*Cercospora althaeina*) causes more or less angular greyish spots scattered irregularly over the leaf. ***Fruiting bodies*** of the fungi formed within the ***leaf spots*** may be seen with a hand lens. Dead tissue often falls out leaving a ***shot-hole effect***.

See Annuals A 5.

Powdery mildew (*Oidium* spp.) causes a grey-white powdery fungal growth which covers ***leaves, stems and other plant parts***. See Annuals A 6.

Root and stem rots

Sclerotinia rot (*Sclerotinia sclerotiorum*)
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 6, Vegetables M 7.

Rust (*Puccinia malvacearum*) ***seriously damages*** hollyhock and other Malvaceae, eg *Lavatera,* mallow. ***Leaves, stems and bracts*** may be attacked. Yellow areas develop on leaf uppersurfaces with corresponding orange-red pustules containing spores on undersurfaces. Leaves may wither. Spore pustules on stems are elongated. See Annuals A 2 (Fig. 10), A 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) have been recorded on hollyhock (*Alcea rosea*). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cotton aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)

Looper caterpillars (*Chrysodeixis* spp.) chew large holes in ***leaves*** during mild, moist weather. Plants in shaded situations are more likely to be damaged.
Cotton tipworm (*Crocidosema plebejana*) caterpillars are tiny and feed in the ***seed capsules*** of Malvaceae including hibiscus, hollyhock, *Abutilon*, *Lavatera, Malva.* They web terminal leaves of *Atriplex,* damage ears of wheat and tunnel in the tips of young cotton plants and feed on young flower buds and bolls. See Hibiscus K 82.

See Annuals A 8.

Metallic flea beetles (*Altica* spp.) chew tiny irregular holes in ***young leaves and buds***. As leaves grow, holes enlarge. See Australian native plants N 12 (Fig. 391), Hibiscus K 82.

Twospotted mite (*Tetranychus urticae*), ***carmine mite*** (*T. cinnabarinus*) and ***other spider mites***, may cause ***leaves*** to develop a sandy mottle, flowers become bronzed and dry. See Annuals A 9, Beans (French) M 29.

Others: Unidentified ***leafminers*** cause small wavy lines on the ***leaves***. See Cineraria A 28.

SNAILS AND SLUGS

Snails may chew large holes in ***leaves***; do not confuse with looper injury. See Seedlings N 70.

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See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Hollyhocks are one of the tallest flowers and grow up to 2-3 m or more in height. There are annual and perennial types. They prefer sunny and sheltered sites and need staking in exposed situations or support on a trellis to prevent ***wind damage***. Leaf spots, rust and snails may need to be controlled during humid weather on susceptible varieties. ***Harvest*** when 1/3 florets open. Remove leaves below the water line and use clean water and a preservative.

Kangaroo paw

Anigozanthos spp.
Family Haemodoraceae
Red and green kangaroo paw (*A. manglesii*) is the Floral emblem of WA

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia* sp.). See Vegetables M 5.

FUNGAL DISEASES

Ink spot, ink leaf spot, ink disease (generally caused by *Alternaria alternata*) is a ***common and serious disease*** of kangaroo paws. *A. alternata* is cosmopolitan, common in WA and is often associated with decaying organic matter. Disease is severe on ***young plants*** and in humid or high rainfall areas. Small black spots first occur on ***older leaves***, and increase in size and coalesce, often causing death of entire leaf. Disease may attack rhizomes and secondary infections may kill plants. ***Any damage to kangaroo paw leaves causes black marks*** so do not confuse ink spot with leaf tips dying back because of cold weather. ***Increased spacing*** will improve air circulation. In cool climates treat as an annual and plant new stock each year. Most species of kangaroo paw are ***susceptible***. The green and red paw (*A. manglesii*) is severely affected, *A flavidus* and hybrids are the least susceptible. Superior cultivars are being bred, featuring ***disease resistance***, vigour under cultivation, prolific flowering, extension of flowering time and new and varied flowers, eg Bush and Gem series. See Annuals A 2 (Fig. 7), A 5.

Powdery mildew (*Oidiopsis taurica*) causes white patches on ***leaves*** which may later blacken. See Annuals A 6.

Root and crown rots, damping off

Phytophthora root rot (*Phytophthora cinnamomi*, *P. nicotianae* var. *parasiticae*) causes wilting followed by rapid death of plant. *A. flavidus* may be least susceptible to *Phytophthora*. ***Pythium crown rot*** (*Pythium* spp., *P. middletoni*) causes blackening and rotting between ***rhizomes and leaves***. ***Both diseases*** are favoured by wet soil, poor drainage and temperatures unfavourable to the host. Apply fungicides to seeds or cuttings. Pasteurise soil before planting or drench media.
Others: Crown rots (*Rhizoctonia solani*, *Sclerotium rolfsii*).

See Annuals 6, Vegetables M 7.

Rust (*Puccinia haemodori*) is a ***serious disease*** of *Anigozanthos* spp. (especially *A. manglesii*) and *Macropidia fuliginosa* in WA. Also *Conostylis* spp. and *Haemodorum*. Strains of rust specialise on different hosts. Rusty brown spots develop on ***leaves***, later turning black. Leaves may die. Severe outbreaks have been due to large scale propagation and planting of clonal material with a high level of ***susceptibility***. See Annuals A 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) on (*A. manglesii*). See Annuals A 7, Ferns E 2.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Green peach aphid*** (*Myzus persicae*) may distort opening flowers which fall in early spring. ***Young leaves*** may be distorted, shrivelled and disfigured with honeydew and sooty mould. ***Favoured*** by cool, wet weather during spring and autumn. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera): ***Corn earworm*** (*Helicoverpa armigera*) and ***native budworm*** (*H. punctigera*) may damage **flowers**, specially of *A. pulcherrimus*, in the early stages of flower development. See Sweetcorn M 89.

Others: ***Leafminer larvae*** (unidentified) damage ***foliage severely***, *A. manglesii* is very susceptible. ***Australian plague locust*** (*Chortiocetes terminifera*) and ***mountain katydid*** (*Acripeza reticulata*) may feed on **foliage**.

SNAILS AND SLUGS

Various species may damage ***leaves and stems***, especially of young plants. See Annuals A 3 (Fig. 19), Seedlings N 70.

Non-parasitic

Environment: ***High soil temperatures*** may cause ***rhizomes*** to die, in hot areas plants should be watered or shaded in summer. In their natural environment kangaroo paws are usually found growing in association with light scrub or trees. They produce a perennial rhizome which is dormant over summer and shoots and flowers each winter or spring. Under cultivation plants are often grown in exposed situations where soil has been cleared of all other vegetation, eg commercial plantings where land is kept clear of other vegetation for ease of maintenance and harvesting of the crop. ***Wind and heat*** in summer can cause production losses through scorching. ***Frost*** may damage most species causing blackening of ***leaves*** and dieback, most evident in the tableland regions of the eastern states. Winter and early spring are the active growth seasons in their natural habitats. Do not confuse frost injury with ink spot. ***Poor drainage*** favours root rot diseases. Although in the natural habitat, summer is the dormant period, application of water during this period produces vigorous flowering. In commercial cut flower production, summer irrigation produces additional flowers but may shorten the plant's life.

Nutrient deficiencies, toxicities: *Anigozanthos* responds to fertilisers. *A. flavidus* is vigorous, appears to be ***phosphorus tolerant*** and is likely to have a higher requirement for nutrients than most other species. Most species show symptoms of ***iron deficiency*** in alkaline soils.

Others: The causes of some problems affecting kangaroo paws are undetermined, eg flower bleaching and flower abortion (Oliver 1992).

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State/Territory Departments of Agriculture/Primary Industry eg

Cultivation of Kangaroo Paws (WA Farmnote)

Kangaroo Paw Growing in Central Australia (NT Agnote)

Kangaroo Paw Rust (Qld DPI Farmnote)

Associations, Journals etc.

Australian National Botanic Gardens

Plants

GrowSearch (database Qld DPI)

Society for Growing Australian Plants (SGAP)

See Annuals and herbaceous perennials A 10, Australian native plants N 8

MANAGEMENT

Remember, always check for recent references

Selection

An overview of the industry is outlined by Coombs (1995). All species are endemic to the south west of WA and most have shown poor adaptation to cultural conditions which differ from their natural habitat (moist winter months and relatively dry summer months, the natural dormancy period for these plants). In the eastern states moist summers are often experienced which are not beneficial to their culture, and most species (except for *A. flavidus)* are short-lived. *A. flavidus* is the most reliable species under most conditions. Other species with desirable horticultural features have been hybridised with *A. flavidus,* resulting in cultivars which have much of the hardiness of *A. flavidus* and the desirable features of other species. Most popular is yellow kangaroo paw (*A. pulcherrimus*) and black and green kangaroo paw (*Macropidia fuliginosa*). Check selections for new hybrids and trends in industry. Choose varieties with some ***resistance*** to ink spot and rust. Most diseases may be carried over in the rhizome. Purchase ***disease-free planting material***.

Establishment and Maintenance

Propagation: By seed, division or by micropropagation, by tissue culture. Most prefer ***well drained, acid, sandy soil.*** Common red and green kangaroo paw (*A manglesii*) and the green paw (*A. viridis*) are less particular about soil type and will grow in heavier soils but not very wet or alkaline conditions. Rhizomes in hot areas should be watered or shaded in summer. Space, fertilise and plant at appropriate time of year. Nutrient requirements can be determined by tissue testing. ***Weed control*** is important especially during the first year. Post and pre-emergence herbicides can be used between plants and between rows but some weeds can be difficult to control once plants are established. Prune in warm areas to remove leaves damaged by ink spot and other diseases, slashing and burning in late summer/autumn reduces inoculum levels for next year.

Postharvest

Harvest when the first 1-2 florets per spray are open, top buds plump. Leave at least 200 mm of stem for development of 2nd flower spike. Place in water with preservative immediately, pulse. For export, flowers require special treatments after harvest. Store at 0-2^{o}C at high humidity; they may be stored dry under certain conditions. ***Vase life:*** Recut stem (at least 20 mm), place in water with preservative immediately (kangaroo paws are very sensitive to water loss), keep at high humidity, avoid sunlight, draughts (Jones and Moody 1993).

Marigold

Tagetes spp., *Tagetes* hybrids
African marigold (*Tagetes erecta*)
French marigold (*T. patula*)
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot
- **Fungal diseases**
  - Fungal leaf spot
  - Grey mould
  - Root rots, wilts
- **Nematode diseases**
  - Root knot
- **Insects and allied pests**
  - Leafhoppers
  - Twospotted mite

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato big bud mycoplasma may cause greening of ***flowers***. ***Tomato spotted wilt virus*** has been recorded on *Tagetes* spp. and ***tobacco streak virus*** on stinking Roger (*T. minuta*). See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas syringae* pv. *tagetis*) is the ***main leaf disease*** of *Tagetes* spp. in Australia. Angular leaf spots develop on African marigold. See Vegetables M 5.

Others: ***Bacterial wilt*** (*Pseudomonas solanacearum*) may occur on *Tagetes* spp. See Tomato M 98, Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spot (*Alternaria* spp.) affects *Tagetes* spp. overseas (Fletcher 1984). See Annuals A 5.

Grey mould (*Botrytis cinerea*) may affect ***flowers***. See Greenhouses N 22.

Root rots, wilts
Damping off (*Pythium* spp.)
Phytophthora rot (*Phytophthora cryptogea*) has been recorded on *Tagetes* spp. overseas.
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Verticillium wilt (*Verticillium dahliae*) is a ***serious disease*** of *Tagetes* spp in Mexico (Hine 1984).
See Annuals A 6, Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.) on *Tagetes* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Leafhoppers (Cicadellidae) may be a ***major pest***. They cause ***leaf speckling***. See Annuals A 3 (Fig. 15), Vegetables M 15.

Twospotted mite (*Tetranychus urticae*) which may also be a ***major pest***, also causes ***leaf speckling***. See Beans (French) M 29.

Others: ***Plague thrips*** (*Thrips imaginis*) feeds in ***flowers***. ***Also greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***leafminer*** (unidentified), ***marigold aphid*** (*Neotoxoptera oliveri*).

Non-parasitic

Environment: ***Frost*** damages ***flowers*** and ***foliage*** of African marigolds.

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Associations, Journals etc.
GrowSearch (database Qld DPI)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Marigolds (*Tagetes erecta*, *T. patula* and *Tagetes* hybrids) are ***annuals*** and are ***propagated*** by seed. They perform well in any soil but need a sunny position and shelter from wind. They are shallow rooted plants so require regular watering in dry weather. Mulches of compost or leaf mould will prevent moisture loss and keep roots cool and discourage weeds. ***Growth regulators*** are used to control compactness and height and promote flowering. ***Harvest*** flowers for direct sale when flowers are fully open, flowers are sensitive to ethylene. Recut stems under water to prevent air from entering the water vessels before arranging and change water frequently, use a floral preservative (Nowak and Rudnicki 1990).

Nasturtium

Tropaeolum majus
Family Tropaeolaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Tomato spotted wilt
- **Bacterial diseases**
  - Bacterial wilt
- **Fungal diseases**
  - Fungal leaf spot
  - Powdery mildew
- **Nematode diseases**
  - Root knot nematode
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Cineraria leafminer
  - Twospotted mite

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt virus: Straw-coloured spots develop on nasturtium ***leaves*** which become cupped, distorted and enlarged. Severely diseased plants are stunted. The disease is not seedborne on nasturtiums, so seed from infected plants can be saved. See Annuals A 1 (Fig. 1), A 4, Tomato M 96.

Others: Beet western yellows virus, broad bean wilt virus, cucumber mosaic virus, turnip mosaic virus have also been recorded on nasturtium (Buchen-Osmond et al. 1988). See Annuals A 4.

BACTERIAL DISEASES

Bacterial wilt (*Pseudomonas solanacearum*) has been recorded on nasturtium. See Tomato M 98, Vegetables M 6.

FUNGAL DISEASES

Fungal leaf spot (*Acroconidiella tropaeoli*) may disfigure ***leaves***. See Annuals A 5.

Powdery mildew (*Oidiopsis sicula*) may occur on the ***leaves***. See Annuals A 6.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) causes plants to look unhealthy and on removing from the soil, ***small nodules*** are seen on the ***roots***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Black bean aphid (*Aphis fabae*) is ***very destructive*** to garden nasturtiums overseas, gathering on ***leaf undersurfaces*** in large numbers causing them to yellow and droop. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)
Cabbage moth (*Plutella xylostella*)
Cabbage white butterfly (*Pieris rapae*)
Leaves are chewed. Because of their green colour, caterpillars may be hard to find. See Annuals A 8, Brassicas M 39.

Cineraria leafminer (*Chromatomyia syngenesiae*) maggots may mine in the ***leaves*** of nasturtium, cineraria, lettuce and some weeds. Thin pale mines develop on the leaves which widen as the maggot grows. See Annuals A 3 (Fig. 16), Cineraria A 28.

Twospotted mite (*Tetranychus urticae*) is occasionally a ***serious pest*** of nasturtiums. ***Leaves*** develop a sandy mottle and in severe infestations, webbing may develop. See Annuals A 9, Beans (French) M 29.

Non-parasitic

Environment: Nasturtiums do not tolerate ***frost***.

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See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Nasturtiums are adaptable colourful ***annuals*** suitable for bedding plants, rockeries and tubs; dwarf annual cultivars are excellent for hanging baskets. Some compact bushy types have marbled or variegated leaves in green and white. ***Seed*** can be sown directly from spring to early autumn but in cold districts only sow in spring. Nasturtiums grow in a range of ***soils*** but avoid compost or animal manures which favour excessive leafy growth. Use complete fertilisers ***high in phosphorus*** so plants produce less foliage and flower more prolifically. They prefer ***open sunlight*** and rather dry conditions but will make quite a good show in partial shade. They are not usually used as a cut flower but if so ***harvest*** when flowers are fully open, place immediately in water with a preservative solution.

Petunia

Petunia hybrida
Family Solanaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf spot
  - Grey mould
  - Powdery mildew
  - Root and stem rots
- **Nematode diseases**
- **Insects and allied pests**
  - Cyclamen mite
  - Looper caterpillars

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus symptoms may be caused by alfalfa mosaic virus, cucumber mosaic virus, potato virus Y, tobacco mosaic virus, tomato big bud mycoplasma (greening), tomato spotted wilt virus (Buchen-Osmond et al 1988). See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas marginalis* pv. *marginalis*). See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spot (*Cercospora petuniae*). See Annuals A 5.

Grey mould, flower blight (*Botrytis cinerea*) causes spotting of ***petals*** in autumn at the end of flowering. Under wet conditions the whole flower collapses and a grey furry mass of spores develops. See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) may affect petunia. See Annuals A 6.

Root and stem rots
Damping off (*Pythium* spp.)
Fusarium root rot (*Fusarium* sp.)
Phytophthora diseases (*Phytophthora* spp.)
Rhizoctonia root rot (*Rhizoctonia solani*)
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Sclerotium stem rot (*Sclerotium rolfsii*)
Thielaviopsis black root rot (*Thielaviopsis basicola*)
See Annuals 6, Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.), ***spiral nematode*** (*Helicotylenchus dihystera*) have been recorded on *Petunia hybrid*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Cyclamen mite (*Phytonemus pallidus*) feeds on ***new buds and leaves*** causing them to curl, twist and in some cases die. ***Control is difficult*** because the mites are protected inside the buds and the damage has often already occurred before control measures are started. See Cyclamen C 16.

Looper caterpillars (*Chrysodeixis* spp.) chew ***leaves*** and can cause severe damage in shady situations. See Annuals A 8.

Non-parasitic

Environment: Petunias are ***frost*** sensitive.

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Associations, Journals etc.
GrowSearch (database Qld DPI)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Petunias are popular annual bedding plants and are grown in pots, tubs and hanging baskets. ***Breeding programs*** promote perennial types, vigour, ground habits, disease resistance, drought tolerance, more colours and longer flowering. ***Propagate*** by minute seed which may be slow to germinate. Petunias are ***susceptible*** to the same pests and diseases as other Solanaceae, eg tomato, potato, capsicum, eggplant, nightshade, so ***crop rotation*** is recommended. Plant in well drained loam, with plenty of organic matter. They are sunloving plants and will tolerate dry conditions after establishment. Shelter taller, large-flowered types from strong winds as stems are weak. ***Encourage bushy growth*** by pinching out, prune back when flowers almost finished to encourage more flowers. ***Growth regulators*** are used for height control and flower promotion. Ethylene causes flowers of ***potted petunia*** to wilt, growers may treat them with anti-ethylene compounds.

Phlox

Annual phlox (*Phlox drummondii*)
Perennial phlox (*P. paniculata*)
Family Polemoniaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Tomato big bud
- **Fungal diseases**
  - Damping off
  - Fungal leaf spots
  - Powdery mildew
  - Root and stem rots, wilts
- **Nematode diseases**
  - Stem and bulb nematode
- **Insects and allied pests**
  - Twospotted mite

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato big bud (greening) causes greening of the ***floral parts***. See Annuals A 4, Tomato M 97.

FUNGAL DISEASES

Damping off (*Pythium* spp., other fungi) may affect ***seedlings***. See Seedling N 66.

Fungal leaf spots: *Septoria drummondii* develops mainly on *Phlox drummondii,* and *S. phlogis* mainly on *P. paniculata.* See Annuals A 5.

Powdery mildew (*Oidium* sp.) is the ***most serious disease*** of phlox. A white mealy growth develops on ***leaves and new shoots***, plants may die back. See Annuals A 6.

Root and stem rots, wilts are mainly a problem on perennial phlox, eg
Rhizoctonia root rot (*Rhizoctonia solani*)
Sclerotium stem rot (*Sclerotium rolfsii*)
Verticillium wilt (*Verticillium* sp.) (unconfirmed)
See Annuals A 6, Vegetables M 7.

NEMATODE DISEASES

Stem and bulb nematode (*Ditylenchus dipsaci*). See Annuals A 7, Daffodils C 20.

INSECTS AND ALLIED PESTS

Twospotted mite (*Tetranychus urticae*) may infest ***leaf undersurfaces*** and webbing may be produced. Leaves develop a sandy mottle. Perennial phlox (*P. decussata*) is ***very susceptible***, bedding or annual phlox (*P. drummondi*) is not so severely affected. See Annuals A 9, Beans (French) M 29.

Non-parasitic

Environment: Phlox are ***frost*** sensitive.

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See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Phlox is an important bedding and border plant and is one of the brightest summer flowers. Annual phlox (*P. drummondii* Drummondii Dwarf) is the most widely grown variety. Phlox may be ***propagated*** by seed sown directly (seeds germinate easily), or in punnets for transplanting later. Annual phlox prefers ***full sunlight*** but performs well in any situation which has sun for part of the day. Phlox should be ***watered*** regularly but not overwatered as they tolerate fairly dry conditions. Water around the base of plants and mulch to keep soil moist and protect shallow roots. When flowering commences avoid overhead watering as flowers last better if dry. Remove spent flowers to promote new buds and prolong flowering. ***Harvest*** when 1/2 florets are open and keep the stems in water. Sear stem ends in boiling water for a few seconds to seal latex. Flowers are sensitive to ethylene (Jones and Moody 1993).

Poppy

Field poppy, Flanders poppy (*Papaver rhoeas*)
Iceland poppy (*P. nudicaule*)
Opium Poppy (*P. somniferum*)
Family Papaveraceae (poppy family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt virus: Infected Iceland poppy plants are ***striking in appearance***, yellow and stunted and may be severely damaged. See Annuals A 4, Tomato M 96.

Others: Cucumber mosaic virus and tomato big bud affect Iceland poppy; beet western yellows virus may affect field poppy. See Annuals A 4.

BACTERIAL DISEASES

Pseudomonas cichorii on Iceland poppy, *P syringae* pv. *syringae* on field poppy, *Xanthomonas campestris* pv. *papavericola* on Iceland and opium poppy.

FUNGAL DISEASES

Grey mould, bud and neck rot, (*Botrytis cinerea*) rots ***buds and stems***. See Greenhouses N 22.

Root and stem rots: ***Dendryphion rot*** (*Dendryphion penicillatum*) may cause ***leaf spots, crown and roots rots and damping off*** (Bodman et al. 1996). ***Seedling blight, poppy fire*** (*Pleospora papaveracea*) is ***seedborne*** and can cause root rot and seedling blight of *Papaver* spp. ***Others: Rhizoctonia rot*** (*Rhizoctonia* sp., unconfirmed), ***sclerotinia base and flower rot*** (*Sclerotinia sclerotiorum*), ***sclerotium stem rot*** (*Sclerotium rolfsii*). See Annuals A 6, Vegetables M 7.

Others: ***Downy mildew*** (*Peronospora arborescens*) may be ***serious*** on young plants. ***Also capsule moulds*** (*Alternaria*, other fungi), ***powdery mildew*** (*Oidium* sp.), ***leaf smut, fungal leaf spot*** (*Entyloma fuscum*).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* spp.), ***spiral nematode*** (*Rotylenchus robustus*) and ***stem and bulb*** (*Ditylenchus dipsaci*) have been recorded on *Papaver* spp. See Annuals A 7, Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Budworms (*Helicoverpa* spp.)
Greenhouse whitefly (*Trialeurodes vaporariorum*)
Lucerne flea (*Sminthurus viridis*)
Redlegged earth mite (*Halotydeus destructor*)
Springtails (Collembola)

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State/Territory Departments of Agriculture/Primary Industry eg
Poppy Growing : Cultural Notes : Opium Poppy (Tas Farmnote)
Associations, Journals etc.
Poppy Advisory and Control Board
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Poppies are magnificent bedding plants and unsurpassed for indoor decoration. There is a wide colour range. Poppies are also grown ***(by licensed growers only)*** for the production of pharmaceutical products in Tasmania (Coombs 1995). They are not suitable for the tropics. ***Propagated*** by seed, although perennial they are best treated as an annual. They prefer a sunny sheltered position, good drainage and friable fertile soil. Mulch but do not cover the crown. Root damage during weeding may cause ***stem bending***. Pinch out early buds until plants have formed good clumps. Remove dead flowers to promote flowering and maintain quality. Birds may take the flowers off. ***Harvest*** when buds are coloured, pick in morning, avoid fully open flowers as they damage easily. Stems excrete milky latex, scorch cut stems over a flame or dip stems in boiling water for a few seconds to stop the flow of fluid, prevent rapid wilting and improve vase life; a few drops of stearin placed inside the flower at the base of the petals prevent early petal drop (Nowak and Rudnicki 1990). Poppies may be stored in water at 0-2^{o}C. ***Vase life*** is short (3-4 days) but poppies are not ethylene sensitive.

Primrose

Primula spp.
Family Primulaceae (primrose family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf spot
  - Grey mould
  - Powdery mildew
  - Root, stem and crown rots
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
- **Snails and slugs**

Non-parasitic

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus causes stunting, yellow-green leaf mottle and flower breaking. ***Tomato spotted wilt virus*** causes stunting, yellowing, dried leaves, sometimes brown local lesions. ***Primrose mosaic virus*** affects *Primula* spp. overseas (Strider 1985). See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas syringae* pv. *primulae*). See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spot (*Ramularia primulae*) commonly causes pale brown, circular or irregular spots up to 5 mm across, often with a yellow halo on ***older leaves***. In humid conditions white spores develop on undersides of spots. See Annuals A 5.

Grey mould, crown rot (*Botrytis cinerea*) may be a ***serious disease*** of primroses (cool season plants). See Greenhouses N 22.

Powdery mildew (*Oidium* sp.) may affect ***leaves***. See Annuals A 6.

Root, stem and crown rots: ***Damping off*** (*Pythium* sp.), ***rhizoctonia root rot*** (*Rhizoctonia solani*), ***sclerotinia rot*** (*Sclerotinia sclerotiorum*) and ***thielaviopsis black root rot*** (*Thielaviopsis basicola*). See Annuals A 6, Vegetables M 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) and ***root knot nematodes*** (*Meloidogyne* spp.) occur on *Primula* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cowpea aphid (*Aphis craccivora*)
Foxglove aphid (*Aulacorthum solani*)
Green peach aphid (*Myzus persicae*)
Primula aphid (*Microlophium primulae*)
Root aphid (unidentified species)
See Annuals A 7, Roses J 4.

Others: ***Mealybugs*** (Pseudococcidae) and ***twospotted mite*** (*Tetranychus urticae*) may also damage *Primula* spp.. ***Root-eating weevils*** (Curculionidae) are a ***serious pest*** in Spain, plants collapse and die. Pine bark compost promotes root growth which increases food for weevils.

SNAILS AND SLUGS

Various species of ***snails and slugs*** cause damage. See Seedlings N 70.

Non-parasitic

The calyx and flower stalks of potted *P. obconica,* contain a skin irritant ***(primin)*** which causes ***primula dermatitis*** in sensitised persons (Frohne and Pfander 1983). Primula are very susceptible to ***iron deficiency*** especially *P. obconica* and *P. polyantha* (Strider 1985).

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Associations, Journals etc.
GrowSearch (database Qld DPI)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Primulas are ideal bedding or border plants, and for hanging baskets and pots. *P. malacoides* is a perennial but is usually grown as a spring-flowering annual. Plants require dispersed light, abundant water and temperatures of 12-15^{o}C during flowering. Higher temperatures accelerate flower wilting. ***Control soil diseases*** by pasteurisation and fungicidal drenches. ***Harvest*** flowers when 1/2 florets open; flowers are sensitive to ethylene causing flowers to wilt. Place stems in tepid water immediately after picking. ***Store*** in water at 7-10^{o}C. ***Sell potted plants*** at the beginning of flowering. Nowak and Rudnicki (1990).

Snapdragon

Antirrhinum spp. (*Antirrhinum majus*)
Family Scrophulariaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus causes a mosaic on lesser snapdragon (*Antirrhinum orontium*), ***tomato big bud mycoplasma*** causes greening of the floral parts of snapdragon. See Annuals A 4.

BACTERIAL DISEASES

Bacterial seedling blight (*Pseudomonas syringae* pv. *antirrhini*) affects Scrophulariaceae, eg snapdragon, *Calceolaria, Penstemon.* ***Leaves and stems of young seedlings*** rot in wet conditions. The bacteria ***overwinter*** in debris from infected plants and are ***spread*** by water splash. This disease can be difficult to control. Avoid over-moist conditions and destroy infected plants and debris. Where the disease is a problem ***pasteurise*** seedbeds. Copper products are the only ones effective against bacteria in Australia but they are only protectants so they will not eradicate existing infections in plants. See Seedlings N 66.

FUNGAL DISEASES

Damping off (*Phytophthora* spp. *Pythium*) and ***thielaviopsis black root rot*** (*Thielaviopsis basicola*). See Annuals A 5, Seedlings N 66.

Downy mildew (*Peronospora antirrhini*) causes dwarfing of plants, leaf tips and margins are curled downwards. Fungal threads and masses of spores develop on ***leaf undersurfaces*** giving them a mealy-white or whitish-violet appearance, healthy leaves have smooth green surfaces. See Annuals A 5.

Fungal leaf spots

Anthracnose (*Colletotrichum antirrhini*) attacks seedlings or mature plants during ***warm moist*** weather. Sunken spots are formed on the ***leaves and stems***. Spots are oval or circular and at first yellowish green to dull white with a narrow brown border. Small black spots, the fruiting bodies of the fungus, are formed later on affected areas. Anthracnose is very similar to a mild type of shot-hole blight. ***Stem cankers*** may coalesce to girdle the base of plants causing collapse of upper parts. May be seedborne. See Fruit F 5.

Fungal leaf spots (*Septoria antirrhini,* and probably *Phoma* spp.) may disfigure ***leaves***.

Shot-hole blight (*Heteropatella antirrhini*, Imperfect Fungi) affects snapdragon during ***cool humid weather***. Pale yellow spots develop on ***leaves and green stems***. Leaf spots may fall out, leaving a hole bordered by purplish tissue. Young shoots may die. If weather is unfavourable, new growth below affected parts will be healthy.

See Annuals A 5.

Grey mould (*Botrytis cinerea*) may cause a soft rot of ***flowers, stems and seedlings***. See Greenhouses N 22.

Powdery mildew (*Oidium* sp.) causes white powdery patches on ***leaves***. See Annuals A 6.

Root and stem rots
Phytophthora root rot (*Phytophthora* spp.
P. cinnamomi, P. citricola, *P. megasperma*
also *P. cryptogea* overseas
Rhizoctonia stem rot (*Rhizoctonia solani*)
Sclerotinia rot (*Sclerotinia sclerotiorum*
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 6, Vegetables M 7.

Rust (*Puccinia antirrhini*) is common and is the ***most serious disease*** of snapdragon (Fig. 47). ***All parts*** (leaves, buds, stems, branches and occasionally seed pods) and ***all stages of growth*** may be attacked, but it is most severe just before blooming during cool humid weather. Varieties vary in ***resistance***. If plants are used as perennials, resistance may break down to varying degrees after the first season. See Annuals A 7.

Verticillium wilt (*Verticillium dahliae*) causes plants to wilt. The fungus enters through the fibrous roots and grows into the woody tissue of the stem and roots, blocking the ***vascular system*** which becomes discoloured. See Vegetables M 9.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) may affect snapdragon. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Cotton aphid*** (*Aphis gossypii*) and ***green peach aphid*** (*Myzus persicae*) causes twisting and curling of ***new leaves*** especially in cool, dry weather. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.) may be ***serious pests*** of snapdragons and may feed on ***buds and flowers*** (Fig. 48). See Sweetcorn M 89.
Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) may roll ***leaves*** together. See Pome fruits F 112.
Meadow argus butterfly (*Junonia villida calybe,* Nymphalidae) caterpillars feed on snapdragon, *Centaurium australis*, *Convolvulus valsinoidi, Plantago* spp., in warm humid weather. Male and female butterflies are similar; females have a wingspan of about 43 mm, males are slightly smaller. Undersides of forewings are greyish-brown with dark irregular lines and spots. Fully grown ***caterpillars*** are ***black with bristly spines*** and ***30-40 mm*** long (Fig. 49). There are probably several generations each year. Female butterflies lay green eggs singly on foliage. Pupae are brown with cream and pink marks and are suspended from a silken pad in sheltered spots, not far from food plants. ***Overwinters*** as pupae. ***Spread*** by butterflies flying. In northern Australia, the ***blue argus*** (*Junonia orithya albicincta*) feeds on *Antirrhinum* and other plants.

See Annuals A 8.

Mites (Acarina)

Cyclamen mite (*Phytonemus pallidus*) is microscopic and sucks sap from ***flower buds, flowers and leaves*** causing them to wither and curl. See Cyclamen C 16.
Earth mites (Penthaleidae) and their nymphs suck sap from ***leaves*** causing them to silver. Severely affected plants may die. See Vegetables M 16.

Twospotted mite (*Tetranychus urticae*) feeds on ***leaf undersurfaces*** causing them to become sandy mottled. Webbing may just be visible to the naked eye and can be seen on the undersides of infested leaves. See Beans (French) M 29.

See Annuals A 9.

SNAILS AND SLUGS

Snails can damage seedlings and older snapdragons. See Seedlings N 70.

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State/Territory Departments of Agriculture/Primary Industry eg
Diseases of Antirrhinums (NSW Plant Disease Bull. 110, 1980)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Choose varieties with some ***resistance*** to rust, eg some of the dwarf varieties. Some diseases of snapdragon are seedborne, eg rust, so only purchase ***certified disease-free seed*** or save seed from disease-free plants or treat seed. ***Propagation:*** Although a perennial treat as an annual. Sow thinly to avoid crowding of seedlings. ***Plant*** in well drained soil, in a sheltered position in full sun. ***Destroy crops*** as soon as possible after display or harvest to prevent buildup of inoculum, many diseases overwinter in the debris from infected crops. ***Pesticides*** are registered for the control of rust and other diseases and pests. There are ***US standards for snapdragon***, eg weight, minimum florets open per stem and minimum stem length (Nowak and Rudnicki 1990). ***Harvest*** straight spikes when at least 1/3 of florets at the bottom of spikes are open. If flower preservatives are used, flowers may be harvested when 2-3 buds show colour. ***Keep flower stems upright*** after harvest as flowers are negatively geotropic (tend to grow away from the centre of the earth); or treat flowers after harvest with auxins to prevent bending; pinching the top bud when arranging flowers will also prevent bending and promote even flowering of the rest of the buds. Flowers are sensitive to ethylene, and may be treated with anti-ethylene compounds by the grower. ***Storage:*** At 2^{o}C with high relative humidity (90%) for up to 2-3 days. After storage recut under water to prevent air entering water vessels, place in fresh floral preservative for bud opening at correct temperature, relative humidity and light. ***Vase life:*** Up to 10 days. Recut stems removing at least 25 mm. Remove all leaves below the waterline and place in a clean container with preservative solution. Remove dying flowers and replace water with preservative every 1-2 days (Jones and Moody 1993).

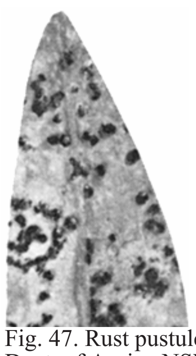

Fig. 47. Rust pustules. Dept. of Agric., NSW.

Fig. 48. Budworms (*Helicoverpa* spp.) are up to 50 mm long.

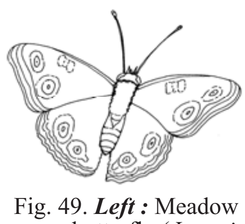

Fig. 49. ***Left :*** Meadow argus butterfly (*Junonia villida calybe*) has a wingspan of 40-43 mm. ***Right :*** Black caterpillars are 30-40 mm long.

Statice

Sea lavender

Limonium spp.
Perennial sea lavender (*Limonium sinuatum*)
Family Plumbaginaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus and ***tomato spotted wilt virus*** occur on *Limonium* sp. See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf and stem spot (*Pseudomonas andropogonis*) may be ***serious***. See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots

Anthracnose (*Colletotrichum gloeosporioides* and *C. dematium*) cause ***serious leaf and stem blights and cankers***. See Fruit F 5.
Fungal leaf spot (*Cercospora insulana*) ***commonly disfigures leaves***. See Annuals A 5.

Grey mould (*Botrytis cinerea*) can attack ***seed, seedlings, flowers, flower stalks, foliage, crowns and stubs*** left after harvesting flowers. Grey mould may cause severe damage to ***stems***, especially at nodes and on leafy 'wings', chlorosis of entire stalks and wings. See Greenhouses N 22.

Root and crown rots
Phytophthora root rot (*Phytophthora* sp.)
Sclerotium stem rot (*Sclerotium rolfsii*)
Rhizoctonia stem rot (*Rhizoctonia* sp.)
See Annuals A 6, Vegetables M 7.

Rust (*Uromyces limonii*) has been recorded on native yellow sea-lavender (*Limonium australe*) but not on cultivated species. See Annuals A 7.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cutworms (Noctuidae)
Mealybugs (Pseudococcidae)
Spider mites (Tetranychidae)
Thrips (Thysanoptera)
See Annuals A 7.

WEEDS

Young plants ***compete poorly with weeds***. Flower crops can be delayed by early uncontrolled weed competition. Cultivation can be difficult because of the ***rosette form*** and the ***shallow fibrous root*** system. ***Weeds can be controlled*** effectively by mulches, weed mats or herbicides. ***Pre-emergence herbicides*** can be applied to established plants in autumn and spring. See Annuals A 9.

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State/Territory Departments of Agriculture/Primary Industry eg
Statice for Cut Flower Production (SA Fact sheet)
Associations, Journals etc.
Biotech Plants
GrowSearch (database (Qld DPI)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Statice is used for cutting or drying. Although a perennial it is usually grown as a spring flowering annual, but may be cut back for a second flowering. The most commonly grown variety is *L. sinuata* hybrid which has an excellent colour range. ***Propagation*** is by seed. Statice prefer a fertile soil, wind protection (stems need support from at least 1 layer of mesh netting). It will flower under a wide range of temperatures but consistent and early flowering is best under cool conditions such as 10-13^{o}C night and 16-18^{o}C day. ***Effective weed control*** is essential during establishment. ***Harvest*** when most of the flowers are fully open. For everlastings, tie in bunches and hang them head downwards in a cool dry place. If dried well, the flowers will last for a long time without losing colour. ***Store*** fresh flowers in water at 2^{o}C. ***Vase life:*** Recut stems, removing at least 20 mm of stem, remove lower leaves under water line and place in a clean container with a preservative solution to help prevent fouling of the water and a bad smell. Replace water daily (Jones and Moody 1993).

Stock

Common stock (*Matthiola incana*)
Family Brassicaceae

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Turnip mosaic virus
Bacterial diseases
Bacterial blight, black rot
Fungal diseases
Downy mildew
Fungal leaf spots
Grey mould
Root and stem rots
Nematode diseases
Root knot nematode
Insects and allied pests
Aphids
Caterpillars
Plague thrips
Redlegged earth mite
Non-parasitic
Environment
Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Turnip mosaic virus may affect stock. ***Leaves*** are distorted, wrinkled and mottled with patches of a lighter colour (Fig. 50). ***Flowers*** are spotted and streaked with lighter colours or white (Fig. 51), reducing their market value ***(flower break)***. Whole plants may be stunted, with leaves closer together than normal. Symptoms vary with temperature. Turnip mosaic is ***spread*** by the cabbage aphid (*Brevicoryne brassicae*) and green peach aphid (*Myzus persicae*), not by seed. See Annuals A 4, Brassicas M 36.

Others: ***Tomato big bud mycoplasma*** (greening) causes greening of the ***floral parts***.

BACTERIAL DISEASES

Bacterial blight, black rot (*Xanthomonas campestris* pv. *incanae*) affects common stock and wallflower. ***Young plants*** wilt and collapse, plants are stunted, lower leaves yellow and fall. Plants infected at an older stage may survive and flower. If the stem of an infected plant is cut open, the ***vascular tissues*** are discoloured. If ***seedborne*** infection occurs, the disease may cause ***significant losses***. Most damaging in seedbeds and early sown crops during warm humid weather. ***Do not plant stocks*** in soil that has carried a diseased crop in the previous year, practise a ***2-year crop rotation***. ***Destroy*** infected crop debris. If there is infection in a crop or seedbed, remove and destroy affected plants or seedlings and those around them together with surrounding soil. Use ***certified seed*** or seed from crops known to be free from the disease, otherwise hot water treat seed (the germination of good grade seed is reduced only slightly or not at all by this treatment). ***Do not allow treated seed*** to come in contact with crop debris, seed dust or old seed packets. Sow seed as soon after treatment as possible in well drained ***disease-free*** seed beds, eg ***pasteurised*** seedbeds. More plants will be affected in each successive crop if stock seed is saved from infected crops. See Tomato M 98, Vegetables M 5.

Others: ***Bacterial soft rot*** (*Erwinia carotovora* subsp. *carotovora*) and ***Pseudomonas syringae pv. syringae***.

FUNGAL DISEASES

Downy mildew (*Peronospora parasitica*) is one of the ***most serious diseases*** of stock. Yellow patches develop on ***leaf uppersurfaces***, corresponding patches of down-like spores develop on ***leaf undersurfaces***. Leaves may become yellow, die and fall. If leaf fall becomes severe enough, the plant may die. The effect of the disease is more severe on small seedlings than mature plants. See Annuals A 2 (Fig. 5), A 5.

Fungal leaf spots (*Alternaria* sp., other fungi) may develop on stock but do not appear to be important. See Annuals A 5.

Grey mould (*Botrytis cinerea*) may affect ***flowers*** of mature plants. ***Young plants*** in seedbeds may die from damping off caused by *Botrytis* (Pirone 1978). See Greenhouses N 22.

Root and stem rots

Damping off (*Botrytis cinerea, Pythium*, *Rhizoctonia*). See Seedlings N 66.
Phytophthora root rot (*Phytophthora* spp.) causes wilting and death of ***fine roots***.
Pythium root rot (*Pythium)* causes similar damage as *Phytophthora*.
Rhizoctonia collar rot (*Rhizoctonia solani*) is a ***major disease*** causing wilting of foliage; sunken cankers on the basal part of the ***stem***. It is easily identified by the presence of soil particles, held by a fine web of brown fungal threads adhering to the damaged tissues. The root system is undamaged and decays only after the plant has died. See Annuals A 2 (Fig. 9).
Sclerotinia rot (*Sclerotinia sclerotiorum*, *S. minor*).
Sclerotium stem rot (*Sclerotium rolfsii*).

Soilborne diseases are ***spread*** in flood or drainage water, soil on machinery, tools, foot wear. Most have a wide host range and previous cropping may leave these fungi in soil. See Annuals A 6, Vegetables M 7.

Others: ***Club root*** (*Plasmodiophora brassicae*).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* spp.) causes plants to yellow, small ***galls*** develop on ***roots***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cabbage aphid (*Brevicoryne brassicae*)
Green peach aphid (*Myzus persicae*)
Aphids cause ***new leaves*** to curl, the whole plant may be severely stunted. These aphids are also vectors of the ***turnip mosaic virus***. ***Other aphids***, eg ***Lipaphis pseudo-brassicae*** (unconfirmed) and possibly ***turnip aphid*** (*L. erysimi*), may also infest stock. See Annuals A 7, Brassicas M 38, Roses J 4.

Caterpillars (Lepidoptera) feed on leaves, eg
Cabbage moth (*Plutella xylostella*)
Cabbage white butterfly (*Pieris rapae*)
See Annuals A 8, Brassica M 39, M 40.

Plague thrips (*Thrips imaginis*) may cause ***flowers*** to brown prematurely. See Roses J 6.

Redlegged earth mite (*Halotydeus destructor*) may suck sap from ***leaves*** causing them to appear silvery. See Vegetables M 16.

Remember, always check for recent references

Non-parasitic

Environment: Stems at ground level may be affected by ***frost***, and may split (Fig. 52). Yeast cells may invade affected areas.

Nutrient deficiencies: ***Potassium deficiency*** causes burning on the ***older leaf margins***.

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State/Territory Departments of Agriculture/Primary Industry eg
Diseases of Stocks (NSW Plant Disease Bull. 1980)
See Annuals and herbaceous perennials A 10

MANAGEMENT

Stocks are popular spring flowering annuals (really biennials), used for beds and borders, but are not suitable for the tropics. They are fragrant and excellent for indoor decoration. There is a large colour range, dwarf and tall varieties. The biggest advancement has been the development of strains with a very high percentage of double flowers. ***Only plant certified seed***, or save from disease-free plants or treat seed from infected plants. ***Propagated*** by seed. ***Cultural methods:*** Do not plant stock where stock or related plants such as cabbages have been grown in the previous 2 years. They prefer neutral to slightly acid soil with plenty of organic matter and a sheltered position in the full sun. Good drainage is essential if root rots are to be avoided. Soil should be kept moist but avoid overwatering. ***Sanitation:*** Destroy diseased crops after the final display or harvest. ***Harvest*** stems with at least 1/3 to 1/2 of the lower flowers open. Flowers are sensitive to ***ethylene*** so growers may treat flowers with anti-ethylene compounds after harvest. Cutting off the root system is considered to decrease vase life of flowers (Nowak and Rudnicki 1990). ***Store*** upright to prevent bending (geotropism) at 1-5°C for no more than 1-5 days in a preservative solution. ***Vase life:*** Recut stems at an angle with a sharp knife, remove woody base, remove all leaves below the water line and place in preservative solution, change vase water daily to prevent odour due to bacterial growth (Jones and Moody 1993).

Fig. 50. Leaf mosaic on stock caused by turnip mosaic virus. NSW Dept. of Agric.

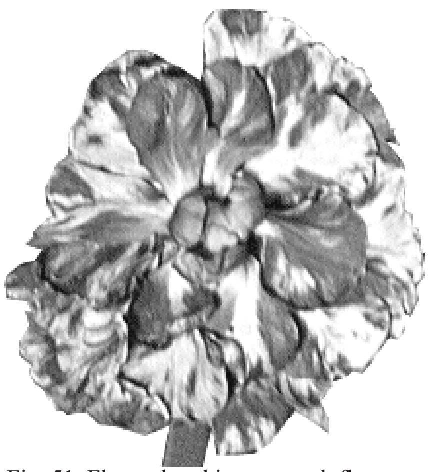

Fig. 51. Flower breaking on stock flowers caused by turnip mosaic virus.

Fig. 52. Split stems due to frost injury.

Violet, Pansy

Viola spp.
Family Violaceae (violet family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Downy mildew
  - Fungal leaf spots
  - Grey mould
  - Powdery mildew
  - Root and stem rots
  - Rust
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Twospotted mite
- **Snails and slugs**

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities
- Oedema

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Mosaic and ringspots are common on ***leaves*** of the common violet (*V. odorata*). Symptoms are more pronounced during spring and autumn and seem to fade during summer months. Veinclearing and bright yellow leaf chlorosis may develop in pansies. Viruses recorded in Australia include ***cucumber mosaic virus*** and ***tomato spotted wilt virus***. Some varieties of violets naturally have speckled flowers. ***Viola mottle virus*** has been recorded in Tasmania, causing reduced growth, leaf mottling and white stripes on petals. There is no vector; it is ***spread*** by vegetative propagation and mechanical inoculation. Overseas ***aster yellows mycoplasma*** causes veinclearing and bright yellow leaf chlorosis on *Viola* spp. ***Beet curly top virus*** may also occur on *Viola* spp. overseas. See Annuals A 4.

FUNGAL DISEASES

Downy mildew (*Peronospora violae*) may attack pansies causing light green to yellow patches on ***leaf uppersurfaces***. Masses of mauve coloured spores form directly below these patches on ***leaf undersurfaces***. White, clear blue and yellow flowering varieties are more susceptible than the variegated ones. Spectacular epidemics may occur after sprinkler irrigation during dry autumn weather (Michinton et al 2003). See Annuals A 5.

Fungal leaf spots

Anthracnose, pansy leaf spot (*Colletotrichum* spp.) affects pansy and violet. Circular spots with black margins, sometimes zonate, appear on ***leaves***. ***Flowers*** have petals which are spotted or improperly developed and produce no seed. Entire plants may be ***killed***. The fungus ***overwinters*** in infected plant parts and infected crop debris in soil. Spores are ***spread*** by wind-splashed rain. ***Favoured*** by wet weather, overhead irrigation. ***Remove*** and destroy infected plants or plant parts. ***Clean up*** old leaves in autumn. If considered necessary, ***fungicides*** may be applied at first sign of leaf spots. See Fruit F 5.

Spot anthracnose, scab (*Sphaceloma violae,* Ascomycetes) affects pansies and violets (Horst 1990). All green parts of plants may be attacked, including seed capsules. Plants may be twisted and deformed. Elongated-circular lesions up to 8 mm across develop on ***leaves***. Infected areas or spots may be bright yellowish, brown, rose-coloured or whitish. Some have dark greenish edges. Diseased areas readily fall out leaving a shot hole effect. If ***stems or leaf and flower stalks*** are completely girdled, the parts above die. ***Overwinters*** on host plants. Spores are ***spread*** by wind from infected plants and infected plant debris, movement of infected plants and seed. ***Sanitation:*** Destroy infected crops or badly affected plant parts. ***Do not propagate*** vegetatively or save seed from infected plants. ***Fungicides*** may be applied to susceptible species at first sign of the disease. See Fruit F 5.

Fungal leaf spots may be ***serious*** and develop most commonly on pansies (*V. tricolor*). *Cercospora violae* is probably the ***commonest*** and ***most serious***. Also *Phyllosticta violae*, *Septoria australis* (only on native species) and *S. violae*. ***More fungi cause leaf spots on Viola spp. than on most other ornamental plants*** (Pirone 1978). See Annuals A 5.

Grey mould (*Botrytis cinerea*) may cause a slimy decay of ***leaves*** and ***flower clusters***. If wet weather continues a grey furry growth develops on the rotted areas. See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) may attack pansies and violets causing grey-white mildew on ***leaves***. Pansies (*V. tricolor*) are ***most commonly attacked***, although it has also been recorded on the common violet (*V. odorata*). See Annuals A 6.

Root and stem rots
Thielaviopsis black or brown root rot (*Thielaviopsis basicola*), probably also:
Damping off (*Pythium* spp.)
Phytophthora root rot (*Phytophthora* spp.)
Pythium root rot (*Pythium* spp.)
Rhizoctonia root rot (*Rhizoctonia solani*)
Sclerotium stem rot (*Sclerotium rolfsii*)
These soilborne fungi are only likely to cause problems in over-wet areas with poor drainage. ***Plant crowns*** just above soil level. Usually there is a history of the disease occurring on surrounding plants. See Annuals A 6, Vegetables M 7.

Rust (*Puccinia hederaceae*) occurs on some native *Viola* spp., eg *V. betonicifolia* and *V. hederacea*, but not on introduced species. Rusty brown pustules develop on ***leaf undersurfaces***. See Annuals A 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) is uncommon but cause unthriftiness and small ***galls*** on ***roots***. See Annuals A 7, Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Foxglove aphid (*Aulacorthum solani*) is brown and may be found on the ***back of leaves*** of common violets (*V. odorata*).
Green peach aphid (*Myzus persicae*) causes curling of ***leaf tips***. See Stone fruits F 129.

See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera)

Cluster caterpillar (*Spodoptera litura*) may feed on violets. See Brassicas M 40.
Butterfly (*Argyreus hyperbius*, Nymphalidae) caterpillars feed on native violet (*V. betonicifolia*) at night, sheltering away from the small violet plants during the day. The butterfly occurs uncommonly in the Gympie area of NSW (Common and Waterhouse 1981).

See Annuals A 8.

Twospotted mite (*Tetranychus urticae*) is a ***serious pest*** causing a fine sandy mottle of ***leaves*** especially on common violet (*V. odorata*). Do not allow mite populations to build up. Direct spray irrigation to ***leaf undersurfaces*** reduces numbers. This is difficult with pansies and violets because of their low-growing habit. As there are few other serious pests, this should be an ideal situation for predatory mites. See Annuals A 3 (Fig. 17), Beans (French) M 29.

SNAILS AND SLUGS

Snails and slugs are serious pests, eating holes in ***leaves***. Vast numbers may build up in violet beds during wet weather so that it is difficult to keep them in check. See Seedlings N 70.

Non-parasitic

Environment: Violets and pansies are shallow-rooted plants and must receive ***adequate moisture*** during hot dry weather. They readily wilt but recover when watered. Care should be taken to site violets so they are sheltered from ***hot summer sun*** and drying winds.

Nutrient deficiencies, toxicities: ***Iron deficiency*** (chlorosis) can be a problem in alkaline soils. Iron can become unavailable to many plants, including violets and pansies, causing plants to develop interveinal yellowing of new growth. The problem can be ***prevented*** by planting violets in slightly acid soil and not applying alkaline fertilisers, or ***corrected*** by the application of iron chelates. See Azalea K 29.

Oedema causes small blisters to develop on ***leaf undersurfaces*** especially those closest to the ground. The blisters enlarge, become corky and leaves may yellow and fall. See Geranium A 35.

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Associations, Journals etc.
GrowSearch (database Qld DPI)
See Annuals and herbaceous perennials A 10

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: Violets (*V. odorata*) are hardy perennials. Pansies (*V. tricolor*) need a sunny location and are useful for hanging baskets. Native violets (*V. hederacea*) prefer shady areas under trees. ***Resistant varieties:*** Many new hybrid pansy varieties offer great diversity in flower size and colour. They are earlier flowering, free flowering, produce high quality flowers, stretch resistant (do not become leggy) and are ***tolerant*** to heat and low temperatures. ***Disease-free planting material:*** Do not propagate from diseased or pest-infected plants. Rhizoctonia root rot (*Rhizoctonia solani*), grey mould (*Botrytis cinerea*) and other diseases may be ***seedborne***.

Establishment and Maintenance

Propagation by division or by seed depending on the type. ***Cultural methods:*** Shelter from hot summer sun and drying winds. Plant in well-drained and slightly acid soil, in a medium to sandy loam with plenty of organic matter. Crowns should be set just above the soil surface. Irrigate plants appropriately to discourage twospotted mite, however, leaf wetness encourages diseases. ***Sanitation:*** Remove dead or withered flowers. If disease is spreading from leaf to leaf, ***fungicides*** may be applied to commercial crops.

Postharvest

Violets are mainly used in posies. ***Harvest*** when flowers are almost open and place in water containing preservative solution. Flowers lose their fragrance after several days. Regularly ***mist*** violets as they can absorb water through their flower heads. For storage, flowers are not placed in water but bunches are wrapped in waxed paper and may be stored at 1-4^{o}C for up to 2 weeks (Larson 1992, Nowak and Rudnicki 1990).

Zinnia

Zinnia elegans, *Zinnia* spp.
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato big bud mycoplasma (greening) and tomato spotted wilt virus. See Annuals A 4.

BACTERIAL DISEASES

Bacterial leaf spot, angular leaf spot (*Xanthomonas campestris* pv. *zinniae*) may kill ***seedlings and growing tips***. On older leaves, angular or circular, reddish brown spots, 1-4 mm across, are often surrounded by a yellow halo. See Vegetables M 5.

Others: ***Bacterial wilt*** (*Pseudomonas solanacearum*). See Tomato M 98.

FUNGAL DISEASES

Fungal leaf spots (*Alternaria zinniae*, *Didymella ligulicola*). See Annuals A 5.

Grey mould (*Botrytis cinerea*). See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) affects leaves. See Annuals A 2 (Fig. 8), A 6.

Root and stem rots
Damping off (*Pythium* spp., *Rhizoctonia solani*)
Rhizoctonia root rot (*Rhizoctonia solani)*
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Sclerotium stem rot (*Sclerotium rolfsii*)
See Annuals A 6, Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest ***young shoots***. See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera): ***Budworms*** (*Helicoverpa* spp.) feed on ***buds*** which may not open. See Sweetcorn M 89. ***Cluster caterpillar*** (*Spodoptera litura*) and other species chew ***flowers and stems***. See Annuals A 8.

Mites (Acarina): ***Twospotted mite*** (*Tetranychus urticae*), ***cyclamen mite*** (*Phytonemus pallidus*), ***broad mite*** (*Polyphagotarsonemus latus*). See Annuals A 9.

Plague thrips (*Thrips imaginis*) infests ***flowers*** causing them to brown. See Roses J 6.

Non-parasitic

Zinnia need protection from ***frost and wind.*** ***Cold damage*** can make flowers dry out and die. Some large flowered varieties may have ***weak necks.***

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State/Territory Departments of Agriculture/Primary Industry eg
Powdery Mildew of Ornamentals (NSW Agfact)
See Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Zinnias are popular summer flowering ***annuals***. Dahlia and cactus-flowered classes are the most popular for cut flowers. Bushy varieties have some ***resistance*** to powdery mildew. ***Propagated*** by seed. Zinnias require a warm sunny position, rich soil, a good water supply, but they tolerate drought. Protect from wind and frost. ***Growth regulators*** are used to promote flowering and control height. ***Harvest*** fully open flowers, avoid old flowers with centres full of yellow pollen. ***Vase life*** is approximately 7-10 days, recut stems, removing at least 20 mm underwater. Remove all leaves below waterline and place in preservative solution. Replace water regularly (Jones and Moody 1993).

Bromeliads

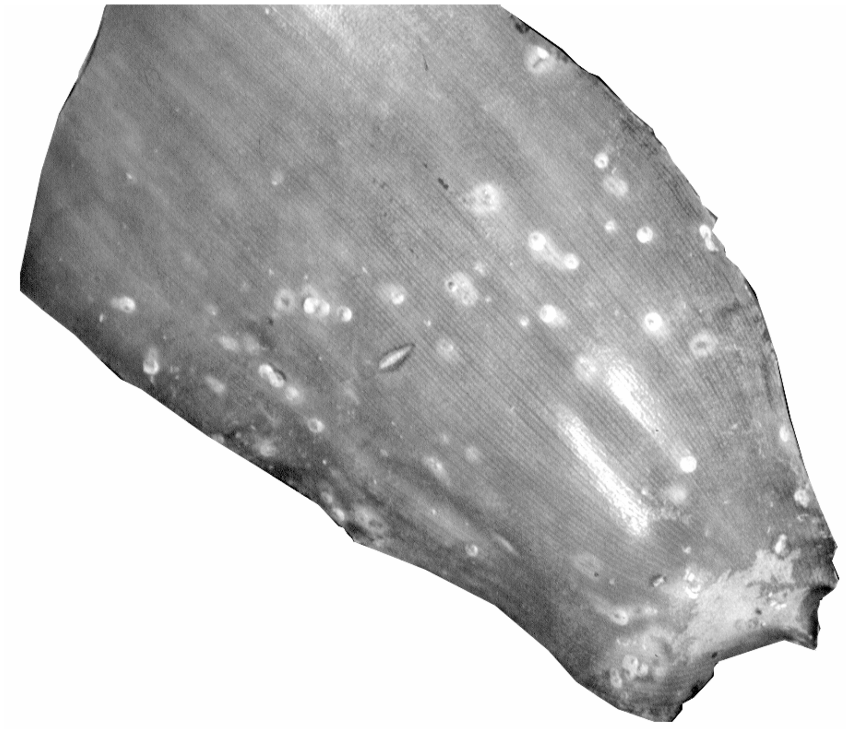

Fig. 53. Tiny armoured scales on bromeliad leaves.

SYMPTOMS	CAUSE
Leaf tips may yellow and later brown	Drainage inadequate Too dry or too cold Too little air movement Water is alkaline
Brown marks on leaves	Watering in direct sun Overwtaering Poor drainage Light intensity too strong Improper use of pesticides
Leaves elongated (long and thin)	Not enough light Too much nitrogen
Leaves wilting	Lack of water Poor drainage
Inner leaves quilling (sticking together)	No water in cup Excess pesticide rate Insufficient misting
Lower leaves dying (yellow-brown)	Senescence of older base leaves
Lower leaves brown at base	Overwatering Mixture too dense Poor drainage Leaved embedded in mixture

Fig. 54. Some symptoms of inappropriate environmental conditions. After Williams (1988).

Fig. 55. Natural whitish waxy bloom on leaves of *Aechmea fasciata*.

Bromeliads

Family Bromeliaceae

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Damping off
  - Root and top rots, wilt
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Mealybugs
  - Scales
  - Twospotted mite
- **Snails and slugs**

Non-parasitic
- Algae
- Environment
- Nutrient deficiencies, toxicities
- Pesticide injury
- Variegated leaves

WEEDS

PESTS AND DISEASES
Parasitic

In contrast to many other house and tropical greenhouse plants, bromeliads are remarkably free from major pests and diseases. Probably the most important are the ***various scales*** which can be disfiguring and difficult to eradicate. Bromeliads have tough leaves so are resistant to many pests.

FUNGAL DISEASES

Damping off (various species) has proved to be one of the ***more serious diseases*** of bromeliads grown from ***seed***. Sowing seeds farther apart and placing in a well lit and well ventilated position will reduce the risk of damping off. ***Before sowing***, pasteurise or treat the growing medium with a suitable fungicide and disinfect containers. Treat seeds with ***fungicide*** to minimise the danger from any fungal spores which may be attached. See Seedlings N 66.

Root and top rots, wilts

Aechmea wilt, fusarium wilt (*Fusarium* sp.) occurs overseas and damages *Aechmea fasciata* by blocking ***water conducting tissue*** within the plant. Initially a brown, fast-spreading rot develops on lower areas of exterior leaves causing foliage to rapidly deteriorate, die and finally fall. If foliage remains attached to the plant then the fungus will gradually penetrate and kill the inner leaves of the rosette. Aechmea wilt is ***favoured*** by high humidity and temperatures > 25^{o}C. Remove and destroy affected plants. *Fusarium moniliforme* and *F. oxysporum* have been recorded on bromeliads in Australia. See Vegetables M 9.

Phytophthora root and top rot (*Phytophthora* spp.) may occur due to excessive watering or poor drainage of the potting medium. See Trees K 6, Vegetables M 7.

Others: ***Fungal leaf spots*** (various species).

NEMATODE DISEASES

Many species attack ***field grown pineapples*** (*Ananas comosus*) which belong to the same family. Infestations on bromeliads do not seem to be common. ***Root knot nematode*** (*Meloidogyne* spp.) has been recorded on bromeliads (Bodman et al. 1996). See Pineapple F 104.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest ***young soft tissue*** causing stunted growth. Although uncommon they should be controlled promptly. See Roses J 4.

Caterpillars (Lepidoptera): ***Looper caterpillars*** (*Chrysodeixis* spp.) chew ***flower spikes and the foliage*** of most soft-foliaged bromeliads, eg *Guzmania, Vriesea*, leaving gaping holes and ragged edges. They are always well camouflaged and are difficult to find. If there are only a few, they may be removed by hand. See Annuals 8, Vegetables M 13.

Mealybugs (Pseudococcidae, Hemiptera)

Pineapple mealybug (*Dysmicoccus brevipes*) ***commonly*** infests bromeliads. Infestations build up at the ***base of plants*** in warm weather but may occur on other parts (Broadley et al. 1993, Swaine et al. 1991). See Pineapple F 104.

Root mealybug (*Rhizoecus falcifer*) bodies are slightly smaller than those of longtailed mealybugs and are evenly covered with white wax. They live only in soil and attack ***roots*** of terrestrial plants, stunting them.

Others: Possibly ***tuber mealybug*** (*Pseudococcus affinis*) and ***longtailed mealybug*** (*P. longispinus*).

Sooty mould grows on the honeydew excreted by the mealybugs. Mealybugs are ***spread*** via planting material and by ants within a planting. Mealybugs may be controlled using predatory ***mealybug ladybirds*** (*Cryptolaemus montrouzieri*) or ***parasitic wasps*** (*Leptomastix dactylopii*). Root mealybugs may also be controlled by immersing the entire plant in an ***insecticide***, making certain that the potting medium is either thoroughly soaked or removed from the plant prior to treatment. See Greenhouses N 25.

Scales (Hemiptera)

Armoured scales (Diaspididae) are the ***most serious pests*** of bromeliads (Fig. 53). ***Aechmea scale***, flyspeck scale (*Gymnaspis aechmeae*) infests Bromeliaceae (especially *Aechmea* and *Billbergia*), overseas also pineapple, occasionally other plants. Scale infestations at the base of plants are ***difficult to detect***. The crawlers select a favourable site on the host plant, often near the parent scale, and insert a thread-like feeding tube and commence feeding. It forms a round, black protective cover scale < 0.5 mm across and then moults (losing its legs) to become an adult. ***Males*** form an oval scale. ***Females*** form a hemispherical black scale about 1 mm across and remain encased within the skin of their previous stage. This double covering of the adult make the flyspeck scale more difficult to control with insecticides than other scales. Scale is ***spread*** by the introduction of infested plants to collections, by crawlers moving from plant to plant, eggs and crawlers may be spread on plants, clothing and by wind. ***Favoured*** by overcrowding. ***Sanitation:*** Remove or burn badly infested leaves or whole plants. ***Biological control:*** Two small parasitic wasps and a ladybird beetle are important natural enemies which keep small infestations under control. ***Plant quarantine:*** Inspect newly acquired plants for scales. Isolate infested plants and destroy severely infested plants. ***Disease-free planting material***: Do not propagate from infested plants. ***Pesticides:*** Only spray if natural controls are ineffective, eg infestation is severe. Spraying must be thorough to reach scales at the base of the plant. Repeat spraying after several weeks may be necessary. It is advisable after spraying to turn potted plants on their side if possible to allow excess spray to drain from leaf bases. Treat a few plants of different species first to check plant tolerance to insecticide. After 3 weeks, try to wipe the scales off at the base. If scales are dry and wipe off easily with a finger then they are dead; if not, then they are probably still alive. See Citrus F 39. ***Orchid scale*** (*Diaspis boisduvalii*) affects smooth-leaved bromeliads, eg *Aechmea*, *Guzmania*, *Tillandsia*, *Vriesea*. Scales are tiny, female scales are circular, males are more elongated with 3 ridges along them. Scales tend to congregate under sheathing leaves around the base of the plant. See Orchids G 6. ***Pineapple scale*** (*Diaspis bromeliae*) prefers green leafed bromeliads, eg green *Tillandsia*, *Vriesia*, *Guzmania*, pineapple, *Agave* spp., *Bilbergia* spp. and *Bromelia* spp. Female scales are about 2 mm across, circular and greyish white. See Pineapple F 104.

Soft scales (Coccidae): ***Soft brown scale*** (*Coccus hesperidium*) may infest *Aechmea,* eg *Aechmea tillansioides,* and is frequently found on glossy leaves of *Vriesea* and *Guzmania*. Soft scales produce ***honeydew*** resulting in ***sooty mould***. Soft scales are easily controlled by dipping in insecticide or spraying, after which the scales can be wiped or brushed off when dead. See Citrus F 41.

Twospotted mite (*Tetranychus urticae*) infestations may be ***difficult to detect***. The first indications of their presence are pin-prick holes in the ***leaves***, fine webbing in the underside of foliage and spotting with rusty yellow and black dots. ***Leaf margins*** may blacken. If twospotted mite becomes established and remains unchecked, the chance of survival of affected bromeliads is slight. Daily spraying with water will help prevent attack and a forceful spray of water will remove them. See Beans (French) M 29.

Others: ***Grasshoppers*** (Acrididae) may attack bromeliads outdoors during summer, destroying young shoots, soft leaves and flowers.

SNAILS AND SLUGS

Various species may damage seedlings, succulent leaves and flowers. See Seedlings N 70.

Non-parasitic

Algae buildup occurs in nature especially in the Peruvian desert *Tillandsia*, whose leaves become grass green during fogs. In cultivation algae may buildup in the scales of grey or white *Tillandsia* due to excessive humidity. See Greenhouses N 27, Turfgrasses L 13.

Environment: ***Symptoms*** of inappropriate environmental conditions are numerous (Fig. 54). ***Light*** is a major requirement. For neoregelieas, good light is essential, even direct sunlight. All other bromeliads need good light but it should not be too strong. Avoid direct sunlight as leaves can be readily ***sunburnt***. Position them where they can be viewed from above as they are best seen from this angle. ***Temperature:*** Most bromeliads need warm temperatures and high humidity. Dryness and cold are the most common causes of damage. Optimum temperatures are 15-21^{o}C. Only some billbergias can withstand temperatures < 13-15^{o}C (Davidson 1982). Constant levels of warmth and humidity are necessary during the active growth period. At temperatures > 18^{o}C mist foliage daily with tepid water. ***Ventilation:*** Leaf tips may yellow or brown due to lack of air movement. ***Watering:*** The main function of roots is to hold the plant in the pot. Bromeliads should be potted only in pebbles, coarse bark and charcoal so that water does not remain around their roots. Bromeliads are ***unique*** in that they require water around the growing point in the centre of the plant. Many have a watertight funnel formed by a rosette of leaves which absorbs food and water. The leaf vase should be kept filled with water. Water soil moderately allowing the top 25 mm to dry out between waterings. During winter rest periods, water only enough to keep the top soil slightly moist. ***Seasonal care:*** Bromeliads probably need to be watered once per week in winter and more frequently in summer.

Nutrient deficiencies, toxicities: Most bromeliads respond well to regular foliar fertilising during active growth. Plants grown in mixtures with peat moss may require extra feeding throughout the year. Those grown in soil should not be fed during winter rest periods.

Pesticide injury: Bromeliads breathe through their leaves (like other plants) and the ***application of white oil will result in death*** if left in contact with the foliage.

Variegated leaves: Leaves may be naturally waxy (Fig. 55), spotted, striped or just plain green. ***Do not confuse*** spotted leaves with scale infestations.

Others: ***Fungus gnats*** (Mycetophilidae, Sciaridae) may infest overwet pots.

WEEDS

Various weeds, eg ***Oxalis spp.*** and ***liverworts*** may infest container-grown bromeliads. See Greenhouses N 27, N 28.

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Associations, Journals etc.

Bromeliad Society Inc., USA (BSI Journals)
GrowSearch (database Qld DPI)
State/Territory/Regional Bromeliad Societies (eg Bromeletter, Bromel News)
The Bromeliad Society of Australia (Journal of the Bromeliad Society)

See Preface xii, House plants N 35, Greenhouses N 22, Nurseries N 51, Pineapple F 105

Remember, always check for recent references

MANAGEMENT

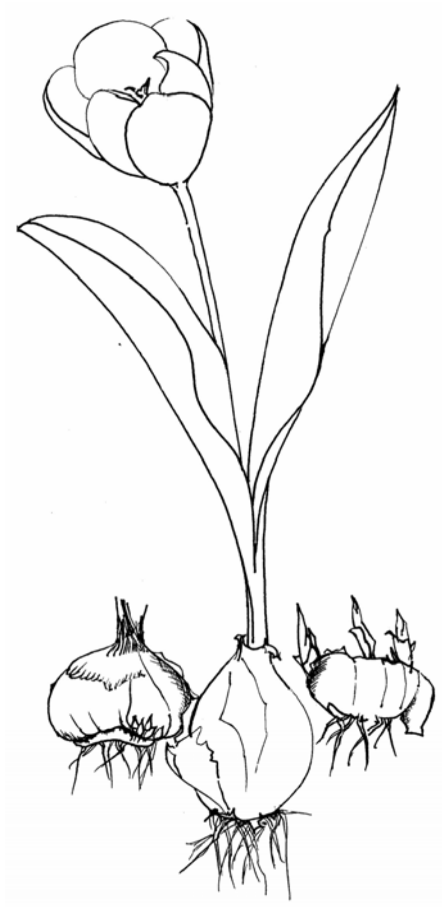
Quality bromeliads are usually available only from specialist nurseries. Some species have some ***resistance*** to low temperatures, and *Fusarium* wilt. Ensure that plants are ***disease and pest-free***, eg free from mealybugs and scales, do not propagate from infested plants. ***Propagation*** is by the removal of offsets from the base of the parent plant and by seed. ***Provide good cultural care***, eg appropriate airy acid potting mix and good drainage. Choose growing sites carefully, most like full sun but not excessive exposure. Plants grow in full or dispersed light, in summer they need frequent misting and moderate watering. In winter when the temperature drops they need only limited watering. The temperature must not be too low in winter. Well-cared for bromeliads seldom develop fungal diseases or become infested with mealybugs and scales. Plants should be ***inspected*** frequently, and any problem assessed and treated promptly if required. Bromeliads ***grow very slowly***, so that any damage that is allowed to develop is evident for a long time. Avoid potting into large pots and ***repot*** only when the plant seems out of proportion to its pot. ***Quarantine*** plants found to be infested with mealybugs or scale. There are no obligatory ***standards*** for potted bromeliads in international trade; principles governing the sorting and preparation of potted plants have been established but function more as recommendations rather than as requirements. ***Proposed standards*** have been prepared in the US (Nowak and Rudnicki 1990). ***Standards for exhibition***, eg stage of flowering, freedom from pests and diseases, should be sought from the appropriate societies. ***Sell*** bromeliads, eg *Vrisea* spp., when plants are well established in pots and at the beginning of flowering. ***After sale care*** is different for different species (Nowak and Rudnicki 1990).

Bulbs, Corms, Rhizomes and Tubers

Flower problems
Virus diseases
Grey mould (*Botrytis*)
Aphids
Gladiolus thrips injury
Failure to flower

Foliage problems
Virus diseases
Fungal leaf spots
Aphids
Gladiolus thrips injury
Snail and slug damage

Bulb problems
Bacterial rots
Stem and bulb nematode
Fusarium wilts
Bulb aphids
Bulb flies and mites
Mealybugs
Thrips



Remember
All virus diseases, nearly all bacterial and fungal diseases, all nematodes diseases and most insect and mite pests are carried over in the bulbs from season to season

Fig. 56. Diseases and pests affecting various parts of bulbous plants.

BULBS, CORMS, RHIZOMES AND TUBERS	C 1

Fig. 57. Flower breaking virus ymptoms on tulip flower.

Fig. 58. Virus symptoms (light and dark green mottle) on tulip leaves.

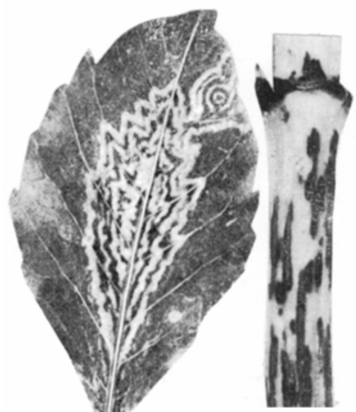


Fig. 59. Tomato spotted wilt virus on dahlia.
Left : Yellow spots/lines on leaves.
Right : Streaking on stem.
Dept. of Agric., NSW.

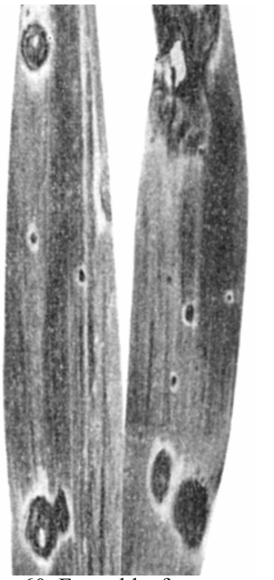


Fig. 60. Fungal leaf spot (*Heterosporium iridis*) on iris leaves. Dept. of Agric., NSW.

Fig. 61. Fusarium wilt, basal rot (*Fusarium oxysporum* f.sp. *narcissi*). Affected bulb cut cut in half to show decay advancing from the basal plate upwards through the scales.

Fig. 62. Sclerotium rot (*Sclerotium rolfsii*) on onion. Note small, brown round sclerotia.

Fig. 63. Fungal rots develop on stored bulbs. Different fungi produce spores masses of various colours, eg *Aspergillus niger* (black), *Botrytis* (grey), *Fusarium* (pink), *Penicillium* (blue or green).

Fig. 64. Stem and bulb nematode damage (*Ditylenchus dipsaci*) to daffodil. Bulb cut longitudinally to show browning of scales.

Fig. 65. Aphids (Aphididae) on garlic.

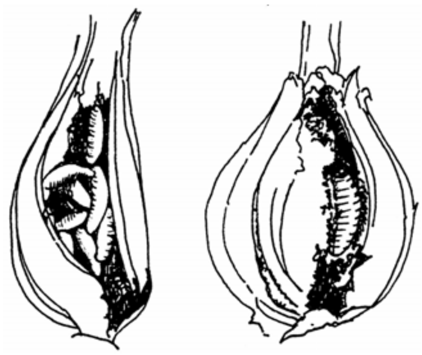


Fig. 66. Bulb flies. ***Left :*** Lesser bulb fly (*Eumerus tuberculatus*) maggots. ***Right :*** Narcissus bulb fly (*Lampetia equestris*) maggot.

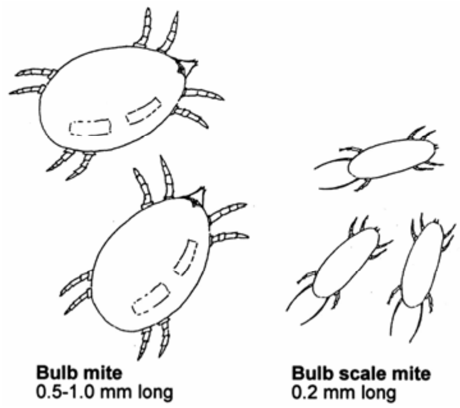


Fig. 67. Bulb mites (Acarina). ***Left :*** Bulb mite(*Rhizoglyphus echinopus*). ***Right*** **:** Bulb scale mite ((*Steneotarsonemus laticeps*) which is less than half the size of bulb mite.

Fig. 68. Gladiolus thrips (*Thrips simplex*) injury. ***Left :*** Silvering of leaves. ***Right :*** White speckling on dark flowers.

Fig. 69. Slime moulds growing on onion bulbs.

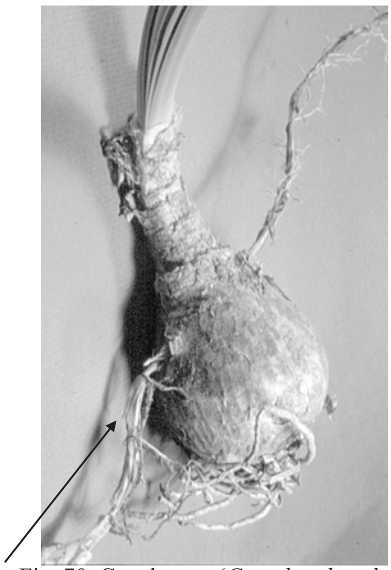


Fig. 70. Couchgrass (*Cynodon dactylon*) rhizomes growing though a nerine bulb**.**

Bulbs

Corms, Rhizomes, Tubers

PESTS AND DISEASES
Parasitic

*The term 'bulb' is used whether the plant is a true bulb, corm, rhizome or tuberous root. Bulbous plants are **remarkably free** from **major problems**. Nearly all those that attack these plants are carried over from season to season **in the bulb** (Fig. 56).*

VIRUS AND VIRUS-LIKE DISEASES

Scientific name: Most species of bulbs can be infected by a number of virus diseases.

Host range: Some viruses affecting bulbs, eg ***cucumber mosaic virus***, have a wide host range, but most can only infect one species or genus, eg ***tulip flower breaking virus*** only infects ***tulip***.

Symptoms: In susceptible varieties flower production and quality are affected. ***Flowers*** may be flecked, streaked or blotched and tulips may show a flower break (Fig. 57). Distortion can also occur. Plants may fail to flower. ***Foliage*** may show mild to severe light and dark green mottling (Figs. 58, 59). Leaves may be malformed and brown to purplish streaks may develop. ***Stems*** may be streaked (Fig. 59). ***Bulbs*** usually do not show symptoms, but distortion can occur. As plants can be infected with more than one virus it is often impossible for the lay person to recognise which virus is causing the problem. Although some species remain vigorous and productive in spite of virus infection, others gradually decline. Virus infections are often ***latent*** (present in the host but no symptoms develop). Symptoms may be more obvious during cool weather.

Overwintering: Infected bulbs in the ground and in storage. Some with a wide host range, eg cucumber mosaic virus, overwinter in other host plants including weeds. Not usually in seed. Also self-sown bulbs from previous crops.

Spread: All viruses are spread by ***vegetative propagation*** (they are present in the bulbs of infected plants even though no symptoms are observed in the bulb itself) and by the ***introduction*** of infected bulbs. Many viruses are also spread by ***insect vectors*** (aphids, leafhoppers, thrips). Some also by ***fungal organisms*** (not common), by ***mechanical transmission*** of plant sap on hands, clothes and tools during plant handling, eg flower cutting. Generally ***not by seed.***

Conditions favouring: Repeatedly planting bulbs from infected plantings. An abundance of vectors, eg aphids. Symptoms may be more pronounced in ***cool weather***.

Control: Virus diseases are ***difficult to control***. As there is no 'cure' for in fected plants, the aim is to prevent spread of virus from infected to healthy plants. ***Control is based primarily*** on the use of virus-tested bulbs, roguing and the application of insecticides to keep aphid vector populations down. To minimise losses:

Cultural methods: Where practical, ***rotate plantings***. Infected bulbs accidentally left in the soil will produce plants the following season and act as a ***source of infection***. Overseas some viruses, eg tobacco necrosis virus, which are spread by soilborne fungi are particularly prevalent where hosts, eg tulips, have been grown on the same land for consecutive seasons.

Sanitation: ***Inspect crops*** regularly, dig up and destroy/burn infected plants. ***Roguing*** (removal of diseased plants) of susceptible varieties should commence ***early in spring*** before rising temperatures mask symptoms and make roguing difficult. In practice this is usually only carried out for plants showing severe symptoms on either the flower or foliage. Now that virus-tested bulbs are available for many species, roguing will probably be practised more extensively. It is not possible to rogue varieties in which viruses are ***latent*** (varieties which carry the virus but show no symptoms). For this reason susceptible varieties which are being rogued for virus should be grown in isolation to minimise reinfection. As many of the viruses are spread by insects, even with severe roguing in susceptible varieties in commercial plantings (and insecticide applications to control aphids), ***over 10-15%*** of plants the following season may be infected. ***Control weed hosts*** in the close vicinity of cormlet and commercial plantings.

Resistant varieties: Some bulb varieties are ***more susceptible*** to virus infections than others.

Plant quarantine: Grow newly acquired bulbs, unless guaranteed virus-tested, ***in isolation***. Do not plant virus-tested bulbs adjacent to infected crops, eg plant virus-tested gladiolus corms at least 1 km from virus-infected gladiolus crops.

Disease-free planting material: ***Do not propagate*** from older diseased bulbs. Plant ***virus-tested bulbs*** for new plantings on a regular basis. Virus-tested bulbs grown adjacent to old infected plantings will become infected.

Physical and mechanical methods/Pesticides: Control aphids during the growing season, commencing as soon as blades appear through the soil. Aphid flights occur throughout the year in Australia and virus diseases are spread from infected plants ***before the symptoms of virus disease can be recognised*** and plants rogued. In outdoor plantings, unless granular soil insecticides are applied at planting, it is difficult to obtain satisfactory control of aphids by spraying. When used in conjunction with growing plants in ***aphid-proof greenhouses***, spraying is much more successful, anti-virus netting is now available. ***Insect vectors***, eg aphids and thrips, should be controlled in ***stored*** bulbs and corms. ***In home gardens*** it is impossible to control insect vectors and this should not be attempted.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora, Erwinia* spp.) may affect bulbs, eg irises, both in the ground and in storage. Leaves of infected plants turn yellow, wilt and collapse. When the plant is lifted, the ***bulb*** below the wilted foliage is a soft, wet, pulpy mass. The bacteria are generally present in soil or decaying plant material, entry usually occurs through wounds. ***Cultural methods:*** Avoid ***overcrowding*** of beds, shaded or poorly drained sites and over-irrigation. ***Rotate bulbs*** with non-susceptible crops. Bulbs become more susceptible ***with age*** or poor storage conditions. ***Avoid injury*** during cultivation and harvesting. Bulbs should be dried before storage and stored under cool, well-ventilated conditions. ***Sanitation:*** Tools used for separating rhizomes and tubers should be ***disinfected***. Rotting tubers in the field and in storage should be ***destroyed***. See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots (*Botrytis, Heterosporium, Stagonospora,* other species) can be disfiguring (Fig. 60), leaves may die prematurely. Plants may be weakened and flowering affected. Sometimes leaf spot fungi attack other parts of the plant, eg *Botrytis,* commonly attacks ***leaves, flowers, flower stems and bulbs***. Leaf spot fungi ***overwinter*** on the tops of bud scales, crop debris and infect leaves as they emerge. They are ***spread*** by the use of infected bulbs, spores are spread by wind. In small plantings, infected leaf tips may be ***removed*** by hand, and destroyed/burnt. Growing crops may be sprayed regularly if necessary with a ***fungicide***. ***Crop debris*** should be destroyed. See Annuals A 5.

Fusarium wilt, fusarium basal rot (*Fusarium oxysporum* f.spp.) may affect many bulbs in the ***field*** and in ***storage***. A firm brown rot of the basal plate and scales is seen when an infected ***bulb*** is cut down the middle (Fig. 61). The fungus gains entry through dead root bases to the ***basal plate*** and ***bulb scales***, or through wounds at the beginning or at any time during dormancy. Basal rot can spread through bulbs ***during storage***. Affected bulbs, if planted, rot in the soil, without germinating, or produce weak, yellow ***foliage***, plants die. ***Verticillium wilt*** (*Verticillium dahliae*) may also infect some bulbs. See Vegetables M 9.

Grey mould, neck rot, *Botrytis (Botrytis cinerea*, *Botrytis* spp.) may attack ***flowers*** (petal blights), ***petioles, leaves*** (leaf spots) and ***bulbs*** of many species. A greyish brown powdery fungal growth, often with a crust of hard black sclerotia (resting bodies) may develop on ***corms***. Grey mould causes a decay of the petiole bases of cyclamen and can quickly ***kill bulbs*** so prompt control measures are necessary. Grey mould can develop on ***flowers*** of freesia when packed especially in plastic sleeves. ***Minimise losses*** by only planting in well drained soil and providing good ventilation. ***Remove*** damaged leaves, broken or unpicked flower heads, remove and destroy infected plants and bulbs as soon as noticed, and spray remaining plants with a fungicide. ***Inspect and destroy*** infected bulbs after lifting, after storage and before planting, treat remaining healthy bulbs with ***fungicide*** before storage and before planting. See Greenhouses N 22.

Root, bulb and stem rots are ***common*** in bulbs due to the ***soft succulent tissues*** of underground parts (Fig. 63). Some, eg *Fusarium,* tend to be host specific while others, eg *Sclerotium* stem rot and *Sclerotinia* rot, have wide host ranges and may attack many other plants.

Black mould (*Aspergillus niger*) attacks bulbs, eg onion and other plants. ***Black, powdery masses of spores*** develop on the surface of ***outside scales*** and later between scales. See Onion M 67.

Damping off (*Pythium* spp., *Rhizoctonia solani*) may be ***serious*** on bulbs. Well drained potting mixes and avoiding overwatering will reduce likelihood of ***root, crown and leaf stalk rots***. See Seedlings N 66.

Fusarium rots (*Fusarium* spp.). ***Pink spore masses*** form on ***rotted tissue***. See Vegetables M 7.

Fusarium wilt, fusarium basal rot (*Fusarium oxysporum* f.spp.). See above.

Grey mould (*Botrytis cinerea*) may affect all plant parts of bulbs. See above.

Penicillium moulds, blue and green moulds (*Penicillium* spp.) may develop on ***fleshy bulb scales***. If severe the whole bulb may rot ***during storage*** but in mild infections it may only slightly affect growth after planting. ***Overwinters*** in infected corms and crop debris. ***Spread*** by vegetative propagation from infected bulbs, spores are spread by wind. The disease can also spread from ***corm to corm*** in the field and in storage, by infested soil (mycelium, sclerotia in crop debris) on machinery etc. ***Favoured*** by injury to bulbs during lifting or storage and cool, damp conditions during digging and storage. See Fruit F 6, Vegetables M 6.

Rhizopus soft rot (*Rhizopus stolonifer*) causes a rapidly developing soft rot of ***bulbs*** in ***storage,*** with characteristic coarse open, black and white fungal growth. ***Favoured*** by plant injury during lifting and handling and prolonged warm, moist conditions during transit and storage, packaging in plastic bags. See Fruit F 6, Vegetables M 6.

Rhizoctonia stem or neck rot (*Rhizoctonia solani*) causes individual plants to wilt or collapse due to rotting of the ***stem or neck*** at or above ground level. Affected tissue is brown. See Vegetables M 7.

Sclerotinia* rot** (*Sclerotinia* spp.) causes a soft, brown rot of ***stems and other aerial parts of more ***mature plants***. White fungal hyphae grows over rotted areas. White sclerotia (resting bodies of the fungus) up to about ***12 mm*** in size are produced on rotted areas. Stem infections cause plants to wilt and die. See Vegetables M 7.

Sclerotium* bulb rot** (*Sclerotium rolfsii*) attacks stems of ***mature plants at ***ground level***. A white cottony mat of fungal mycelium grows over affected parts (Fig. 62). Sclerotia, about the size of cabbage seed, ***1-2 mm*** across, are produced on the surface of the mycelium, these later turn brown and are hard to see against the brown soil. A brown dry rot develops, plants yellow and die. Sclerotium bulb rot causes losses in bulbs in Victoria of $1.5 million each year (HRDC Research Report 1994-95, Porter 1994). ***Strategies for control*** include improved management of treated/fumigated soils, effectiveness of treatments and fungicides dips. See Vegetables M 7.

Thielaviopsis* black root rot** (*Thielaviopsis basicola*) may cause bulbs to grow poorly, affected areas on ***roots are dark brown to black, root lesions may be small or may coalesce to affect the whole root. Root systems are reduced and in extreme cases reduced to stubs. See Vegetables M 8.

Many soilborne fungal diseases can be difficult to control. Only plant ***disease-free*** bulbs in ***disease-free soil***. Dipping bulbs in ***fungicides*** combined with late season drenches may eliminate diseases and increase yields. ***Lifting*** and dividing bulbs regularly, eg at least every 2-3 years, helps to reduce incidence. ***Storage rots***, eg ***penicillium moulds*** (*Penicillium* spp.) and ***rhizopus rot*** (*Rhizopus stolonifer*), can be avoided by not digging during damp weather, avoiding injury to bulbs during harvesting and handling. Dry bulbs rapidly after digging. Green-clean bulbs and cure before storage. ***Transport and store*** at the correct temperature (cool conditions) in dry well ventilated conditions (at correct relative humidity) to ensure rapid healing of wounds. ***Inspect bulbs*** after lifting, before storage and again before planting, destroy any infected bulbs and treat remaining bulbs with fungicide before storage and again before planting. ***Ensure strict hygiene*** in packing shed. Remove and destroy all sources of contamination from packing sheds and stores, ie old bulbs, containers. ***Clean and disinfect*** packing sheds and storage areas. Rhizomes may be cleaned of soil and infected portions cut off with a sharp knife and the remaining portion immediately treated with fungicide. Pre- and post-plant applications of appropriate ***fungicidal drenches*** may reduce spread. See Vegetables M 6.

NEMATODE DISEASES

Stem and bulb nematode (*Ditylenchus dipsaci*) is a ***serious pest*** of bulbs especially daffodils. ***Foliage*** is twisted, often pale with raised lumps which can easily be felt if the leaf is drawn between the fingers. If ***bulbs*** are cut lengthwise, scales are rotted (Figs. 64). If cut across, rotted scales appear as ***concentric rings***. The basal plate is ***not rotted*** in the initial stages of nematode infestation. See Daffodil C 20, 23 (Fig. 74).

Others

Foliar nematodes (*Aphelenchoides* spp.) may infest African violet, anemone, *Anigozanthos* (*A. manglesii*), begonia, chrysanthemum, cyclamen. Water soaked lesions on ***leaves***, infested leaves die and fall. In the early stages, leaf spots are produced which tend to be triangular and bordered by veins but this is not always so. Early stages of attack may look like fungal leaf spots. Disease progresses from the lower leaves upwards. ***Flowers*** may be infested and decay is often only on one side. See Ferns E 2.

Root knot nematodes (*Meloidogyne* spp.) attacks causes ***bulbs*** to be stunted and yellow, swellings develop on ***roots and tubers*** of dahlias. See Vegetables M 10.

Others: ***Root lesion nematode*** (*Pratylenchus* spp.).

INSECTS AND ALLIED PESTS

*Compared with many other groups of plants, bulbs have relatively **few insect pests**.*

Aphids (Aphididae, Hemiptera)

Bulb and potato aphid (*Rhopalosiphoninus latysiphon*)
Cotton aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Mangold aphid (*Rhopalosiphoninus staphyleae*)
Potato aphid (*Macrosiphum euphorbiae*)
Tulip bulb aphid (*Dysaphis tulipae*)
Violet aphid (*Neotoxoptera violae*)

Aphids are variously coloured depending on the species and may be a ***major pest*** of bulbs in gardens, field crops, greenhouses and storage. ***Aphids*** suck sap from ***leaves***, severely checking growth, and other above ground plant parts during the spring. ***Bulbs*** may be infested both in the field and in storage (Fig. 65), and may become sticky with honeydew. Aphids also transmit ***virus diseases*** of bulbs. Aphids ***overwinter*** on bulbs in the field and in store and on alternate hosts. ***Spread*** by winged forms flying and the introduction of infested bulbs. ***Favoured*** by cool, moist weather. ***Aphid control in the crop and in bulbs in store is essential***. ***In the crop*** foliage may be sprayed when aphids are observed during the growing season with a recommended ***insecticide***. Granular insecticides may be applied at planting. ***On bulbs in store*** aphids are controlled in the same way as ***bulb mites***. See Bulbs C 7, Roses J 4.

Bulb flies

Scientific name: Syrphidae, Diptera.

Host range: The maggots of these flies attack the bulbs of various plants including daffodil, hyacinth, amaryllis and tulip.

Description and damage:

Lesser bulb fly (*Eumerus tuberculatus*) is of a blackish green colour, 8-9 mm long, with white markings on the side of the abdomen. This species is nearly bare of hairs. ***Maggots*** are grey or yellowish-grey, and the body is markedly wrinkled. Usually ***many maggots*** are found in ***one bulb*** (Fig 66). Injury to bulbs by the lesser bulb fly is similar to that caused by the *Narcissus* bulb fly (McMaugh 1994).

Narcissus bulb fly (*Lampetia equestris*)is a shiny yellow and black hairy fly, resembling a small bumble bee. **Maggots** are large, about 10-15 mm long, white or yellowish-white. Usually **one maggot** is found in **one bulb** (Fig. 66). Damaged bulbs become soft and the outer scales often have brown scars on them.

Overwintering: In bulbs in store and in the soil.

Spread: By adults flying, by introduction of infested bulbs.

Conditions favouring: Warm weather.

Control: As for bulb mites.
Sanitation: As for bulb mites.
Disease-free planting material: As for bulb mites.
Physical and mechanical methods/Pesticides: **Bulbs** may be treated during **dormancy** in hot water at 43-46°C for 2.5 hours (hot water treatment for aphids and mites is 44.4°C for 3 hours, and for stem and bulb nematode in daffodils 43°C for 3.5 hours). As a precaution, all bulbs should be dusted with an **insecticide/miticide** prior to storage and again before planting. **Insecticide soil drenches** may be applied to plant bases at the beginning of adult fly activity.

Bulb mites

Scientific name: Acarina:
Bulb mite (*Rhizoglyphus echinopus*, Acaridae)
Bulb scale mite (*Steneotarsonemus laticeps*, Tarsonemidae). Other mites may also infest bulbs, eg **twospotted mite** (*Tetranychus urticae*) which may infest the leaves of some bulbs, eg alstroemeria. Also **broad mite** (*Polyphagotarsonemus latus*), **cyclamen mite** (*Phytonemus pallidus*) and **redlegged earth mite** (*Halotydeus destructor*).

Host range: **Bulb mite** infests bulbs and similar plants, eg **ornamentals**, eg crocus, daffodil, dahlia, freesia, gladiolus, hyacinth, jonquil, lily, tulip; **vegetables**, eg onion, shallot, chives, garlic, beetroot, potato. **Bulb scale mite** infests Amaryllidaceae, eg eucaris, hippeastrum, *Narcissus.*

Description and damage:

Bulb mites are **0.5-1 mm** long, globular, whitish with brownish legs and move slowly (Fig. 67). They **glisten** but are difficult to see without a hand lens. Adult females may live for 1-2 months and each may lay more than 100 eggs behind bud scales. Immature mites are the most destructive. **Bulbs** may be infested both in the **field** and in **storage**. Mites are commonly found in large numbers sheltering behind, or boring into bud scales, causing bulbs to rot (due to the feeding of secondary microorganisms). **Foliage** that grows from infested bulbs may become yellow, there may be no flowers, or only misshapen ones. **Leaves** may be small and distorted.

Bulb scale mites are smaller than bulb mites and are only about **0.2 mm** long, colourless when young but becoming pale brown when older (Fig. 67). Mites are often found in groups near the neck of bulbs feeding **internally** in spaces between the scales. As numbers increase, the mites spread to foliage which may be abnormally bright green, streaked with yellow and distorted. Damaged **flower buds** may result in deformed flowers, buds may be killed. **Leaves and flower stems** may be disfigured by elongated, serrated scars. Crops gradually lose vigour. Mites cause red streaks and spots on the base of developing leaves and stems of hippeastrum. Feeding in **stored dormant bulbs** causes brown scars on one or more scales. If the bulb scales are pulled apart, the brown marks may be seen to extend downwards. Bulbs infested with bulb scale mite go soft when stored.

Overwintering: In bulbs.

Spread: By the introduction of infested bulbs to field plantings and storage. **Bulb mites** seem to prefer **healthy bulbs** and migrate through soil from decaying to healthy bulbs. Under certain conditions, a non-feeding, but very active, immature stage (known as the hypopus) may occur and last for about 2 weeks. The hypopus has a group of suckers on the lower side of the body which enables it to attach readily to insects, mice and other animals and so be transported to other areas. **Bulb scale mites** spread by crawling along leaves and over the ground.

Conditions favouring: **Bulb mites** prefer high humidity and temperature (optimum 23-26°C). Attack is most likely on bulbs that are already damaged during digging, by bulb flies and other pests. Warm moist conditions during storage. In the colder months **bulb scale mites** remain in bulbs but when brought in for forcing under glass, they increase rapidly and the life cycle may be as short as 2 weeks. Bulb scale mite numbers increase in the neck of the bulbs from where they infest leaves and flower buds.

Control:
Cultural methods: **Bulb scale mite** cannot usually live in the absence of *Narcissus* so provided the ground is clear of self-set bulbs re-infestation in the field is unlikely.
Sanitation: **Inspect bulbs** at digging and before storage. All heavily infested bulbs should be **destroyed**, remaining bulbs should be **treated** either by dusting with an **insecticide** prior to storage even if there is no sign of infestation, or with hot water (see below). **Keep crops clean** after harvest, remove volunteer bulbs. **Inspect bulbs** again before planting. After the bulbs are removed, the store must be thoroughly cleaned to remove old bulbs, bulb scales and other debris on which infestation might persist.
Biological control: Small active predatory mites (*Gamasellodes*, Ascidae) are thought to feed on eggs of bulb mite (*Rhizoglyphus*).
Disease-free planting material: **Do not introduce** infested bulbs to clean field or storage areas. **Inspect all new purchases** for infestations.
Physical and mechanical methods/Pesticides: Bulbs may be **disinfested during dormancy** by either soaking in an insecticide/miticide, treating with hot water, eg 44.4°C for 3 hours, or by fumigation (by professionals). **After treatment**, bulbs should be dried and dusted with a **fungicide/insecticide** prior to storage or planting. **Only treat bulbs for planting** not for forcing, as they may be damaged Treated bulbs should be separated from untreated ones to prevent re-infestation. Plant treated stock as soon as possible into land which has not recently carried a *Narcissus* crop. If necessary, in the **field**, a soil miticide drench may be applied to the base of the plants.

Caterpillars (Lepidoptera), eg ***looper caterpillars*** (*Chrysodeixis* spp.), may chew holes in ***leaves, stems and flowers*** destroying developing ***buds***. A few caterpillars, can be removed by hand, otherwise treat with an insecticide. Spraying should not be necessary. See Annuals A 8.

Mealybugs (*Pseudococcus* spp.) suck sap from ***bulbs*** in the ***field*** and in ***storage*** (if the temperature is 15°C or above). Insects multiply on bulbs causing them to shrink and die or produce sickly plants. See Greenhouses N 25.

Thrips (Thripidae, Thysanoptera)

Gladiolus thrips (*Thrips simplex*) cause silvering of ***foliage*** and speckling of ***flowers*** (Figs. 68). ***Corms*** may be damaged during ***storage,*** becoming sticky, hard and scaly, young root buds may be injured. Pale coloured varieties are reputed to have some resistance to attack. See Gladiolus C 31, C 34 (Fig. 81).

Plague thrips (*Thrips imaginis*) and other species may infest ***flowers*** of most plants. Petal edges brown and tiny grey to black elongated insects are seen in the flowers and young leaves. Damage is superficial causing silvering, browning and distortion of both petals and young leaves. See Roses J 6.

Western flower thrips (*Frankliniella occidentalis*) and ***onion thrips*** (*Thrips tabaci*) are vectors of the ***tomato spotted wilt virus complex*** which may affect begonia cyclamen, dahlia, gladiolus, ranunculus, zantedeschia and many other plants. See Annuals A 9, Tomato M 96, M 103.

Wireworms (Elateridae) are the larvae of click beetles, they are long smooth segmented larvae, yellowish brown and up to ***18 mm*** long. They live entirely in the soil, burrowing into ***bulbs***, hollowing out ***stems*** as they work their way up, causing plants eventually to fall over. See Seedlings N 69.

Others: ***Millipedes*** (Diplopoda), ***slaters*** (Crustaceae), ***springtails*** (Collembola), ***elephant beetle*** (*Xylotrupes gideon*) and ***weevils***, eg black vine weevil (*Otiorhynchus sulcatus*), may infest bulbs. ***Leafhoppers*** (Ciciadellidae) and ***whiteflies*** (Aleyrodidae) may infest leaves.

SNAILS AND SLUGS

Snails and slugs are ***serious pests*** of bulbs and may chew large ragged holes in ***new shoots, mature leaves, flower stems, buds and flowers***. Young snails and slugs may graze on the surface of leaf blades and skeletonise leaves. As soon as stalks appear apply snail bait between the rows. Do not confuse snail and slug damage with that caused by moth caterpillars. See Daffodil C 23 (Fig. 75), Seedlings N 70.

VERTEBRATE PESTS

Mice and rats may eat bulbs in ***storage***. ***Cockatoos*** and similar birds snap the heads off bulbs in ***outdoor plantings*** or chew the bulbs. See Fruit F 13, Seeds N 77.

Non-parasitic

Environment: ***Failure to flower*** is a common problem in bulbs especially in daffodils. All true bulbs produce the embryo flowers inside the bulb leaf tissue during the previous season. Their performance when planted out will depend on their treatment during the previous season. Reasons for failure to flower or reduction in flower size and numbers include the ***size and condition of the bulb*** (different varieties do produce bulbs of different sized bulbs as a matter of course). Small bulbs may be produced because of ***overcrowding*** of clumps, excessive ***dryness and shade*** during the previous season. Bulbs and varieties of bulbs vary in temperature tolerance, eg alstroemeria, may be damaged by low temperatures. See Daffodil C 21.

Nutrient deficiencies, toxicities: Individual bulbs have ***different requirements***. Generally, ***excess fertilisers*** may damage ***roots.***

Others: ***Chimeras*** (segments of coloured petals) develop in some bulbs. See Tulip C 43. C 44 (Fig. 82). ***Dermatitis*** may occur in susceptible individuals after prolonged contact with ***some bulbs***, eg alstroemeria, daffodils, tulips. Rubber gloves may be worn during handling. Many Armaryllidaceae are regarded as ***toxic*** when ***ingested***, eg daffodil, snowdrop (Frohne and Pfander 1983). ***Slime moulds*** (various species) may develop on bulbs. See Bulbs C 3 (Fig. 69).

WEEDS

Weed control is essential as they compete with bulbs for available food and bulbs may be smothered by annual and perennial weeds. Areas to be planted with bulbs should be weed-free and should be ***kept weed-free*** to reduce bacterial and fungal diseases and pests, to make cutting flowers and the lifting of bulbs easier. Lifting bulbs from areas infested with couch can be difficult (Fig. 70).

Soil-less media should be weed-free. Weeds should only be minor problem in greenhouses especially if the ***soil is disinfested*** (fumigated or pasteurised) before planting. ***Cultivation*** for weed control around tubers may injure plants, eg iris, and has the disadvantage of having to be discontinued when flower spikes appear. ***Hand weeding*** should control any infestation. ***Mulch*** with well rotted leaf mould or chipped garden material or compost.

Bulbs left in the ground, eg daffodils, for a number of years: ***Grass in the rows*** can keep flowers clean in wet winters and be cut when required just above ground level once leaves have died back or turned yellow. ***Overcrowding*** is detrimental as weeds then compete with the bulbs for available food. ***Post-emergence contact or other herbicides***, and a ***pre-emergence herbicide***, can be applied in late summer before new leaves emerge. Active growth may be spot sprayed with glyphosate to control ***volunteer unwanted bulbs*** in crops or adjacent areas.

Herbicides are registered for use on commercial plantings and may be applied both ***pre-plant*** and ***pre-*** and ***post-emergence*** of the crop. Since most herbicides are specific for soil types and prevalent weed populations, no one chemical can be used universally. Preferably emerged weeds should be controlled prior to planting. ***Perennial broadleafed***

weeds can be treated with phenoxy compounds (hormone) herbicides to which monocotyledons are resistant. If the soil has not been treated, ***pre-emergence*** weed control is essential. ***Pre-emergence herbicides*** may be applied soon after planting but before leaf emergence, to control weeds for 2-3 months. The herbicide must be watered in immediately after application For ***daffodils, hyacinth and tulips,*** 4 weeks after planting and while the shoots of the bulbs are ***> 30 mm*** below the soil, the ground may be sprayed with a recommended ***post-emergence herbicide*** to kill existing weeds and a ***pre-emergence herbicide*** to prevent weed seeds from germinating for up to 3 months (Tesselaar's Grower Information Sheets:1-8).

Herbicide injury: Small corms and cormlets are more sensitive to herbicides than larger ones. Corms and cormlets must be planted at the correct depth. ***Never spray with herbicide once bulb growth is within 5 mm of the surface or has emerged*** (Tesselaar's Grower Information Sheet No.1:Daffodils). For some herbicides and for some bulbs the shoots of bulbs must be ***> 30 mm*** below the soil surface. ***Post-emergence herbicides,*** eg glyphosate, should not be applied to ***iris*** foliage even when it has apparently dried up as the old stalks or leaves of some bulbs transport the material to the bulbs and next year's crops show damage with bleached leaves, shortened flower stalks and distorted flowers. ***Pre-emergence herbicides*** must be tested initially on a small area to see whether they are phytotoxic, eg ***freesia***, is readily damaged by some. Chloroxuron (Tenoran®) may spot leaves if not washed off foliage immediately after application. ***Lilies*** tolerate a wide range of residual herbicides including simazine, but not those acting on the emerging shoots, eg oxadiazon (Ronstar®).

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State/Territory Departments of Agriculture/Primary Industry eg

Bulb Scale Mite (Vic Agnote)

Sampling Soils and Plant Materials for Examination of Nematodes (Vic Agnote)

Weed Control in Flowering Bulbs and Corms (Tas Farmnote)

Tesselaar's Padua Bulb Nurseries, Silvan, Vic.

Grower Information Sheet No. 1. Daffodils

Grower Information Sheet No. 2. Hyacinths

Grower Information Sheet No. 3. Tulips

Grower Information Sheet No. 4. Anemones

Grower Information Sheet No. 5. Ranunculi

Grower Information Sheet No. 6. Freesias

Grower Information Sheet No. 7. Suggestions for Potting Spring Flowering Bulbs

Grower Information Sheet No. 8. Forcing Bulbs

Success with Bulbs and Perennials

Tesselaar's Bulb Planting Guide

Associations, Journals etc.

CRC Adelaide, Uni Waite

Cultural Notes for Bulbs & Perennials (Broersen Seeds and Bulbs, Vic)

Floriade (ACT Parks and Conservation, Canberra)

GrowSearch (database Qld DPI)

See Annuals and herbaceous perennials A 10, Preface xii

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Flowering bulbs may be grown outdoors in clumps in massed beds or borders, floriades, or in containers. Generally bulbs are a hardy group of plants.

Resistant varieties: Some cultivars of some bulbs are ***resistant*** to grey mould. Some bulbs, eg crocus and liatris, are relatively disease and pest-free.

Plant quarantine regulations must be consulted prior to importing flower-size corms or cormlets.

Disease-free planting material: Nearly all problems that attack bulbs are ***carried over*** from season to season in the bulb. ***Regularly purchase*** and plant ***virus and pathogen-tested bulbs***.

Establishment and Maintenance

Propagation: By bulbs, offsets, by scales, and depending on the species by tissue culture. Also by seed but they do not usually reproduce true to type; however, seeds may be virus-free.

Cultural methods ***(Tesselaar's Grower Information Sheet No.8:FORCING BULBS*):*** ***1. On arrival:*** Unpack bulbs immediately and store in an area where they have moderate temperatures and are away from excessive heat; 17-20^{o}C for tulips and daffodils and 20-25^{o}C for hyacinths. All will tolerate up to 5^{o}C higher in daytime, but higher temperatures will delay flowering. ***2. Forcing:*** Bulbs should not start their cooling period before the 1st February. ***Tulips and daffodils*** can be cooled between 5-9^{o}C but ***hyacinths*** prefer 9^{o}C for 6-9 weeks. Starting after this date the effect of the cooling is lessened. Do not begin cooling before this time as the flower may not yet be fully formed in the bulb (bulbs begin elongating under cool storage, and if the flowers have not been formed, ***then the 2nd process has begun before the 1st process is complete***). ***Careful temperature control*** is important, and in cool rooms keep the air in constant motion. ***3. Planting:*** For earliest flowering, bulbs can be planted out from mid-March onwards, ***soil temperatures should be no greater than 20^{o}C.*** Planting in temperatures > 20^{o}C may cause bud blast (no flowers). Always plant pre-cooled bulbs in moist soil, never warm, dry soil. After planting, keep the soil moist at all times to help root development, watering also helps keep the soil cool. If planting out into boxes or pots, for extra early flowering, these can be placed back into the cool store at 9^{o}C for fast root development. Once the roots show at the end of the boxes or pots, after approximately 4-6 weeks, bring the temperature up to 13^{o}C (or 17^{o}C maximum) for continued fast growth. Normal growing and spraying conditions apply as with un-cooled bulbs. If pre-cooled bulbs are to be planted ***in the open ground***, they require some type of protection, such as a plastic house structure, to protect flowers from damage during the winter and early spring. Note, ***plant*** bulbs during correct season at the correct depth in properly prepared soil, eg not in fresh manure.

Sanitation: Rogue (selectively remove) diseased bulbs in the field, after lifting and again before planting.

Pesticides: ***Fungicides*** are registered for control of fire blight (*Botrytis*), fungal leaf spots, *Fusarium* diseases, penicillium moulds. ***Insecticides*** are registered for control of various insect pests, eg aphids, thrips. A suitable ***wetting agent*** may need to be added to foliage sprays to improve adhesion to leaf surfaces. Some bulbs may need to be ***treated/soaked*** in recommended fungicide before planting. ***Snail baits*** may be used. ***Pre-emergence herbicides*** may be applied to some bulbs after planting.

Potting spring flowering bulbs ***(Tesselaar's Information Sheet No.7:SUGGESTIONS FOR POTTING SPRING FLOWERING BULBS*):*** ***1. Potting mix:*** A well drained mixture, regardless of the exact composition, should be used. The ***2 basic functions*** of the planting medium are to anchor the bulbs and to serve as a source of moisture. The mixture must provide some nutrients to ensure high quality flowers and should have a pH of 6-7. ***2. Pots*** must provide good drainage. Preferably use new pots, so sanitation is not a problem. If old pots are used they must be disinfected. For a single bulb a 100 mm pot can be used. For 3 bulbs per pot, a minimum of 125 mm squat to a standard 150 mm pot. ***3. Planting:*** Fill containers to within 40-45 mm of the surface with the potting mix, then gently place bulbs on top of this, being careful not to push the bulbs into the soil as this compacts the medium directly beneath the rootplate. Now cover the bulbs to within 5 mm of the rim of the pot so that the initial watering will have to drain through the pot and not flow over the sides. Preferably the potting mix should be no warmer than 18-20^{o}C when potting up. ***4. Growing on:*** Select a cool shady area that is well drained and is clean. Place pots loosely together from mid-March to May and cover them completely with approximately 50 mm straw, making sure that the pots on the outside of the group are also well covered. Once the straw is down, water well and it may be necessary to supplement natural rainfall, depending on the weather conditions. The pots have to be kept moist at all times, so the straw covering will help to retain much of the moisture. If quicker flowering is required, place bulbs in a cool store with a temperature of 5-9^{o}C for approximately 6 weeks or until the roots appear at the bottom of the pots. These can then be brought into the greenhouse or warmer area with temperature of not more than 17^{o}C where they can be quickly brought into flower.

Postharvest

Cut flowers: Postharvest care varies with the species.

Potted bulbs: Market pots of spring flowering bulbs when flowers show first signs of colouring. Flowering bulbous plants, however, can be stored at 5-12^{o}C, at higher temperatures the flower buds of these plants develop faster, senescence is accelerated and the plants ***lose their decorative value more quickly***.

Lifting and storage: Different species vary in their requirements. After bulbs have finished flowering, do not cut the foliage back. During this time bulbs store food for growth the following year. Some bulbs form the flower buds for the following year at this time also. Feed lightly with blood and bone and control weeds around plants. Most bulbs can be left in the ground for many years and need only to be dug up when clumps become overcrowded. ***Inspect*** all bulbs carefully after lifting, unhealthy ones should be discarded and the rest dusted with sulphur (an insecticide/fungicide) to control aphids, mites, thrips, nematodes and fungal rots during ***storage*** in a dry airy place. Avoid damaging bulbs during digging, division or when cultivating, as injuries provide entry points for diseases. ***Hyacinths and tulips*** are best lifted when foliage completely dies down (summer is too hot for them to flower well the 2nd year). ***Hyacinths*** should be kept in shallow containers after lifting and covered with peat moss in a cool dry place. ***Commercial growers*** may treat some bulbs, eg daffodils, with hot water after lifting. See Bulbs C 7. Fumigation treatments may be carried out.

* *This information is given as a guide only. See Disclaimer, Page iii.*

Remember, always check for recent references

Anemone,
Ranunculus

Anemone spp.
Anemone coronaria, A. japonica
A. quinquefolia (wood anemone)
Ranunculus spp.
Family Ranunculaceae (crowfoot family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Viruses include ***cucumber mosaic virus*** on *Anemone* sp., ***tomato big bud mycoplasma*** (greening) on *Anemone coronaria* and *Ranunculus* spp. and ***tomato spotted wilt virus*** on ornamental and native buttercup (*Ranunculus* sp.). ***Insect vectors*** for these viruses include various aphids, leafhoppers and thrips. See Bulbs C 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) has been recorded on *Anemone* sp. See Stone fruits F 125. Overseas a new disease of ranunculus caused by ***Xanthomonas campestris*** has been recorded (Azad et al. 1996).

FUNGAL DISEASES

Anthracnose, leaf curl (*Colletotrichum acutatum*) commonly causes ***leaf and stem curling*** of anemone, ranunculus and celery. ***Leaves*** curl downwards, cup and do not open completely (Fig. 71), ***stems*** are twisted, newly emerged ***shoots*** may die. Sunken cankers up to 30 mm long occur on ***stems*** which may split to expose masses of orange spores. ***Seed*** of ranunculus may be discoloured by the orange spore masses (but not anemone seed because the seed is covered by hairs). ***Corms*** of anemone and ranunculi show no external symptoms, but when cut open, tissue close to the crown is purplish-black. The fungus can ***survive*** in seed and corms for ***> 2 years***. It also ***overwinters*** in the soil. At sowing time the fungus ***infects seedlings*** directly and adjacent healthy seedlings. 3-4 weeks after infection the fungus grows up the plant and causes cracking of stem tissues. Spores are produced in the cracks which spread by water splash to other plants. The fungus ***infects seeds*** when spores are splashed on to developing flower heads. In corms the fungus is present in internal tissues. The fungus ***infects corms*** during the growing season through the crown region and survives the drying of the corm during storage. As the corm germinates, the fungus grows up the stem and produces spores in the same way as in infected seedlings. Anthracnose is ***spread*** by spores water splashed onto other plants and flower heads, and by the introduction of infected corms, seed and soil. Infection is ***favoured*** by cool moist conditions in early spring. ***Plant quarantine:*** Export of seed and corms is limited because plant health regulations prevent import of infected stock by other countries. ***Disease-free planting material: Seed from ranunculus plants*** which show no sign of disease can be disinfected with hot water. Anemone seed ***cannot be hot water treated*** because hairs on the seed coat prevent penetration of heat. Hot water treatment can reduce levels of germination in seed that is > 2 years old. ***Corms of anemone and ranunculus*** from plants which show no sign of disease can be treated with hot water. To prevent damage to seeds and corms prescribed procedures for the hot water treatments must be followed otherwise temperatures that are too low will give less effective control of disease, while those that are too high will damage the seeds and corms (Woodcock 1988). ***Pesticides:*** Plant ***treated seed and corms*** in ***disease-free soil*** or pre-plant treat all sites where disease has recently occurred. Also treat or pasteurise all soil to be used in seedling trays. See Celery M 47, Fruit F 5.

Downy mildew (*Peronospora* sp.) may affect ***ranunculus***. During cool and humid weather greyish spore masses develop on ***leaf undersurfaces***. See Annuals A 5.

Fungal leaf spot: ***Leaf smut*** (*Entyloma microsporum*) occurs on the introduced 'weedy' ***ranunculus*** that grow by the roadside in moist places (Walker 1994). See Annuals A 5, Bulbs C 5.

Grey mould (*Botrytis cinerea*) may affect ***anemone***. See Bulbs C 5, Greenhouses N 22.

Powdery mildews (*Erysiphe ranunculi*, possibly other species) have been recorded on ***ranunculus***. White powdery fungal growth develops on ***both leaf surfaces***. See Annuals A 6.

Root and stem rots
Phytophthora root rot (*Phytophthora nicotianae*)
Rhizoctonia root rot (*Rhizoctonia solani*)
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Sclerotium root and crown rot (*Sclerotium rolfsii*)
Thielaviopsis black root rot (*Thielaviopsis basicola*)
See Bulbs C 5, Vegetables M 7.

Rust (*Aecidium* sp.) has been recorded on ***A. coronaria***. Its importance lies in the fact that it is a ***spore stage***, ie aeciospores produced in a cup-shaped fruiting body, of ***prune rust*** (*Tranzschelia* *discolor*). It appears to be systemic in anemone and the bulbs' from an infected plant can ***carry over*** the rust, resulting in rusted anemones next season (Walker 1994). See Annuals A 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) occurs on *Anemone japonica*, ***root knot*** (*Meloidogyne* sp.) on anemone. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) infest anemone. ***Green peach aphid*** (*Myzus persicae*) and other aphids may distort ***new growth*** and spread ***virus diseases***. See Bulbs C 6, Roses J 4.

Cutworms (*Agrotis* spp.) damage has been recorded on ***anemone*** in weedy areas. See Seedlings N 68.

Others: ***Major insect pests*** occurring overseas include thrips, spider mites, mealybugs and leafrolling caterpillars (Larson 1992). These pests may become more important in Australia. The introduction of the ***western flower thrips*** (*Frankliniella occidentalis*) to Australia may result in an increase in ***tomato spotted wilt virus*** infection.

Non-parasitic

Herbicide toxicity: ***Ranunculus*** may be damaged by the pre-emergence herbicide chloroxuron (Tenoran®), possibly because ranunculus are planted shallowly. All pre-emergence herbicides should be tested prior to large scale use.

Others: Some Ranunculaceae, eg *Anemone*, *Helleborus* and *Ranunculus,* are ***skin irritants***; some, eg *Delphinium,* are ***toxic to ingest*** (Frohne and Pfander 1983).

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Grower Information Sheets No.5. Ranunculi
Associations, Journals etc.
GrowSearch (database Qld DPI)
See Bulbs, corms, rhizomes and tubers C 9

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Anemone and ranunculi are excellent bedding and border plants, and are ideal for cutting. They prefer full sunlight and friable fertile soils, well drained soil to which organic matter and fertiliser has been added before planting. Make sure corms are planted with 'claws' downwards.

Disease-free planting material: Diseases, eg anthracnose, rust and viruses are carried over from year to year in corms. Plant new corns each year. Plants grown from seeds are more disease-free than those grown from tubers (Larson 1992).

Establishment and Maintenance

Anemones and ranunculi are tender perennials. They can be ***propagated*** by seed or divisions of tuberous roots but are most often grown from the roots. Culture and production of anemone and ranunculus is almost identical. Both are field and greenhouse grown but field production has become most common in the USA. Temperatures of 7-10^{o}C at night and a maximum day temp of 20^{o}C are suggested for ranunculus (Larson 1992). High temperatures can cause short stems and small flowers.

Cultural methods (Tesselaar's Grower Information Sheets No. 4 : ANEMONE and No. 5 RANUNCULI*):

1. On arrival: Keep anemone and ranunculus corms dry during storage. ***Anemone*** prefer a storage temperature range of 15-20^{o}C, ***ranunculi*** prefer 15-25^{o}C. Kept this way they can even stay over until the following planting season if necessary. Corms only begin to grow once they have sufficient moisture.

2. Planting: Do not soak ***anemone*** corms before planting as often this may create problems. Anemones grow satisfactorily in most soils, although they seem to prefer a light open soil. There should be sufficient organic matter in the soil to give good water retention. If soil is very poor, add some manure before planting. However too much available food will promote leaf growth, which could cause problems with *Botrytis* during winter. Plant corms from February until late May directly into well worked soil that is lightly damp. The corms should be pushed into the soil, ***flat side upwards***, to a depth of 30-40 mm. An over-all density of 35-40/m^2 is advisable. Planting groups at 3-4 week intervals gives an extended flowering season. ***Ranunculi*** are adaptable and grow satisfactorily in most soils. However, before planting loosen the soil to allow for easy penetration of roots. The small corms produce a bushy plant and so are gross feeders especially Picasso. In rich soils add 200-300 g/m^2 of blood and bone and work well in. For Picasso in poorer soils, work in up to 300-500 g/m^2 of blood and bone for best results. Stagger plantings from the end of February until the beginning of May, plant with ***points down***, approximately 50 mm below the soil surface. Spacing should be approximately 30/m^2 or 20-25/m^2 (Picasso strain). Top dress plants 6-8 weeks later when 100 mm high and again when 300 mm high with any propriety foliar fertiliser. ***3. Weeds:*** Areas to be planted with ***anemone and ranunculus*** may be sprayed for weeds prior to planting, they may be fumigated, which will help in producing better blooms and less fungal problems. Once corms are planted, do not spray with pre-emergence herbicides unless test trials have been carried out; plants may be killed by pre-emergence herbicides. ***4. Spraying: Anemones and ranunculus*** can suffer from anthracnose (leaf curl) and fire (*Botrytis*). To help limit these problems, once the corms are 20 mm high, they may be sprayed regularly, eg every 10 days, with a fungicide.

Postharvest

Cut flowers: ***5. Harvesting the flowers: Anemones*** should be picked when buds show good colour, but before the calyx reflexes. Flowers are pulled from the head of the corms with a twisting movement so that the plant is not pulled out of the soil. Anemones flower over a period of 6-8 weeks under most conditions, and yield per plant can range from 4-5 to 8 or more. ***Harvest ranunculi flowers*** when buds begin to open (Larson 1992). Each plant produces up to 6 stems with up to 50 flowers in all. ***Vase life:*** Keep ***ranunculi*** well supplied with water. Recut ***anemone*** stems, removing at least 20 mm. Remove all leaves below the water line. Place in clean container with a preservative. Avoid ethylene, eg keep away from vehicle exhausts and ripening fruit. Do not place in the same container as daffodils or jonquils (Jones and Moody 1993).

Lifting and storing corms: ***6. After flowering: Anemone*** corms can be dug up when foliage dies then dried and stored for the following season; ***ranunculi*** can be dug when the foliage yellows. Due to the relatively minor cost of the corms and the fact that these do degenerate, most growers prefer to hoe them under after flowering and replant fresh corms each season for maximum flower production.

Potted plants (Tesselaar's Grower Information Sheet No. 7 : SUGGESTIONS FOR POTTING SPRING FLOWERING BULBS*): ***Ranunculi*** also make ideal pot plants. Picasso ranunculi are best suited for this. Plant 3 corms to a 125-150 mm pot in a well enriched potting soil. A liquid fertiliser should be added weekly once the plants are 50-80 mm high or when the leaves show their first signs of yellowing. For maximum flowering and a good bushy plant, ranunculi should be planted out in full sun. Partial shade is not suitable for ranunculi. See also Bulbs C 10.

* *This information is given as a guide only. See Disclaimer, Page iii.*

Fig. 71. Leaf and stem curling of anemone leaves caused by anthracnose (*Colletotrichum acutatum*). ***Left :*** Healthy leaf. ***Centre and Right :*** Infected leaves showing distortion.

Remember, always check for recent references

Begonia

Begonia spp.
Family Begoniaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot
- **Fungal diseases**
  - Fungal leaf spot
  - Grey mould, blotch, *Botrytis*
  - Powdery mildew
  - Root, crown and stem rots
- **Nematode diseases**
  - Foliar nematode
  - Root knot nematodes
- **Insects and allied pests:**
  - Aphids
  - Caterpillars
  - Greenhouse thrips
  - Greenhouse whitefly
  - Mealybugs
  - Mites
  - Scales
  - Weevils
- **Snails and slugs**

Non-parasitic
  - Environment
  - Pesticide injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt has been recorded on some *Begonia* spp. ***Leaves*** may be deformed with marked stunting and bronzing of plants. Typical ***ringspots*** may also develop. See Bulbs C 4, Tomato M 96.

BACTERIAL DISEASES

Bacterial leaf spot (*Xanthomonas campestris* pv. *begoniae*) affects *Begonia* spp. ***especially tuberous begonia*** (Fahy and Persley 1983). Minute circular to angular watersoaked spots develop on ***leaves*** (more obviously on undersurfaces) which enlarge to dark green lesions up to 5 mm in diameter. As these age they dry to brown, papery, angular spots with greasy margins. Lesions can also occur around the margins or along veins distorting leaves. On ***stems and petioles*** dark green to brown watersoaked streaks about 5 mm long by 1 mm wide appear, these enlarge, brown and may split longitudinally. The disease is particularly damaging when plants are grown in nurseries under high humidity. ***Provide good ventilation*** to reduce humidity, do not overhead water, especially when temperatures are high. Remove and discard severely infected plants and surrounding soil. Rieger elatior begonias are ***very susceptible*** (Pirone 1978). Cultivars have been rated for ***resistance*** (Strider 1985). Propagate only from ***disease-free plants*** and ***pasteurise*** soil. See Vegetables M 5.

Others: ***Bacterial soft rot*** (*Erwinia carotovora* pv. *carotovora*).

FUNGAL DISEASES

Fungal leaf spot (*Cladosporium*) and ***anthracnose*** (*Gloeosporium begoniae*) may affect begonia ***leaves***. See Annuals A 5, Bulbs C 5.

Grey mould, blotch, *Botrytis* (*Botrytis cinerea*) causes ***leaf and stem blights***. Under cool cloudy conditions with poor ventilation grey mould develops on ***leaves and flowers*** which become brown and die. Avoid syringing plants; provide good ventilation. Pick off and discard all diseased leaves and destroy severely infected plants. See Bulbs C 5, Greenhouses N 22.

Powdery mildew (*Oidium* spp.) is a serious disease of ***some tuberous begonias*** especially Rex and Reiger begonias. The large flowering begonias grown from tubers are not so seriously affected. ***Leaf and flower stalks*** are covered with whitish patches of fungal spores. These patches ***brown***. It may be difficult for inexperienced growers to associate these brown areas on leaves with earlier active powdery mildew infections. See Annuals A 6.

Root, crown and stem rots
Damping off (*Fusarium*, *Pythium, Rhizoctonia*)
Phytophthora rots (*Phytophthora cryptogea*)
Rhizoctonia root, crown rot (*Rhizoctonia solani*)
Sclerotium stem rot (*Sclerotium* spp.)
Others, eg *Colletotrichum* spp.
See Bulbs C 5, Vegetables M 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) has been recorded on *B. maculata*, *B. tuberhybrida* and *Begonia* spp. and causes irregular brown blotches on ***leaves*** which increase in size until leaves curl up and drop off, plants become unsightly. ***Space plants*** so that the leaves do not touch. ***Avoid*** overhead irrigation. ***Prune off*** and destroy all infested parts of plants. If severely infested destroy the whole plant. ***Pasteurise*** soil and ***disinfect*** benches before planting the next crop. Only propagate from ***nematode-free*** plants and plant in ***nematode-free*** media. See Ferns E 2.

Root knot nematodes (*Meloidogyne* spp.) occur on *Begonia rex*, *B. semperflorens*, *B. tuberhybrida* and *Begonia* spp. Some cultivars are ***symptomless carriers***. Plants are stunted and do not grow properly regardless of cultural treatments. On tuberous begonias, ***galls*** may become as large as hazelnuts. ***Pasteurise*** contaminated soil or treat with an appropriate chemical. ***Soak*** tuberous begonias while dormant in hot water. Cool and plant in ***nematode-free*** soil. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Cotton aphid*** (*Aphis gossypii*) may ***seriously injure*** begonias and be very conspicuous on the glossy begonia ***foliage***. See Bulbs C 6, Roses J 4.

Caterpillars (Lepidoptera) of a ***native moth*** (*Chionophasma lutea*, Noctuidae) feed on rose, forget-me-not (*Mysotis*) and begonia. See Annuals A 8, Bulbs C 8.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause ***leaf silvering***. See Greenhouses N 24.

Greenhouse whitefly (*Trialeurodes vaporariorum*) feeds on ***leaf undersurfaces***. See Greenhouses N 24.

Mealybugs (Pseudococcidae, Hemiptera): ***Longtailed mealybug*** (*Pseudococcus longispinus*) and ***citrus mealybug*** (*Planococcus citri*) may infest begonias. See Bulbs C 8, Greenhouses N 25.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) causes ***leaves*** to take on a glassy appearance. Damage is similar to that caused by cyclamen mite. See Greenhouses N 26.
Cyclamen mite (*Phytonemus pallidus*) and broad mite both cause a stunting of ***young growth*** and curling of the ***leaves*** (distortion of new growth). See Cyclamen C 16.
Twospotted mite (*Tetranychus urticae*) sporadically infests begonia ***leaves***. See Beans (French) M 29, Dahlia C 25.

Mites ***spread*** by crawling and by the movement of infested plants, eg exhibiting plants and taking them home again. Heavily infested plants should be ***destroyed/burned*** to prevent spread. Some times plants are dipped in ***hot water***, seek advice if this is being considered. Commercial growers use ***miticides*** to keep mites in check if necessary.

Scales (Diaspididae, Hemiptera): Overseas ***circular black scale*** (*Chrysomphalus aonidum*) and ***mining scale*** (*Howardia biclavis*) may infest begonias in warm areas. Both these scales occur in Australia. See Citrus F 39.

Weevils (Curculionidae, Coleoptera): Larvae of ***black vine weevil*** (*Otiorhynchus sulcatus*) may completely destroy ***roots*** of tuberous begonia and cyclamen, plants wilt and die. See Grapevine F 63.

SNAILS AND SLUGS

Outdoor plantings are favoured by ***snails and slugs***. See Seedlings N 70.

Non-parasitic

Environment: ***Circular dead areas*** resulting from the evaporation of water droplets, can disfigure leaves of *Begonia rex*. ***Oedema*** (corky scab) is thought to be due to high humidity and overwatering in cloudy weather, light brown corky growths develop on leaf undersurfaces and along stems (Pirone 1978). See Geranium A 35. Seedlings of bedding begonia are ***frost tender***.

Pesticide injury: Some begonias, especially the ***rhizomatous types***, are susceptible to pesticide injury. Test all insecticides first on 1-2 plants prior to large scale use.

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Associations, Journals etc.
GrowSearch (database Qld DPI)
International Socs.
State/Territory Begonia Socs.

See Bulbs, corms, rhizomes and tubers C 9

Remember, always check for recent references

MANAGEMENT

Begonia may be ***propagated*** by leaf cuttings, tubers and by seed. ***Growth regulators*** may be used during propagation. ***Bedding or fibrous-rooted begonias*** tolerate shade more than most other plants. ***Tuberous begonias*** are usually grown in pots in sheltered areas, shade houses or in greenhouses. There are so many different types of begonias today it is impossible to generalise on their culture and harvest. Some types should be staked and tied to prevent breakage, new plants may need to be protected from snail and slug damage. Some begonias are sensitive to ethylene causing buds, flowers and petals to drop, especially when the plant reaches marketing stage (Nowak and Rudnicki 1990).

Cyclamen

Cyclamen persicum
Family Primulaceae (primrose family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Cucumber mosaic virus
- **Bacterial diseases**
  - Bacterial soft rot
- **Fungal diseases**
  - Fusarium wilt
  - Grey mould, *Botrytis*
  - Root, crown, tuber and stalk rots
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Cyclamen mite
  - Mealybugs
  - Thrips
  - Weevils
- **Snails and slugs**

Non-parasitic
- Environment
- Nutrient toxicities, deficiencies

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus causes streaking and malformation of ***flowers***. Overseas also tobacco mosaic virus and potato virus X. See Bulbs C 4, Cucurbits M 50.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*, also *E. chrysanthemi* overseas) is a ***common destructive disease*** of cyclamen during warm summer conditions. Infected plants rapidly wilt and collapse although only slight wilting of a few leaves precedes the collapse. The ***base of the petioles*** develop a soft wet rot and the foliage and petioles are easily removed. ***Corms*** become a soft, wet pulpy mass. ***Favoured*** by plant injury. See Bulbs C 5, Vegetables M 5.

FUNGAL DISEASES

Fusarium wilt (*Fusarium oxysporum* f. sp. *cyclaminis*) can be a ***serious disease*** affecting roots and corms, resulting in wilting and plant death; the ***vascular system*** is discoloured. Symptoms are similar to those caused by grey mould (*Botrytis cinerea*). Grow in ***disease-free soil***. Drenching affected plants with ***fungicide*** may suppress the disease but is unlikely to provide complete control. See Bulbs C 5, Vegetables M 9.

Grey mould, *Botrytis* (*Botrytis cinerea*) is the ***most important disease*** of cyclamen, causing a decay of ***petiole bases***, particularly of the leaves in the plant centre (Fletcher 1984). A grey furry mould develops on ***leaves, stems and flowers***. If not checked it may spread to the corm and destroy the whole plant. Grey mould can quickly kill bulbs such as cyclamen so ***prompt treatment*** is essential. Uniformly green leaf cultivars seem to be ***more susceptible*** than the decorative silver leaf types. ***Reduce watering***, especially overhead application and place plants in a cool, well ventilated situation. ***Increased ventilation*** may reduce the temperature. ***Remove*** all dead tissues promptly at regular intervals. See Bulbs C 5, Greenhouses N 22.

Root, crown, tuber and stalk rots

Damping off (*Pythium* spp., *Rhizoctonia solani*): Potting mixes must drain freely. Care should be taken to ***plant the corm*** so that about half of it projects above the soil surface. This and ***avoiding over-watering*** will reduce the likelihood of damping off and root, crown and stalk rots. ***Clean pots***, seed trays and tools by thorough washing and dipping in bleach. Use prepared seed-sowing mixes and potting composts. See Seedlings N 66.

Others
- Anthracnose, tuber rot (*Colletotrichum acutatum*)
- Grey mould (*Botrytis cinerea*)
- Phytophthora root rot (*Phytophthora* spp.)
- Pythium root rot (*Pythium* spp.)
- Root and corm rot (*Cylindrocarpon destructans*)
- Thielaviopsis black root rot (*Thielaviopsis basicola*)

See Bulbs C 5, Vegetables M 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*)
Root knot (*Meloidogyne* spp.)
Spiral nematode (*Helicotylenchus dihystera*)
See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*) and other species may infest ***leaf undersurfaces*** and ***flower buds*** during summer. Symptoms include crinkling and distortion of foliage, usually accompanied by shiny specks of honeydew. See Bulbs C 6, Roses J 4.

Caterpillars (Lepidoptera) are not common but may occur in conservatories. Species include ***leafrolling caterpillars*** (Tortricidae) and ***looper caterpillars*** (*Chrysodeixis* spp.). Both chew holes in ***leaves***, leafrollers bind leaves together. Caterpillars may be picked off, spraying should not be necessary. See Annuals A 8, Bulbs C 8.

Cyclamen mite

Scientific name: Tarsonemidae, Acarina:
Cyclamen mite (*Phytonemus pallidus*)

Host range: Cyclamen mite is a ***serious pest*** of cyclamen, African violet, begonia and a wide range of plants, eg flowers, shrubs and indoor plants.

Description and damage: ***Mites*** are microscopic, ***0.25 mm*** long, and cannot be seen with the naked eye (Fig. 72). Mites look like dust on ***leaf undersurfaces*** and are semi-transparent with a brownish tinge. Mites suck sap from ***new buds***, ***leaves and flowers*** which become curled and may die. Flower buds may wither and die. Young leaves and flowers may discolour and stiffen. ***Other mites*** also attack cyclamen foliage.

Broad mite (*Polyphagotarsonemus latus*) is of similar length but is broader and more mobile than cyclamen mite, ***eggs are distinctive***. It causes similar damage as cyclamen mite, ***leaves*** may look glassy. See Greenhouses N 26.

Twospotted mite (*Tetranychus urticae*) is ***twice as long*** as broad and cyclamen mites. It feeds mostly on leaf undersurfaces and on flowers. ***Foliage*** is stippled yellow or brownish, in advanced infestations there is profuse webbing. See Beans (French) M 29.

Overwintering: On perennial host plants and plant parts.

Spread: By mites crawling and by the introduction of infested plants, displaying plants at shows and taking them home again afterwards.

Conditions favouring: Warm, humid conditions.

Control is difficult as damage usually has already occurred before control measures are started, mites are protected from sprays inside buds.

Sanitation: Heavily infested plants should be ***destroyed/burned*** so that the pest cannot spread.

Plant quarantine: Isolate all new purchases. Examine new foliage and flowers for wrinkling. Keep ***suspect plants separate*** until a diagnosis is made.

Pesticide: Mites shelter inside buds so are difficult to reach with sprays. If infestation is severe, ***insecticides*** can be applied to buds and undersides of new foliage. Add a wetting agent.

Mealybugs

Mealybugs (Pseudococcidae, Hemiptera) may feed on ***leaves and buds***. See Bulbs C 8, Greenhouses N 25.

Thrips

Thrips (Thripidae): ***Greenhouse thrips*** (*Heliothrips haemorrhoidalis*) are small, narrow, elongated insects of various colours and are visible to the naked eye but often overlooked. They are often hidden in ***buds and flowers.*** ***Leaves*** may become silvered or reddened, and spotted with black excreta, ***blossoms*** may be flecked with white. See Greenhouses N 24.

Weevils

Weevils (Curculionidae, Coleoptera): ***Black vine weevil*** (*Otiorhynchus sulcatus*) may infest many species including cyclamen in pots. ***Weevils*** attack the ***leaves*** of plants but the most serious damage is caused by the feeding of the white legless ***larvae*** on the ***fine root hairs*** in summer and autumn, they may gouge ***corm surfaces*** (Fig. 73). Check plants that ***fail to grow*** in the spring for the presence of larvae by digging around the base of the plant. Only flightless female adults are known, they emerge in November and lay eggs on the soil surface. They are nocturnal, coming out at night to feed on leaf margins where they leave small notches. ***Cultivate*** ground thoroughly in early October to destroy pupal cells. ***Nematodes*** (Otinem®) provide control, or the soil may be watered regularly at fortnightly intervals with insecticides. See Grapevine F 63.

SNAILS AND SLUGS

Protect cyclamen growing outdoors from ***snails and slugs***. See Bulbs C 8, Seedlings M 70.

Non-parasitic

Environment: Plants may be damaged by ***hot sun*** and in hot dry conditions the foliage should be misted with water. ***Water*** when the soil is becoming dry at the top of the pot. Keep plants moist at all times especially during summer as they cannot tolerate hot dry conditions. ***Overwatering and poor drainage*** may cause tubers to rot. Pots should not stand in water.

Nutrient deficiencies, toxicities: ***Overfertilisation*** may cause weak spindly growth and flower drop. ***Corm breakdown*** may develop due to ***calcium deficiency*** induced by excessively ***high levels of potassium*** (Nichols 1992).

Others: ***Flowering:*** High temperatures, too little water, or excessive soil fertiliser levels may cause ***blasting*** of flower buds. ***Delayed flowering*** may be caused by growing the wrong cultivars, high or low temperatures, faulty nutrition, oversized pots or insufficient light. ***Small flowers*** may be caused by high temperatures, excessive soil fertiliser levels or growing the wrong cultivar. ***Stretched plants (too tall)*** may be caused by insufficient space per plant, excessive soil moisture, insufficient light or high temperatures. ***Stunted plants*** may be caused by excess soluble salt levels in soil, or stunt disease (Larson 1992). ***Weak growth*** may be caused by high temperatures, disease, genetic variability, faulty nutrition, crowding or insufficient light. ***Fungus gnats*** (Mycetophilidae, Sciaridae): In heavy infestations the ***maggots*** of small flies in soil attack roots and lower plant vigour (usually when media is overwet and poorly drained). See Greenhouses N 28.

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State/Territory Departments of Agriculture/Primary Industry eg
Cyclamen (SA Adelaide Bot. Garden leaflet)
Cyclamen for the Home Garden (Vic Agnote)
Cyclamen in the Garden (NSW Agfact)
Raising Cyclamens from Seed (Vic Agnote)

Associations, Journals etc.
GrowSearch (database Qld DPI)
See Bulbs, corms, rhizomes and tubers C 9, Annuals and herbaceous perennials A 10

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Cyclamen are commonly grown for greenhouses and as house plants. They can be grown in a semi-shaded position in the garden but are more often grown in containers. In warmer areas they may be grown outdoors. Most modern hybrids are derived form *C. persicum* and have a wide range of flower colours. Some species, eg *C. Africarium* and *C. creticum,* are perfumed.

Resistant varieties: *C. neapolitanum* appears to be hardier than *C. persicum*.

Disease-free planting material: Tubers can be kept for 2-3 years but produce fewer blooms of poorer quality after their 2nd flowering season. Treat as an annual with new seedlings coming on while the older plants are flowering.

Establishment and Maintenance

Propagation: By seed and by tubers.

Cultural methods: General interruption in growth is the main cause of infections, irregular flowering and other disappointments. For the successful growing of cyclamen ***regular growth must be maintained from sowing until flowering.*** Potting mixes must be well drained and disease and pest-free. Cyclamen should be sown in a light soil mixture with a pH of 5.6 (approximately). Plant corms so that half projects above the soil surface. Cyclamen grow well indoors but need a well lit, well ventilated but draught-free spot, preferably with 1-2 hours of sunlight each morning. Water regularly, avoid overhead irrigation and do not overwater or stand pots in water. Fertilise appropriately.

Sanitation: Removal of all damaged and dying plant parts reduces the risk of grey mould (*Botrytis cinerea*). Cyclamen will flower for 2-3 months if spent flowers are removed by giving the stalk a twist and a sharp pull at the same time, removing it at the union with the tuber. ***Do not cut off.***

Plant quarantine: Do not introduce plants infested with diseases and pests to healthy collections.

Pesticides: Growth regulators are used to produce more flowers and longer flowering.

Postharvest

Cut flowers: ***Harvest*** fully open flowers with 4-5 petals of the crown in an upward position. Harvest by pulling them from the corm along with the base of the peduncle or stem. Flowers are susceptible to grey mould. Buds, flowers and petals abscise due to ethylene toxicity. Pollinated flowers drop quickly and growers may spray with anti-ethylene agents to prevent this. ***Bud opening:*** Tightly closed flower buds showing colour and in a downward position, may be placed in an opening solution. Flowers treated in this way will open and develop to similar size and colour as flowers remaining on the parent plant. Flowers may be ***stored*** and ***transported wet*** at $1^{o}C$ in water or ***dry*** after appropriate conditioning. ***After storage*** the base of the scape should be recut. ***Many commercial preservatives*** are harmful to cyclamen flowers. ***Vase life*** may be improved and ***scape bending*** prevented if flowers are conditioned prior to sale. Hardening by holding in water at $4^{o}C$ at high relative humidity for 1 day, also limits scape bending (Nowak and Rudnicki 1990).

Potted cyclamen: ***Sell*** when most flowers are still in the bud stage. ***Quality*** deteriorates after only a few days without light. Plants require bright light, at low light levels foliage is weak and yellow, buds dry out. Hold at < 5-$12^{o}C$, at higher temperatures flower buds develop faster, senescence is accelerated and plants lose their decorative value. During flowering plants need ample watering but overwatering causes crown rots. Water from the base. Pollinated flowers drop, this may be prevented by growers spraying with anti-ethylene agents. Sorting of potted cyclamen is mainly based on container size (Nowak and Rudnicki 1990).

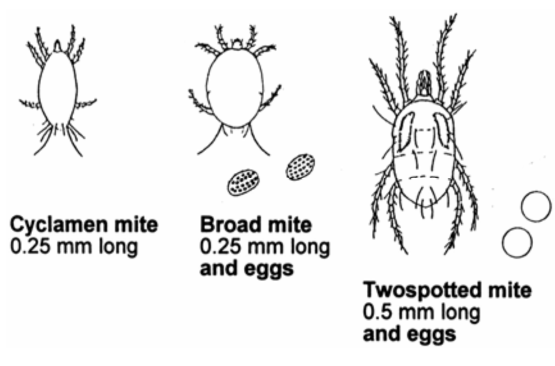

Fig. 72. Mites which attack cyclamen foliage, eg cyclamen mite (*Phytonemus pallidus*), broad mite (*Polyphagotarsonemus latus*), twospotted mite (*Tetranychus urticae*). Mites are microscopic, the female is displayed.

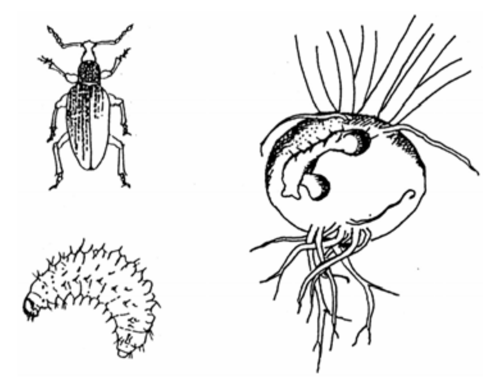

Fig. 73. Black vine weevil (*Otiorhynchus sulcatus*). ***Left :*** Adult (10-12 mm long) and larva(10 mm long). ***Right*** *:* Larvae gouge corm surfaces.

Daffodil, jonquil

Narcissus spp.
Daffodil (*Narcissus pseudonarcissus*)
Jonquil (*N. jonquilla*)
Family Amaryllidaceae

PESTS AND DISEASES
Parasitic

*The most important diseases affecting daffodils are **fusarium wilt** and **stem and bulb nematode**.*

VIRUS AND VIRUS-LIKE DISEASES

Virus symptoms include indistinct mottling, yellow, brown or purplish streaks, twisting of ***leaves***. Plants may be infected with more than one virus and symptoms are more pronounced in ***cool weather***. Some varieties remain vigorous and productive in spite of virus infection, others gradually deteriorate. Virus infections are ***latent*** in some species of *Narcissus*. All virus diseases affecting daffodil are ***spread*** by vegetative propagation from infected plants, some also by various insects and/or by sap.

Narcissus latent virus is a minor disease of iris, daffodil, nerine. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), by mechanical inoculation, not by contact between plants, not by seed, not by pollen.

Narcissus mosaic virus causes indistinct mottling of ***foliage*** of daffodil, hyacinth, iris, nerine, overseas also *Trifolium*, *Nicotiana,* other genera. ***Spread*** also by mechanical inoculation, not by contact between plants, not by seed..

Narcissus yellow stripe: ***Leaves*** may be malformed. ***Spread*** also by aphids, eg potato aphid (*Macrosiphum euphorbiae*), by sap from infected plants during handling and on tools, by introduction of infected bulbs.

Others: Cucumber mosaic virus, potato Y virus and tobacco rattle virus may affect daffodils overseas.

See Bulbs C 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*). See Bulbs C 5, Vegetables M 5.

FUNGAL DISEASES

Fusarium wilt, fusarium basal rot, (*Fusarium oxysporum* f.sp. *narcissi = Fusarium bulbigenum*) affects daffodil. ***Bulbs:*** A rot develops at the ***basal plate*** (see Bulbs C 2, Fig. 61) and eventually spreads up into the ***bulb*** . The fungus gains entry through dead root bases to the basal plate and bulb scales, or through wounds usually during lifting or at any time during dormancy. Basal rot can spread through bulbs during storage. ***Compare symptoms in the bulb*** with those caused by stem and bulb nematode and virus diseases (see Bulbs C 2, Fig. 61, Fig. 64). ***Foliage:*** Affected bulbs, if planted, rot in the soil, without germinating, or produce weak, yellow plants which ultimately die. ***Compare symptoms on foliage*** with those caused by stem and bulb nematode and virus diseases. ***Overwinters*** in infected bulbs in the ground and in storage and in contaminated soil. ***Spread: Soil may become contaminated*** by planting infected bulbs, the movement of contaminated soil, water and the introduction of contaminated soil on machinery, pots, etc. ***Plants become infected*** by planting in contaminated soil or close to infected plants. ***Favoured*** by warm, wet soil conditions during lifting, use of hormone preparations and heavy dressings of nitrogenous fertilisers, continued cropping with the same crop, eg daffodils. ***Fusarium wilt is difficult to control***. The disease must be accurately diagnosed. ***Cultural methods:*** Do not plant daffodils for 5 years in soil in which a diseased crop was grown, unless the soil has been pre-plant treated with a fungicide. Avoid using hormone preparations or heavy dressings of nitrogenous fertilisers. ***Resistant varieties:*** Some varieties are ***more resistant*** than others. Research overseas is directed to developing basal rot resistant daffodils (Anon. 1996). ***Sanitation/ Pesticides:*** If disease is suspected in commercial crops and until all traces of *Fusarium* wilt are gone from a crop:

- ***Lift bulbs*** each year when leaves yellow naturally.
- ***Inspect bulbs*** after lifting and burn diseased specimens. Slight infections are difficult to detect, examine the basal plate of each bulb and if the rim where the new roots originate is white and firm, the bulb is probably healthy. If there is any trace of browning, remove outer scales and see if rot has extended into the fleshy part of the bulb, often apparently healthy bulbs have a slight infection.
- ***Remove superficial scales***, dip and treat remaining bulbs with a suitable ***fungicide***.
- After treatment, ***dry*** the bulbs as rapidly as possible by laying them in shallow layers with air ventilation between each layer. Store them on racks or trays in a cool dry place.
- Again before planting, inspect all bulbs for signs of rot, burn any diseased specimens.
- Plant in a new position each year.
- Carry out recommended bulb and soil pre-plant ***pesticide treatments***. See Bulbs C 5, Vegetables M 9.

Grey mould, *Botrytis* neck rot (*Botrytis narcissicola*): Where this disease occurs, ***fungicides*** may be applied to daffodils several times around ***flowering*** (Tesselaar's Grower Information Sheet No.1: Daffodils). Grey mould is rarely serious with annual cropping in cool climates, where daffodils are grown as a ***biennial crop***; it may be a problem in the ***2nd season***. ***Remove weeds*** to ensure adequate air movement. ***Lift bulbs*** after maturity, ***do not replant*** in the same area. See Bulbs C 5, Greenhouses N 22.

Leaf scorch (*Stagonospora curtisii*) affects ***bulbous plants***, eg daffodil, jonquil, belladonna lily, crinums, African lily, hippeastrums and Kaffir lilies. ***Leaf tips*** of ***daffodils and jonquils*** become scorched and reddish-brown soon after emerging. As leaves grow longer, oval brown spots develop lower down, leaves yellow at the tips and around the spots and this tissue dies. ***Any injury to the leaves*** of the belladonna lily, clivea, crinum and hippeastrum (all Amaryllidaceae) may cause reddening. ***Belladonna lily*** leaves and flower stalks are usually bent at the point of infection and red spots appear along the leaf in lines. ***Bulb scales*** may develop dark, brownish-red spots. ***Overwinters*** on crop debris and at the tops of bud scales, the fungus infects leaves as they emerge from the bulb. ***Spread*** by vegetative propagation, spores are spread by wind and water splash. ***Favoured*** by warm, wet conditions. In small plantings, ***remove infected tips*** by hand and burn them. ***Discard*** badly infected bulbs. ***Fungicides*** may be applied to new growth (McMaugh 1994). See Annuals A 5, Bulbs C 5.

Root and bulb rots

Armillaria root rot, bulb rot (*Armillaria* sp.)
Base rot (*Ceratocystis narcissi*)
Blue mould (*Penicillium* sp.)
Scale speckle fungus (*Sclerotinia narcissi*)
Sclerotium stem rot (*Sclerotium rolfsii*)
Smoulder (*Sclerotinia narcissicola*)
See Bulbs C 5, Vegetables M 7.

NEMATODE DISEASES

Stem and bulb nematode

Scientific name: Nematoda:
Stem and bulb nematode (*Ditylenchus dipsaci*)

Host range: Commonly attacks ***bulbous plants***, ***ornamentals***, eg daffodil, hyacinth, tulip, phlox, ***fruit***, eg strawberry, ***vegetables***, eg carrot, onion, parsnip, ***field crops***, eg rye, oats, red clover. There are several strains, one strain attacks only onions and related plants, other strains attack other plants.

Symptoms: ***Foliage*** of daffodils is twisted, often pale with raised lumps or thickenings which can be felt if the leaf is drawn between the fingers (Fig. 74). Twisting usually begins on one side causing the leaf to curl round in an arc. ***Compare these symptoms on the foliage*** with those caused by virus diseases and basal rot. ***If bulbs are cut transversely***, rotted scales appear as ***concentric rings***. The basal plate is ***not rotted*** in the initial stages of nematode infestation. ***Compare these symptoms in the bulb*** with those caused by basal rot (see Bulbs C 2, Fig. 64, Fig. 61). Infected bulbs can be decayed by secondary rotting organisms. ***Field symptoms:*** Disease usually develops in patches with a badly infected plant in the centre. If crops are not lifted and treated, disease gradually spreads.

Overwintering: In infected bulbs in the ground or in storage, contaminated seed and plant debris (bulbs, leaves, stems), in the soil or as infections on perennial plants and seedlings of other hosts.

Spread: Nematodes cannot travel far in soil, and are usually spread from place to place by water, contaminated soil on tools, machinery, containers, footwear, and the introduction of contaminated seed and infected bulbs.

Conditions favouring: Mild temperatures and wet but well drained soils.

Control:
Cultural methods: Populations of nematodes in the soil can be reduced by long (2-3 years at least) ***rotations*** with a resistant crop such as spinach, potatoes and lettuce.
Sanitation: Inspect growing crops periodically for nematode infestation. ***Remove*** and destroy/burn infected and volunteer plants, preferably with a spadeful of the surrounding soil. ***Destroy/burn*** all infected bulbs, soil, plant residue in an area distant from where bulb crops are grown. Treated nematode-free bulbs can be infested if they come in contact with ***contaminated bulb debris*** on benches, in containers or contaminated soil. All tools should be ***sterilised***.
Resistant varieties: Where nematodes are prevalent choose varieties with some resistance.
Disease-free planting material: Plant ***nematode-free*** bulbs, seeds, cuttings in ***nematode-free*** soil, otherwise pre-plant treat propagation material and soil.
Pesticides: Commercial daffodils growers should ***hot water treat*** their bulbs after lifting. Hot water or chemical treatment is effective for ***bulb flies and bulb mites*** as well. During the dormant period, all bulbs should be lifted and hot water treated at 43^{o}C for 3.5 hours with a recommended disinfectant (Tesselaar's Grower Information Sheet No.1:Daffodils). ***This should be carried out not later than 3-4 weeks after digging, otherwise the bulbs loose their flowering capability.*** Unless contaminated soil can be pasteurised, fumigated or treated with a nematicide to kill the nematodes, nematode-free bulbs when planted will be reinfested.

Others: ***Root knot*** (*Meloidogyne* sp.) has been recorded on *N. pseudonarcissus*, ***root lesion nematode*** (*Pratylenchus penetrans*) on. *Pseudonarcissus, Narcissus* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Bulb and potato aphid (*Rhopalosiphoninus latysiphon*)
Tulip bulb aphid (*Dysaphis tulipae*)
Violet aphid (*Neotoxoptera violae*)

Aphids feed on ***new shoots*** and on ***bulbs*** in the ground and in store. Some species also ***transmit virus diseases***. See Bulbs C 6, Roses J 4.

Bulb flies (Syrphidae) including ***lesser bulb fly*** (*Eumerus tuberculatus*) and ***narcissus bulb fly*** (*Lampetia equestris*) may ***seriously injure*** daffodil and nerine ***bulbs*** which become soft, outer scales develop brown scars. Maggots of the ***lesser bulb fly*** are markedly wrinkled and usually ***many maggots*** are found in a single bulb. Maggots of the ***narcissus bulb fly*** are large, about 10-15 mm long, whitish or yellow-white in colour and usually only ***one maggot*** is found per bulb. See Bulbs C 6.

Bulb mite (*Rhizoglyphus echinopus*) may infest daffodil and nerine bulbs in the ***field*** and in ***storage***. ***Mites*** are only visible with a hand lens, they ***glisten***, are ***about 1 mm*** long or less, globular, whitish with brownish or pinkish legs and move very slowly. ***Infested bulbs*** usually fail to produce good growth, plants that do grow from infested bulbs turn yellow and look sickly, leaves are stunted and distorted, plants generally fail to produce flowers, or produce only misshapen ones. See Bulbs C 7.

Others: ***Mealybugs*** (*Pseudococcus* spp.), ***elephant beetle*** (*Xylotrupes gideon*).

SNAILS AND SLUGS

Snails and slugs may damage ***flowers*** (Fig. 75). See Seedlings N 70.

Non-parasitic

Failure to flower is a ***common problem*** with daffodils. All true bulbs produce the embryo flowers inside the bulb leaf tissue during the previous season. Their performance when planted out depends on their treatment during the previous season. The most common reasons for failure to flower in daffodils include the ***size and condition of the bulb.*** The development of the flower laid down the previous season will be determined by the nutrients already stored within the bulb, so that ***bulb diameter*** has some bearing (length of bulb usually has little bearing), eg when selecting bulbs of any of the larger flowering trumpet daffodils, the diameter of the bulb at its widest point needs to be close to 25 mm. Different varieties produce different sized bulbs as a matter of course. ***Small bulbs*** may be produced because of:

- ***Overcrowding of clumps:*** Daffodil bulbs tolerate both hot and cold conditions and may be left undisturbed in the soil for several years depending on how closely they were planted initially, after a time, they may become too congested and are lifted only when flower size and number decreases. The continual addition of ***mulch*** to undisturbed bulbs may result in them being buried to ***excessive depths*** (Fig. 75).
- ***Excessive dryness*** during the previous spring flowering period and afterwards, while the foliage is still normally green.
- ***Excessive shade*** the previous year may mean essential food storage processes were curtailed.
- ***Temperature*** affects performance of daffodils, eg bulb storage temperatures and periods influence the weeks to flowering (Salinger 1985).
- ***Varietal variations:*** Different daffodil strains may vary in performance, eg many old original strains of King Alfred have a relatively poor flowering performance (as low as ***25%*** of bulbs flowering), most modern varieties perform much better.
- ***Inadequate light*** during the flowering season.
- ***Too late hot water treatment*** after digging.

Toxic properties: Daffodil bulbs and leaves contain Amaryllidaceae alkaloids and are ***poisonous*** to eat. ***Dermatitis*** may occur due to mechanical irritation by oxalate needles on contact with daffodil bulbs (Frohne and Pfander 1983).

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State/Territory Departments of Agriculture/Primary Industry eg

Bulb Scale Mite (Vic Agnote)
Daffodils and Jonquils (SA Adelaide Bot. Garden leaflet)
Diseases of Daffodils (NSW Plant Disease Bull.)
Fungal Diseases of Narcissus in Victoria (Vic Agnote)
Pests of Narcissus (Vic Agnote)
Stem Nematode of Narcissus (Vic Agnote)

Tesselaar's Padua Bulb Nurseries, Sylvan Vic.

Grower Information Sheet. No. 1. Daffodils
Grower Information Sheet No. 7. Suggestions for Potting Spring Flowering Bulbs
Grower Information Sheet No. 8. Forcing Bulbs

Associations, Journals etc.

GrowSearch (database Qld DPI)
Journal of the Tasmanian Daffodil Council
The Daffodil Association NSW and ACT

See Bulbs, corms, rhizomes and tubers C 9

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Different types and strains of daffodils especially some older strains, may vary in their flowering performance. Most modern varieties flower well.

Resistant varieties: Varieties may vary in their ***resistance*** to stem and bulb nematodes and other problems.

Disease-free planting material: All the destructive diseases and pests of daffodil can be carried over in the bulb. Purchase ***virus-tested bulbs*** and examine them carefully for disease symptoms, otherwise purchase from a reputable source or select the healthiest plants available.

Establishment and Maintenance

Propagation: By 'splitting' of the bulbs, ie daughter bulb production. Also by twin scaling, chipping and by tissue culture.

Cultural methods (Tesselaar's Grower Information Sheet No.1 : DAFFODILS*): ***1. On arrival:*** Unpack the bulbs immediately on arrival. As bulbs are still 'living' they require good ventilation during their storage period. A well ventilated shaded position is suitable for this. Inspect all bulbs before planting. Discard any suspect bulbs and plant in clean soil and avoid re-infestation. Daffodils may be used for ***pot culture*** or ***early flower forcing***. See Bulbs C 10. ***2. Field planting:*** Plant new bulbs well away from established healthy stock. Select suitable soil previously cultivated with tines or rotary hoe. Plant bulbs 10-150 mm deep in rows 700-750 mm apart. If planting bulbs that are ***to be left in the ground for a number of years*** then plant bulbs with the base up to 200 mm from the soil surface and at a slightly lower density. ***Closer planting*** to the surface gives a greater multiplication rate and these bulbs should be dug away every 2-4 years, otherwise overcrowding occurs and less flowers will appear each year. ***Deeper planting*** seems to limit multiplication and the bulb's main concern is to produce flowers each year. Bulbs can be planted from the end of February to mid-April. To ensure a good display plant in clumps rather than in rows. Rogue during the growing season. Bulbs may be treated for fungal and insect problems.

Pesticides: ***3. Spraying:*** Daffodils are hardy and normally do not require spraying in home gardens. Where there is the possibility of fungal problems in commercial crops, eg grey mould (*Botrytis narcissicola*), then several sprays, eg 3 times, during flowering may be required. ***4. Snails:*** As soon as the stalks appear put down the recommended amount of snail bait between the rows. ***5. Weed control:*** See Bulbs C 8.

Postharvest

Cut flowers: ***6. Flowers***: Normally flowers begin from the end of July for non-cooled flowers. These are best picked just after they begin to open. Flowers picked after the seed pod has enlarged have a very short vase life (the seed pod is situated directly behind the flower and does not begin to enlarge until the flower has been in full bloom for approximately 5-7 days). ***Harvest daffodils*** for direct sale at the ***gooseneck stage***, the sheath should be split. Avoid fully open flowers. ***Jonquils can be harvested*** at the 'one bell' stage when 1 flower is open on the spike. If open, flowers should have a 'crisp' feel and be slightly green in colour. ***When the stems are cut the peduncles of daffodils exude a sap that is harmful to other cut flowers***, eg especially roses, carnations, freesias, tulips. So avoid combining daffodils and jonquils with other flowers in a vase. If they are to be combined with other flowers, after recutting put them alone in a container for at least 24 hours before arranging with other flowers. Stem recutting renews ***mucous flow*** (Jones and Moody 1993). ***Storage:*** Flowers may be stored either dry or wet in water. For dry storage they should be packed in polyethylene foil and stored in open boxes in a cold room, periods for dry or wet storage depend on the ***temperature*** (Nowak and Rudnicki 1990). Avoid storing flat as the stems will ***bend upwards***. ***Vase life:*** Approximately 4-6 days. ***Do not use sugar*** in solutions as it deforms flowers. ***Floral preservatives*** do not significantly affect the longevity of flowers. Flowers are sensitive to ethylene, sunlight and draughts (Jones and Moody 1993).

Potted plants: See Bulbs C 10.

Lifting and storing bulbs: ***7. After flowering:*** Leave plants to die back naturally. Lift every year but at least every 3 years when foliage has died or yellowed. Loose bulbs can be separated however small bulbs tightly attached to the mother bulb should not be pulled apart. Dry and remove shrivelled leaves. Discard any diseased bulbs. Dip or dust in fungicide/insecticide mix and store in an airy place till planting time. If digging the bulbs, air dry them in any well ventilated shady position, keep them dry until replanting. If the bulbs are being left in the ground, grass should be cut occasionally just above ground level once the leaves have died back or turned yellow. ***8. Diseases:*** During the dormant period, commercial growers should lift all bulbs and treat them with hot water. This should be done not later than 3-4 weeks after digging, otherwise bulbs loose their flowering capability.

* *This information is given as a guide only. See Disclaimer, Preface iii.*

Remember, always check for recent references

Healthy basal plate (in *Fusarium* wilt, the basal plate is decayed early in the disease).

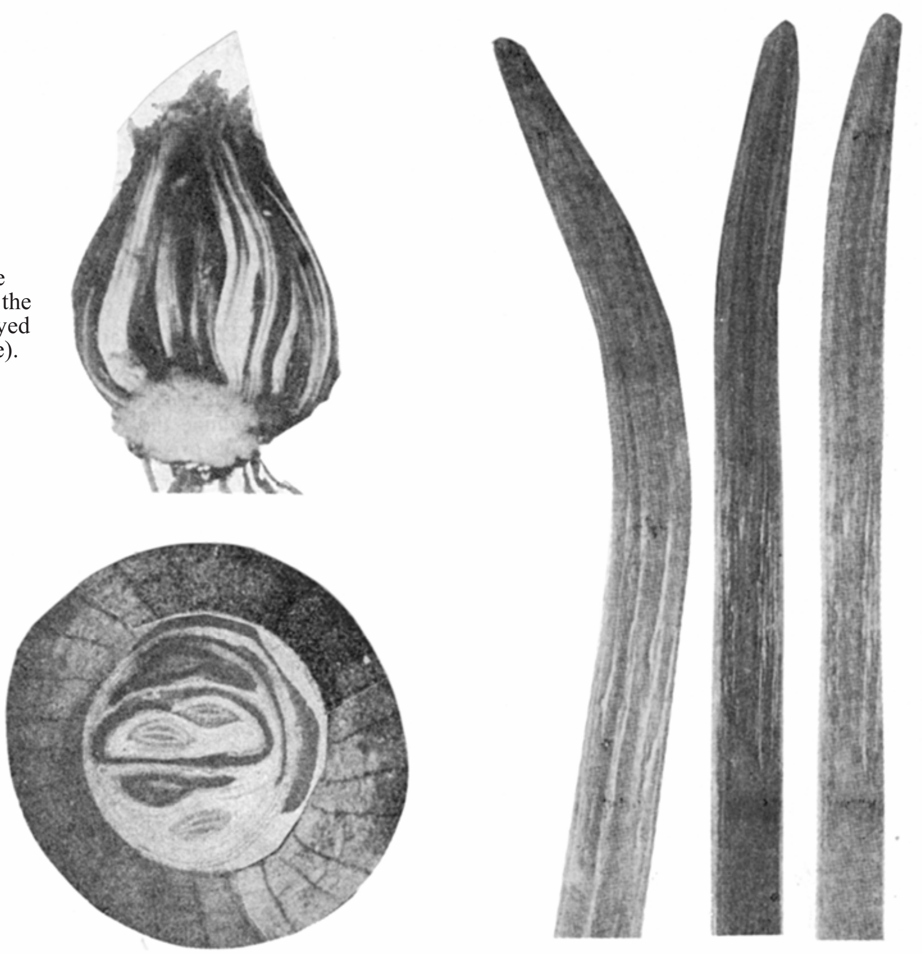

Fig. 74. Stem and bulb nematode (*Ditylenchus dipsaci*) damage to daffodils.
Upper left : Bulbs cut longitudinally to show how browning of scales.
Lower left : Cross section at neck of bulb to show rings of brown scales.
Right : Leaves showing raised blister-like streaks. Dept. of Agric., NSW.

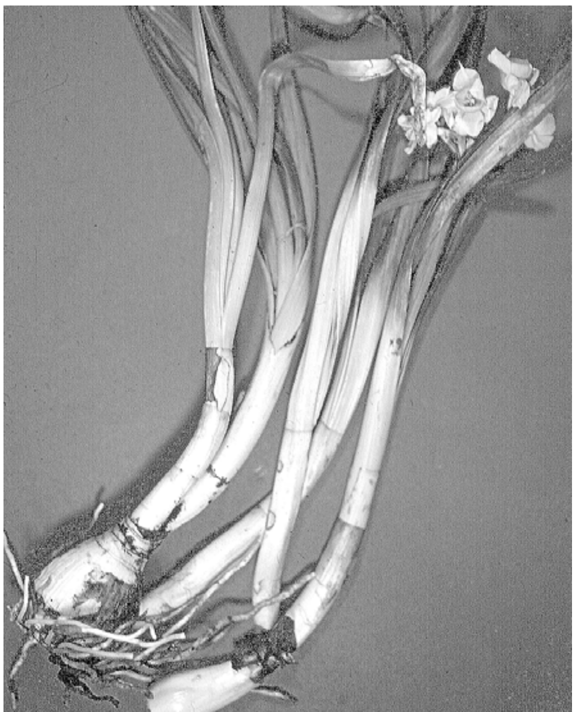

Fig. 75. ***Left :*** Daffodil flowers damaged by snails.
Right : Daffodils at the bottom of a slope. Bulbs have been gradually buried deeper and deeper as mulch has moved downhill.

Dahlia

Dahlia pinnata
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial soft rot
  - Bacterial wilt
  - Crown gall
- **Fungal diseases**
  - Damping off
  - Fungal leaf spot, leaf smut
  - Grey mould, *Botrytis*
  - Powdery mildew
  - Root and stem rots, wilts
- **Nematode diseases**
  - Root knot nematode
  - Root lesion nematode
- **Insects and allied pests**
  - Aphids
  - Beetles
  - Caterpillars
  - European earwig
  - Leafhoppers
  - Mealybugs
  - Mites
  - Thrips
- **Snails and slugs**

Non-parasitic
- Environment
- Nutrient deficiencies, excesses
- Pesticide injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus symptoms include mottling, yellow, brown or purplish streaks, twisting. Plants may be infected with more than one virus and symptoms are more pronounced in ***cool weather***. All virus diseases affecting dahlia are ***spread*** by vegetative propagation from infected plants, some also by various insects and by pollen.

Dahlia mosaic virus affects dahlia (*Dahlia pinnata*). Susceptible cultivars may be ***stunted*** and there may be many small shoots (plants look bushy). ***Flowers*** may be deformed, ***leaves*** may have yellow veinbanding, a general mosaic and be small and distorted, ***tubers*** may be small and their outer surfaces cracked. Symptoms are more obvious in spring and autumn when night temperatures are cool, during summer they are ***masked*** and growth and flower production may be almost normal. Some cultivars produce only mild symptoms and are an unsuspected source of infection. ***Spread*** also by aphids, eg green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), by mechanical inoculation, not by seed.

Tobacco streak virus may cause appreciable damage to dahlia. Symptoms are rather similar to those of spotted wilt, ***young leaves*** are mottled while ***older leaves*** have wavy light or dark green oak-leaf or concentric line patterns. ***Spread*** also by seed, by pollen, by thrips carrying pollen, not by a vector.

Tomato spotted wilt virus: Symptoms are common and clearest on ***first formed foliage***, especially in early-planted dahlias. New leaves formed during summer may only show slight mottling or no symptoms at all. Later, concentric yellow or brown rings or wavy lines appear (Fig. 76). Leaves of very susceptible varieties may brown and die. Early infection causes stunting. ***Young stems*** may have brown to purplish or black streaks. Many varieties grow and flower satisfactorily while others do not. See Bulbs C 2 (Fig. 59), Tomato M 96.

Others: Potato X virus, tomato bug bud mycoplasma.

See Bulbs C 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*), other bacteria (and some fungi) may cause ***storage rots*** of dahlia tubers but are not a serious problem. ***Tubers and stems*** develop a soft, brown rot. See Bulbs C 5, Vegetables M 5.

Bacterial wilt (*Pseudomonas solanacearum*) is not common. Plants wilt rapidly and do not recover despite watering. ***Roots, tubers and stem bases rot***, but woody parts may remain to give a shredded appearance to the tissue. Stem bases are initially watersoaked but may blacken as the rot progresses. See Tomato M 98, Vegetables M 6.

Crown gall (*Agrobacterium* sp.) may uncommonly cause ***large warty galls*** to develop on ***stem bases, tubers or roots***. Infected plants lack vigour, are stunted and produce spindly shoots and few flowers. See Stone fruits F 125.

FUNGAL DISEASES

Damping off (*Pythium* spp., *Rhizoctonia solani*) may be ***serious*** causing small plants to wilt and die, older plants are not affected unless injured. *Pythium* causes death of ***young roots***; *R. solani* causes a ***girdling of the stem*** near ground level. See Seedlings N 66.

Fungal leaf spot, leaf smut (*Entyloma dahliae*) is uncommon but may occasionally cause ***serious damage to leaves***. Small clear circular brown spots 2-10 mm in diameter surrounded by a narrow lighter margin develop mainly on older leaves. Spots may fall out to give a shot-hole effect. If many spots appear, the leaf withers and dies prematurely. See Annuals A 5, Bulbs C 5.

Grey mould (*Botrytis cinerea*) is a minor disease. Under favourable conditions, numerous small spots 1 mm across appear on petals of ***new flowers***, flower tissue may be watersoaked or dry. The disease occurs mainly on ***old flowers*** as a grey furry mould during humid conditions, but may also affect ***buds, leaves, stems and tubers in store***. See Bulbs C 5, Greenhouses N 22.

Powdery mildew (*Oidium* sp.) may become ***serious*** as the crop matures during hot humid weather. A mealy white growth develops on ***leaves and young stems***. White, powdery, round patches appear first on undersides of young leaves and later on both surfaces of ***older leaves*** and ***stems*** (Fig. 77), leaves may die. See Annuals A 6.

Root and stem rots, wilts

Rhizoctonia stem rot (*Rhizoctonia solani*) causes individual plants to wilt or collapse due to rotting of the ***stem*** at or above ground level. Fungal growth may cover affected tissue.
Sclerotinia stem rot (*Sclerotinia sclerotiorum*) rots the ***stem base*** causing wilting and death. A prolific white cottonwool-like mycelium develop on affected areas. Later characteristic ***large black sclerotia*** are formed within this white mycelium.
Sclerotium stem rot (*Sclerotium rolfsii*) causes a dry rot of the ***stem***, usually at ground level, producing symptoms of wilt and ***tiny brownish sclerotia.***
Verticillium wilt (*Verticillium dahliae*) may cause wilting and sudden death of the ***whole plant*** but is not common. See Vegetables M 9.
Others: Fusarium **sp.** may rot ***tubers*** in store, *Phytophthora cryptogea* occurs on *Dahlia* sp. overseas.

See Bulbs C 5, Vegetables M 7.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* spp.) may ***commonly*** damage *Dahlia rosea* and *Dahlia* sp. Plants are stunted and yellow, small pea-like ***swellings*** develop on ***roots and tubers***. Severely affected young plants fail to produce tubers. Use green-shoot cuttings, destroy old roots and cuttings. See Vegetables M 10.

Root lesion nematode (*Pratylenchus coffeae*) occasionally causes unthriftiness and stunting. ***Roots and tubers*** develop surface cracking and internal browning. Nematodes persist in soil or in tubers. ***Favoured*** by well drained warm soils. Use green-shoot cuttings, destroy old roots, cuttings. See Vegetables M 11.

Others: *Criconema, Gracilacus, Helicotylenchus, Macroposthonia, Paratrichodorus, Paratylenchus, Xiphinema* also occur on *Dahlia* sp.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Aphids cause distortion of ***new shoots, leaves and flower buds*** and transmit ***virus diseases*** of dahlia. See Bulbs C 6, Roses J 4.

Beetles (Coleoptera)

Driedfruit beetles (Nitidulidae) and ***nectar scarabs*** (*Phyllotocus* spp., other species, Scarabaeidae) may enter ***newly opened flowers*** and tear them. ***White and yellow flowers*** are most frequently infested. Remove and destroy spent flowers. Application of an insecticide may be necessary. See Fruit F 8, Roses J 8.
Redshouldered leaf beetle (*Monolepta australis*) chews ***leaf edges*** ragged. See Trees K 15.
Weevils (Curculionidae): ***Fuller's rose weevil*** (*Asynonchus cervinus)* and other species chew ***leaf edges*** ragged too. See Roses J 6.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.) tunnel into developing ***flower buds***. See Sweetcorn M 89.
Cutworms (Noctuidae) chew the ***stems*** of young plants at ground level. See Seedlings N 68.
Loopers caterpillars (*Chrysodeixis* spp.) chew ***leaves***. See Vegetables M 13.

See Annuals A 8.

European earwig (*Forficula auricularia*) chews ***petals and leaves***. See Vegetables M 14.

Leafhoppers (Cicadellidae, Hemiptera) suck sap from leaves, severely affected ***leaves*** have a dotted, mottled and bleached appearance. See Vegetables M 15.

Mealybugs (Pseudococcidae) feed on parts of ***tubers***, exposed by cracking or disturbance of the soil. They are slow moving, white and mealy and are commonly found on the ***undersurface of older leaves***. They feed by sucking on sap causing premature defoliation and reduced plant vigour. See Greenhouses N 25.

Mites (Acarina)

Broad mites (*Polyphagotarsonemus latus*) can only be seen with a microscope ***if shoot tips*** are carefully examined. ***New leaves*** are distorted and may be bronzed and reduced in size. See Greenhouses N 26.
Cyclamen mite (*Phytonemus pallidus*) causes similar damage as broad mite. See Cyclamen C 16.
Twospotted mite (*Tetranychus urticae*) can be a ***major pest*** of dahlias. Where numerous, fine webbing is seen on ***leaf undersurfaces. Leaves*** have a bleached and sand blasted appearance, particularly beside the main veins. Leaves fall. See Beans (French) M 29.

Thrips (Thripidae, Thysanoptera): ***Plague thrips*** (*Thrips imaginis*) and other species are tiny blackish elongated insects which may infest ***flowers***. Petals may be ***silvered and browned***. Both petals and young leaves may be ***distorted***. See Annuals A 3 (Fig 18), A 9, Roses J 6.

Others: ***Grasshoppers*** (Orthoptera) cause isolated damage on bushes.

SNAILS AND SLUGS

Slugs and snails may damage ***foliage and flowers*** (upper parts of plants) making their control by baits difficult. See Seedlings N 70.

Non-parasitic

Environment: ***Frost:*** Do not plant tubers in spring until danger of frost has passed. Protect dug tubers from low temperatures in cool areas. Dahlias need staking to protect them from ***wind***.

Nutrient deficiencies, toxicities: ***Excessive fertilising*** may induce molybdenum, boron and other deficiencies. ***Excess nitrogen*** causes soft weak leaves and stems (flowers bend over), reduces flower production and possibly tuber storage life.

Pesticide injury: ***Dimethoate*** (Rogor®) may injure the flowers of some varieties. ***Hormone herbicides*** (and aphid and mite infestations) may result in dark green distorted top foliage.

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State/Territory Departments of Agriculture/Primary Industry eg

Diseases of Dahlias (NSW Agfact)

Associations, Journals etc.

America Dahlia Soc.

Australian Dahlia Council

GrowSearch (database Qld DPI)

See Annuals and herbaceous perennials A 10, Bulbs, corms, rhizomes and tubers C 9

MANAGEMENT

Remember, always check for recent references

Selection

Dahlias are popular bedding plants, there are hundreds of cultivars. They are tender perennials but are treated as bulbous annuals. As many diseases are transferred on or in tubers, reject diseased plants. Purchase ***pathogen-tested planting material*** or select planting material from disease and pest-free plants.

Establishment and Maintenance

Dahlia are ***propagated*** by division of tuberous roots in spring (each tuber must have one or more sprout eyes), stem cuttings or by seed. Dahlias for cut flower production are mostly ***field grown.*** Change growing area, if possible every year, and do not replant dahlias for ***at least 5 years***. Dahlias require abundant water but sites need to be well drained. ***Do not confuse diseases*** with symptoms caused by poor cultural care, environmental conditions or insect injury. ***Destroy*** all plant debris after the display is finished. Do not ***introduce*** plants infected with virus or other diseases and pests. Place tubers from unknown sources in ***quarantine*** until disease and pest status is established. ***Pesticides*** are ***registered*** for control of diseases, pests and weeds.

Postharvest

There are ***quality standards*** for exhibition dahlia (Australian Dahlia Council). ***Harvest*** flowers when almost fully open but centres tight and foliage firm and green. If cut at too early a stage of bud development, flowers will not develop properly even in opening solution or their development will be prolonged and flower quality poor. Flowers are sensitive to ethylene so may be treated with ant-ethylene agents by growers. Coloured buds may be ***opened*** in preservative solution (Nowak and Rudnicki 1990). Recut stems and remove at least 20 mm, immerse stems in boiling water for 30 seconds or sear with a flame to prevent bleeding. Remove most leaves as they discolour quickly. Flowers may be ***stored*** at 4-5^{o}C for 3-5 days in water (Jones and Moody 1993). Flowers may be stored and transported under low light intensity or in total darkness, high light intensity is required only for opening flowers cut at the bud stage, lack of light during long distance transport or prolonged storage hastens leaf yellowing (Nowak and Rudnicki 1990). Clumps of tubers are ***lifted*** in autumn and ***stored*** at -1^{o}C and covered with soil or vermiculite to prevent them drying out during winter. Divide clumps in spring.

Fig. 76. Tomato spotted wilt virus infection

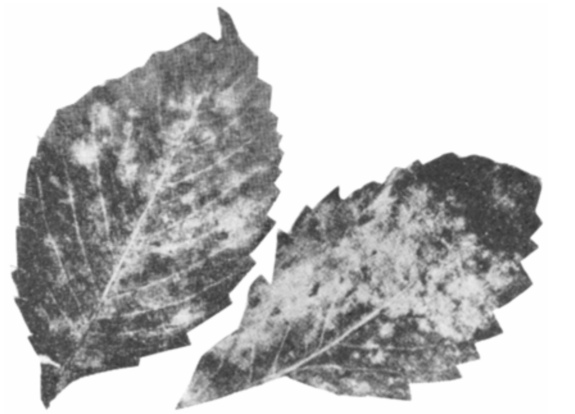

Fig 77. Powdery mildew (*Oidium* spp.) on dahlia leaves.

Freesia

Freesia hybrida
Family Iridaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot
- **Fungal diseases**
  - Grey mould
  - Root and corm rots
- **Insects and allied pests**
  - Aphids
  - Gladiolus thrips
  - Twospotted mite

Non-parasitic
- Environment
- Leaf necrosis
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Freesia mosaic virus affects *Freesia hybrida*, overseas also *F. refracta*. ***Leaves*** develop mild leaf yellowing or are symptomless. ***Flower size*** may be reduced and ***flowers*** may show a colour blotch. Symptoms shown by naturally infected plants persist. ***Overwinters*** in infected corms and is ***spread*** by vegetative propagation, by aphids, eg green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphon euphorbiae*), by mechanical inoculation, on cutting tools, not by contact between plants, not by seed, not by pollen.

Bean yellow mosaic virus causes mottling and dark flecking of ***leaves*** and ***stunted flowers***. Affects freesia overseas. See Beans (French) M 25.

Both viruses are ***spread*** by infected corms and aphids as well as on harvesting tools. After cutting healthy flowers, ***dig out*** plants with flowers showing virus symptoms. ***Aphid control*** in the crop and during storage is essential. See Bulbs C 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas gladioli* pv. *gladioli*) affects gladiolus and is considered to be able to also infect crocus, freesia and other Iridaceae (Fahy and Persley 1983). See Gladiolus C 29.

FUNGAL DISEASES

Grey mould (*Botrytis cinerea*) may cause ***leaf dieback*** and pale spots on ***flowers***. Flowers packed in plastic sleeves are especially susceptible. See Bulbs C 5, Greenhouses N 22.

Root and corm rots

Fusarium wilt (*Fusarium* sp.) is considered to be the ***most important disease*** of freesia and the species is thought to be the same that can affect gladiolus. See Gladiolus C 29.

Others:
- Blue mould (*Penicillium* spp.)
- Sclerotinia rot (*Sclerotinia gladioli*)

See Bulbs C 5.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphon euphorbiae*)
Tulip bulb aphid (*Dysaphis tulipae*)
Aphids ***transmit virus diseases*** and during cooler weather damage ***new growth*** by their direct feeding. See Bulbs C 6, Roses J 4.

Gladiolus thrips (*Thrips simplex*) and possibly other species of thrips may damage ***leaves, flowers and corms***. See Gladiolus C 31.

Twospotted mite (*Tetranychus urticae*) may infest ***leaves***. See Beans (French) M 29.

Non-parasitic

Environment: ***Thumbing*** (separation of the first floret from the other florets) is caused by ***fluctuating temperatures*** during the development of florets on the spike (Salinger 1985). ***Tip burn*** (drying and browning of flower tips) is caused by ***water stress***.

Leaf necrosis is a browning and death of ***leaf blades***; no flower distortion occurs. Although it has symptoms similar to virus infection, no causal organism has yet been identified (Salinger 1985).

Nutrient deficiencies, toxicities: Tap water containing ***fluoride*** may cause leaf burning, small flowers and failure of smaller buds to open.

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State/Territory Departments of Agriculture/Primary Industry eg
Freesia Growing in Tasmania (Tas Farmnote)
Tesselaar's Padua Bulb Nurseries, Sylvan, Vic.
Grower Information Sheet No. 6. Freesias.
Association, Journals etc.
GrowSearch (database Qld DPI)
See Bulbs, corms, rhizomes and tubers C 9

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Choose proven varieties for cut flowers and pot culture, eg *Freesia hybrida* Bergunden. Freesia will flower as long as soil temperatures remain < 18°C.

Disease-free planting material: Freesias degenerate with virus diseases, and after a number of years new corms which are free from virus and other diseases should be obtained to maintain flower quality. Seed is virus-free initially.

Establishment and Maintenance

Propagation: By daughter corms and by seed.

Cultural methods (Tesselaar's Grower Information Sheet No.6 : FREESIAS*): ***1. On arrival*** after purchase, keep corms in any dry, ventilated position at storage temperatures of 20-30°C. ***2. Planting:*** Freesias will grow in almost any soil, but prefer a well cultivated soil with a reasonable amount of organic matter. Plant corms from February until April, 50 mm deep and 50 mm apart in rows that are 150 mm apart. Do not plant freesias twice running in the same position or where gladioli have been planted unless the soil has been treated/fumigated to control soilborne diseases (and weeds), otherwise they will not grow to their fullest potential. After aeration of the soil the 1st layer of supporting net is laid on the surface and 2 corms per mesh area planted with the apical tip just below the surface. Where shoots have already emerged they can be exposed. If the weather is sunny, they should be shaded with shade cloth or even newsprint or paper until they become green. Subsequent care is the same as for those grown from seed. ***Freesias, unlike bulbs, do not have a flower in the corm before they are planted.*** Corms, firstly, produce leaves and then when the plant has received the correct ratio of light and temperature it will begin to form the flowers. The main flowering period for freesias is August/September to October. Planting in greenhouses promotes earlier flowering and longer stems. Each well grown plant can produce several sprays of highly fragrant blooms. Irrigate and fertilise appropriately. ***3. Pesticides:*** Should grey mould (*Botrytis cinerea*) become a problem, spray with a ***recommended registered fungicide*** alternating every 7 days to prevent flower and foliage damage. Control aphids and thrips using recommended insecticides. Weed control is essential prior to and after planting.

Pot culture: Plant 5 corms of the Bergunden strain per 150 mm pot in any well enriched potting soil. Set outside in a semi-shaded to sunny position until flowering. Freesias for pots should not be planted into the pots before the beginning of June. This will give good flowering, without long leaves. Planting earlier gives more time for the leaves to grow, resulting in long leaves drooping over the pot, when what is required in potted freesias is short leaves and good flower stems ***(Tesselaar's Grower Information Sheet No.6 : FREESIAS*).***

Postharvest

Cut flowers: There are Quality Standards (US) for freesias. Freesias should be picked when the 1st flower is coloured and starts to open (buds will rarely open if picked prior to the first bud opening). Pick the flowers by 'snapping' the stem just above the 2nd bottom leaf, some varieties do not snap easily, so a sharp knife should be used ***(Tesselaar's Grower Information Sheet No. 6 : FREESIAS*).*** Two leaves are always left to give energy back to the bulb for multiplication and next year's growth. There should be no less than 7 flowers opening in succession and facing in the same direction, per spike. Flowers and leaves should show no signs of tip browning. Flowers are ethylene sensitive and may be treated by the grower to block sensitivity. Stems should be recut and placed in water containing floral preservative, flowers may be ***stored*** at 0-2°C at high relative humidity, ***dry*** for 2 days at 0°C after an overnight drink in water, or ***wet*** for a varying number of days depending on temperature (Jones and Moody 1993). ***Do not arrange with daffodils or jonquils*** as their exudate will decrease freesia vase life. Preferably use rain water or deionised water as flowers are sensitive to fluoride.

Lifting and storing corms: Dig the corms approximately 4 weeks after the flowers have finished. Discard diseased corms. Dry in a warm, well ventilated place. Corms multiply rapidly but only separate the loose corms. All these corms can be planted out the following autumn and will flower ***(Tesselaar's Grower Information Sheet No. 6 : FREESIAS*).***

* *This information is given as a guide only. See Disclaimer, Page iii.*

Gladiolus

Gladiolus spp.
Family Iridaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial scab, neck rot
- **Fungal diseases**
  - Fungal leaf spots
  - Fusarium wilt
  - Grey mould (*Botrytis*)
  - Root and corm rots
  - Rust
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Gladiolus thrips

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Viruses diseases can be a ***limiting factor*** in gladioli production. Because plants can be infected with more than one virus, it is usually impossible for the lay person to tell which virus is causing the problem. Symptoms vary according to the time of infection and the cultivar affected. Plants grown from infected corms or infected at an early stage are often stunted. ***Leaves and flower stems*** usually show angular, light to dark green mottling which may sometimes become necrotic. ***Flowers*** do not usually show symptoms but occasionally severe flecking and distortion occurs. A flower break may occur, white or yellow pencil stripes or blotches may appear on petals. ***Do not confuse virus symptoms on flowers with thrips injury.*** Viruses are ***spread*** by vegetative propagation from infected corms and cormlets, some also by insects (aphids and thrips) and in sap adhering to hands and tools.

Bean yellow mosaic virus causes a mild mottle of young foliage, flowers may show a colour break, and are often stunted. See Bean (French) M 25.
Others: ***Cucumber mosaic virus*** and ***tobacco ringspot virus*** occur in Qld in the cultivar Spic and Span, elsewhere in the world this virus is transmitted by a nematode vector and has a wide host range, but neither of these properties has been noted in Australia (McKay and Hughes 1985). ***Tomato spotted wilt virus*** may also affect gladiolus.

Pickers should harvest healthy flowers first then dig out and ***destroy infected plants*** including the corms. Only plant ***virus-tested corms*** and plant them at least 1 km from virus-infected gladiolus crops. Aphid and thrips should be controlled with ***insecticides*** in commercial crops and on corms in store. See Bulbs C 4.

BACTERIAL DISEASES

Bacterial scab, neck rot (*Pseudomonas gladioli* pv. *gladioli*) is a ***common but minor*** disease of gladiolus, freesia, crocus and other Iridaceae. ***Corms*** develop pale yellow, watersoaked circular spots which exude gum containing bacteria, gluing the husk and fragments of soil to the corm. Spots darken with age, becoming circular, depressed, shiny with gum and with a prominent, light-coloured, raised rim (Fig. 78). Lesions are shallow and old lesions are usually on the lower surface of the corm, and can be lifted out, exposing undamaged tissue below. ***Necks*** rot and plants collapse. Initially ***leaf spots*** are tiny and reddish brown, later they enlarge and become circular or slightly elongated with a darker margin and may join together. Scab ***overwinters*** in infected corms and crop debris in soil for up to 2 years. ***Spread*** by introduction of contaminated soil or plant debris on machinery, tools, containers, healthy corms become infected by planting in contaminated soil, soil becomes contaminated by planting infected corms, also by bulb mite (*Rhizoglyphus echinopus*). ***Favoured*** by warm, wet, soil. Practise ***crop rotation.*** Harvest corms as soon as mature, cure prior to storage in dry, well ventilated conditions and treat with ***fungicide*** prior to planting. ***Sanitation*** is reduces their spread. Only plant ***scab-free corms.*** See Vegetables M 5.

Others: ***Bacterial blight*** (*Xanthomonas campestris* pv. *gummisudans*) may occur in warm, rainy seasons. ***Sanitation*** is helpful in reducing its spread. ***Crown gall*** (*Agrobacterium* sp.).

FUNGAL DISEASES

Fungal leaf spots

Stemphylium leaf spot (*Stemphylium botryosum*) is a common but minor disease ***seriously damaging some cultivars*** near flowering time during cool, wet weather. Large circular yellow spots up to 3 mm in diameter develop on ***leaves*** which may wither and die. Dark brown spores develop on the spots. On some cultivars, small yellow spots with red centres surrounded by a ring of clear translucent tissue develop. Plant cultivars with ***some resistance***.
Others: Some leaf spotting fungi also damage ***corms*** and are described under root and corm rots, eg *Botrytis* spp. (Fig. 79), *Curvularia trifolii* f. sp. *gladioli* and *Septoria gladioli*. *Bipolaris bicolor* may also cause leaf spotting (Walker 1994).

See Annuals A 5, Bulbs C 5.

Fusarium wilt,

fusarium yellows and basal brown rot (*Fusarium oxysporum* f.sp. *gladioli*) is the ***most destructive disease of gladiolus.*** There are several strains which vary in symptoms produced and in the range of varieties attacked. An extremely virulent form is responsible for the disease called ***basal brown rot***. The fungus enters the plant through roots, leaf bases or old corms. Water-conducting strands of roots, stems and parent corms are discoloured, roots rot and young infected shoots curve due to unequal growth, plants may die. ***Leaves*** yellow and die starting at the tips of the oldest leaves. ***Parent corms*** and part of the ***root system*** are usually found to be decayed. If the corm is cut across, the rotting of the core and radiating strands or pockets of brown can be readily seen. The first symptom is the production of a brown lesion at the base, starting from the dead root bases. Rotting continues in ***storage***, develops in concentric rings and in damp conditions may have ***pinkish-white surface growth*** on which spores are produced. The degree of corm rotting depends on ***varietal susceptibility***, corms of susceptible varieties may be completely destroyed, but in varieties with some resistance (none seem to be completely resistant) there may be no obvious external symptoms but vascular browning is easily seen. ***Flower spikes*** may be deformed and individual flowers may fail to open properly and give a tulip shape. Fusarium wilt should be ***positively identified by a pathologist*** to confirm diagnosis. Immediately after ***corms*** are cleaned, treat with fungicide for 15-30 minutes prior to curing. ***Cormlets*** can be ***hot water treated*** for more efficient eradication of the fungus, cool store them after drying for 5-6 weeks before planting in ***Fruarium-free soil***. ***Contaminated soil*** must be treated prior to planting susceptible cultivars. Plant ***treated corms*** in ***Fusarium-free soil***. See Bulbs C 5, Vegetables M 9.

Grey mould, neck rot, corm core rot (*Botrytis gladiolorum*) and grey mould (*Botrytis cinerea*), is present in many gladiolus plantings, but ***field damage*** is usually slight. Serious losses may occur ***postharvest*** after cutting, during the marketing of flowers. ***Leaves*** develop small red-brown spots which may enlarge to form dark blotches with tan centres (Fig. 79), these may coalesce and leaves yellow and die. Petals of ***flowers*** opening under damp conditions develop watersoaked circular spots, which soon coalesce causing flowers to wither. Affected leaves and flowers during humid conditions, are covered with grey spores. Spores may infect ***necks*** of plants causing them to rot at ground level, yellow and fall over (Fig. 80). Sometimes black resting bodies (sclerotia) are produced by the fungus on affected areas. If leaf and flower infection has occurred in the crop, spores infect husks and ***corms*** during damp conditions at lifting time. Corms are only susceptible when soft and newly dug. Even a short period of ***curing*** renders them ***resistant*** to attack. ***Favoured*** by cool (15-21^{o}C), wet, humid weather, subsequent warm and dry weather stops the development of leaf and flower spots. Practise ***crop rotation***, a minimum of 4 years is desirable. Avoid overcrowding and overmoist growing conditions. ***Rogue*** and burn badly infected plants. ***Corm treatments:*** If *Botrytis* leaf spots have occurred during the growing season or if the weather is damp at digging, corms should be treated as recommended for basal rot. ***Treat corms with fungicide*** prior to planting. ***Dig corms*** as soon as possible after flowering, ***cure corms*** before storage at 35^{o}C for about a week and store in well-ventilated conditions. If corms are required for late planting, cool-store them at 3-9^{o}C. Plant cool-stored corms immediately after removal from the cool store. Destroy infected corms. Reject obviously affected plants when harvesting corms, green-clean corms and reject diseased corms. ***No completely resistant variety is known***. Use sterilants in packing sheds. Apply ***fungicides*** to ***flowers*** when necessary prior to harvesting, and during ***transit of flowers***; provide adequate ventilation. See Bulbs C 5, Greenhouses N 22.

Root and corm rots

Properly identify root and stem rots. Use a test kit or send to a pathologist. Many fungi affecting corms and flowers also cause leaf spots.

Curvularia leaf and flower spot and corm disease (*Curvularia trifolii* var. *gladioli*) is most severe on gladiolus ***seedlings*** and plants grown from ***cormlets***. *Curvularia* is often present but not usually serious. It attacks young leaves or flowers, and is particularly destructive on young cormlets where it destroys the plant at soil level during warm humid or moist conditions. ***Leaf spots*** are 1-20 mm across with prominent, dark, reddish-brown margins with a lighter halo and a pale brown centre. Leaf tips often shrivel and shred. Black spore masses may appear on the surface of the spots. ***Flower spots*** are small, colourless, watersoaked areas initially, but may later turn brown and then blacken as the spores develop. Spots on the cut flower spikes continue to develop in transit. ***Corms:*** Shallow, light to dark brown depressions (pinpoint to more than 20 mm across) which easily separate from the healthy tissue. The fungus may also cause a core rot with discoloured water-conducting strands extending from the rotted tissue. Picardy is ***very susceptible*** and the disease seems to be most severe on seedlings and plants grown from cormlets. Some other varieties have leaf resistance but not corm resistance.

Fusarium wilt, fusarium yellows and basal brown rot (*Fusarium oxysporum* f.sp. *gladioli*) is described separately. See Gladiolus C 29.

Grey mould (*Botrytis* spp.) may rot corms and is described separately (see above).

Penicillium mould (*Penicillium gladioli*) is a ***common and important storage disease***. Firm, circular, brown lesions, enlarging irregularly and becoming sunken develop on ***corms***. In cool, damp conditions a ***fluffy, bluish fungal growth*** is produced through which small, round, yellow sclerotia (< 0.5 mm in diameter) are scattered. Usually plants are not affected. However, earliest leaves to emerge may show lesions. See Bulbs C 5, Fruit F 6.

Sclerotium stem rot (*Sclerotium rolfsii*) is a minor disease. ***White fungal threads*** with hard, brown ***1-2 mm sclerotia*** are produced on ***rotting old corms*** and in ***surrounding soil***. Sclerotia can remain viable for many years. Infection is facilitated by mechanical injury, and warm weather. Allow organic matter to decompose well before planting. See Bulbs C 6, Vegetables M 8.

Septoria leaf spot and hard corm rot (*Septoria gladioli*) may be a minor disease. Initially small, circular or oblong, brown or purple-brown spots develop on ***leaves***. These enlarge, have brown borders and light coloured centres. Tiny, black, fungal fruiting bodies (pycnidia) develop on the centres. Under moist conditions spots may enlarge to involve most of the leaf margin. ***Hard corm rot:*** A firm brown or olive discolouration with a marbled appearance, extending into the flesh, which is mottled with brown, develops. Lesions do not follow the veins or invade the corms. During storage, infected tissue becomes a uniform dark brown and the surface of the lesion shrinks and becomes hard.

Stromatinia rot (*Stromatinia gladioli = Sclerotinia gladioli*) may cause death of more than ***30%*** of gladiolus plants. ***Neck rot:*** Leaves commence to yellow from the tip, then dry and die and the plant may fall over. Young plants may be stunted, yellow and may eventually die singly or in clumps. Larger plants may not be killed, but the bases of the leaves and stems are rotted with a black colour and often the outer leaf bases are so shredded that only the leaf veins remain. Many small, black, round ***sclerotia (< 0.5 mm across)*** form in the rotted tissue. ***Corm rot:*** Lesions are at first inconspicuous yellowish or reddish specks, which enlarge to roughly circular spots 6 mm across, often found along the lines of origin of the covering scales. The lesions may join together to cover much of the surface, particularly the upper surface. Lesions are not usually deep although in extreme cases the whole corm may become mummified. ***During storage,*** corms may become covered by surface lesions, and when cut across may show dark streaking along the veins rather like yellows, except that they start only from surface infections, and not from the parent corm. When corms are planted in contaminated soil, roots are attacked and die. Older leaves of these plants wither back from the tips and flower spikes are poor or fail to develop. Corms produced by these plants are usually heavily infected around the base. ***Favoured*** by high soil moisture and sandy rather than clay soils, by cool weather when sclerotia germinate to produce fungal threads which infect healthy plants at distances up to 0.5 m. It can also cause damage under warm soil conditions (24-28^{o}C). The fungus can also survive in flooded soils. See Bulbs C 6, Vegetables M 7.

Overwintering: Several of these leaf spotting fungi can persist in the soil for years and also on the corms, some form resting bodies (sclerotia) in the soil and these persist for many years, eventually re-infecting gladioli or other Iridaceous plants. ***Spread:*** Spores are spread by water splash and wind, from leaf spots and infected plant debris, and by the movement of contaminated ground water, by propagation from infected corms and the movement of infected corms and contaminated soil on machinery, tools, containers etc. Different root and corm rots are ***favoured by different weather conditions***. ***Cultural methods:*** Practice crop rotation, a minimum of 3 years, grow crops in warm conditions. Ensure good drainage, avoid over-moist soil conditions. Plant shallowly. ***Sanitation:*** Remove and destroy severely infected plants, corms and crop debris. Discard and burn any ***corms*** with any visible disease after lifting, before curing, storage and planting. Green-clean (wash and clean immediately after lifting) corms and cure prior to storage. Corms may be treated with fungicide prior to curing and planting. ***Disease-free planting material:*** Reject affected corms before planting; only plant ***disease-free corms*** and plant in ***disease-free soil***. ***Soil treatments*** may be necessary. ***Fungicides*** are registered for these diseases. See Bulbs C 5, Vegetables M 7.

Rust, leaf rust (*Uromyces transversalis*) may be a ***serious disease*** of cultivated gladiolus and watsonia. Other rusts occur overseas. Rust appears as powdery orange pustules on ***both sides of leaves***, the pustules often occur as lines running ***across the leaf blades***. Gladiolus rust is ***spread*** by wind-blown spores, on leaves (attached to cut flowers) and possibly on other leaf material and clothing carrying spores. Consideration is being given to ***regulating the movement*** of gladioli plants within Australia. This rust is difficult to control with ***chemicals***. See Annuals A 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) may cause ***serious losses overseas*** but do not seem to be important in Australia. ***Corms*** are distorted with swellings approximately 5 mm across. Tissue breakdown is rare. ***Roots*** are distorted and swollen, breakdown may occur. ***Root lesion nematode*** (*Pratylenchus penetrans*) also occurs on gladiolus. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum euphorbiae*)
Aphids damage developing ***foliage and flowers*** by their sap sucking activities. They may also transmit some ***virus diseases*** of gladioli. See Bulbs C 6, Roses J 4.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.)
Cluster caterpillar (*Spodoptera litura*)
Painted apple moth (*Teia anartoides*)
Sugarcane and maize nutborer (*Bathytricha truncata*)
Budworms can damage ***flower buds*** from spring until autumn. Caterpillars generally are more damaging at ***plant emergence*** at the 2-leaf stage, at the ***slipping stage*** and just ***prior to the opening of the lowest floret***. See Annuals A 8, Bulbs C 8.

Gladiolus thrips

Scientific name: Thripidae, Thysanoptera:
Gladiolus thrips (*Thrips simplex*) is a ***major pest***. Other species, eg ***plague thrips*** (*Thrips imaginis*), ***western flower thrips*** (*Frankliniella* occidentalis) may infest gladiolus. Other *Frankliniella* spp. may infest gladiolus overseas.

Host range: Gladiolus, carnations, iris, arum lily, red-hot poker (*Kniphofia* sp.), monbretia (*Tritonia* sp.), tiger flower (*Tigridia pavonia*).

Description and damage: ***Adult females*** are about ***2 mm*** long, dark brown in colour and possess 2 pairs of delicately fringed wings. Males are slightly smaller than females. ***Nymphs*** are initially yellow and wingless and are found hidden in crevices in leaves and flowers. Pre-pupal and pupae are lemon-yellow. Nymphs and adults rasp and suck plant sap from ***leaves*** causing silvering (Fig. 81), if damage is extensive, new corms may be stunted. Thrips in developing ***flower spikes*** cause blooms to become deformed, or prevent them opening. This injury is often attributed to other causes such as drought or disease. Slight injury on ***dark blooms*** appears as irregular, ***whitish or***

flecked areas. Buds and flowers brown and wither. Damage is not so noticeable on light-coloured varieties. Thrips also feed and breed on ***corms*** in storage which become sticky, hard and scabby/scaly, young root buds may be injured, their subsequent development is affected (Fig. 81).

Pest cycle: Gradual metamorphosis (egg, nymph (2 stages), pre-pupa, pupa, adult) with many generations during the warmer months. Eggs are deposited in the plants. Larvae and pre-pupae are found within leaf sheaths and flower buds, adults feed mainly in the open on leaves. The pupal stage occurs either on plants or in soil.

Overwintering: In warm areas all stages may occur during winter. If plants are left for a long time in the field after flowering, thrips migrate to corms as leaves die. In cooler areas, thrips may overwinter in infested corms and on volunteer hosts.

Spread: As thrips do not fly readily, spread through crops is slow and assisted by wind. They are also spread by introduction of infected corms.

Conditions favouring: Hot, dry conditions. Cool, wet weather is unfavourable, heavy rain may destroy large numbers. Slow growing varieties are more susceptible.

Control:

Cultural methods: For ***new plantings*** select land as far removed as possible from old plantings and volunteer plants. Commercial growers with properties isolated from areas in which gladioli or other hosts are growing, should make a ***break in plantings***, so that for a period of several months there is no foliage on which thrips can develop. Where there are dominant prevailing winds, plant ***early-flowering varieties*** in beds furthest down-wind (thrips do not fly readily). Frequent use of ***overhead sprinklers*** or hosing plants retards thrips development before flowering but may damage flowers. Provide good drainage.

Sanitation: ***Volunteer gladiolus plants*** and other hosts should be pulled up and destroyed before the main crop is planted. Thrips may migrate from drying leaves to corms if digging is left too long. The husks which provide protection for the thrips should be removed.

Biological control: There are many natural enemies, eg wasps.

Resistant varieties: Pale coloured varieties are considered to have ***some resistance***. Deep red and purple (some exceptions) and slow growing cultivars (they have a sweeter sap than rapidly growing ones) are most severely affected.

Physical and mechanical methods/Pesticides: ***Foliage treatments*** for susceptible varieties should commence when shoots are 150-200 mm high and continue at regular intervals until flowering. Sprays are usually more effective than dusts, it is usually necessary to add a wetting agent. ***Soil treatments:*** Granular insecticides applied when planting corms out, provide control for about 10 weeks. ***Corm treatments*** include storage at 10^{o}C, hot water treatments ***(obtain expert advice on how to do this so that thrips are controlled but corms not injured)***, and dusting with insecticide prior to storage.

Others: ***Bulb flies*** (Syrphidae, Diptera), ***bulb mite*** (*Rhizoglyphus echinopus*), ***mealybugs*** (Pseudococcidae, Hemiptera), ***twospotted mite*** (*Tetranychus urticae*) and ***wireworms*** (Elateridae) are not usually a problem in commercial plantings.

Non-parasitic

Environment: Severe ***frost*** damage may follow warm days and cold nights and early growth can be stunted. Usually only younger leaves are affected, becoming soft and watersoaked and later dry and whitish. Sometimes only parts of leaves or leaves facing the ***rising sun*** show symptoms. Basal parts of new leaves not fully emerged at the time of frost injury are not usually affected. ***Saprophytic fungi*** may invade damaged areas. Affected plants may later recover but ***new growth*** may be ***puckered*** and ***distorted***, with alternate bands of yellow and green tissue along the young leaves. ***Flowers*** may be normal on frost affected plants if spikes are protected within the leaves at the time of injury. Abortion of individual florets occurs when frost affects the flower at the heading stage. Sufficient loss occurs each year to make this an important consideration in winter plantings in some areas. Maintain wet soil conditions. Install warning devices, spray irrigate before frost thaws. ***Inadequate irrigation*** during flower formation reduces stem length and number of florets per spike. ***Provide support for plants*** to protect them from wind damage and to keep the flower spikes vertical.

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State/Territory Departments of Agriculture/Primary Industry eg

Diseases of Gladioli (NSW Agfact)

Pests of Gladiolus (Vic Agnote)

Virus Diseases of Gladiolus (Vic Agnote)

Associations, Journals etc.

GrowSearch (database Qld DPI)

North American Gladiolus Society

See Bulbs, corms, rhizomes and bulbs C 9

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Gladioli are an important cut flower crop.

Resistant varieties: Select cultivars with ***some resistance*** to major diseases and pests (Salinger 1985).

Disease-free planting material: Most serious bacterial and fungal diseases are carried ***in or on corms*** and are transferred from old to new corms each year. Diseases may be introduced to an area on infected corms and can then remain in the soil for varying lengths of time, multiplying with each succeeding gladiolus crop. ***Only plant corms free from specified diseases***. To obtain disease-free replacement corms, ***grow cormlets*** separately from production crops and on ground that has not previously grown gladioli or that has been treated with an effective registered pesticide/fumigant. ***Select cormlets*** only from apparently disease-free plants and treat with hot water and recommended fungicides. Hot water treatment of cormlets (< 19 mm in diameter) prior to planting, ensures even germination and elimination of latent fungal infections before planting in disease-free soil. ***Hot water treatment will injure corms***.

Establishment and Maintenance

Propagation: By daughter corms.

Cultural methods: Practise ***crop rotation*** to avoid build up of inoculum near susceptible cultivars, prepare the area for planting early and ensure that organic matter is well decomposed. Ensure adequate drainage. Avoid land infested with fungal diseases or nematodes. Select a frost-free site or arrange for prescribed irrigation to minimise frost damage, control weed growth in and around the crop area. Grow in ***warm weather*** to avoid sclerotinia, in ***cool weather*** to avoid fusarium and nematodes. Plant shallowly and hill as late as practical. ***Accurate diagnosis of diseases and pests is essential.*** A comprehensive summary of their description and possible treatments is available (Salinger 1985).

Sanitation: Rogue virus-affected plants regularly, discard rotted corms after storage and decontaminate stores and structure with commercial sodium hypochlorite at recommended strength.

Pesticides: ***Insecticides*** are registered for controlling gladiolus thrips and ***fungicides*** for grey mould (*Botrytis*), fungal leaf spots and bacterial scab.

Postharvest

There are US Standards for gladiolus, grades are based on spike length and minimum number of florets.

Cut flowers: ***Harvest*** cut flowers when 1-5 buds showing colour. If picked tighter then opening solutions are necessary. Quality and opening is dramatically improved if growers pulse prior to packing and transporting to market. ***Flowers are very susceptible*** to grey mould (*Botrytis*), ensure strict hygiene in the packing shed, pack only dry flowers and provide adequate ventilation for flowers in transit. ***Vase life:*** Salt (700 ppm) decreases vase life and fluoridated tap water at concentrations of 0.25 mg/L and higher causes flower injuries, petal tips may look bleached and burnt, florets may fail to open and develop normally (Jones and Moody 1993). Gladioli are heavy drinkers, replenish water regularly, avoid ethylene. Lack of light during long distance transport or prolonged storage accelerates leaf yellowing. ***Storage***: Flowers spikes must remain and be stored in an ***upright position*** to prevent stem bending (negative geotropic bending of stems away from the centre of the earth), growth inhibitors may be used to prevent this and special packaging must be used to hold them vertically. Flowers may be stored ***dry*** or ***wet,*** prior to storage, they should be treated against grey mould (*Botrytis*) and conditioned at prescribed temperatures (Nowak and Rudnicki 1990). After storage stem ends should be recut and placed in an opening solution at 18-20^{o}C until flowers reach the commercially desirable stage.

Lifting and storage of corms: ***Corms*** are generally lifted 5-6 weeks after the main flowering, preferably when soil is hot and when corms are still attached to the parent corm (attached corms are less likely to be infected with soilborne diseases). ***Remove foliage*** from corms at harvesting to reduce diseases and, if left in the field, to prevent diseases. ***Dry corms*** rapidly after harvest. Corms are ***adequately cured*** when old corms can be broken off cleanly from the base of new ones. If leaves are removed or damaged during flower gathering, new corms and cormlets will be smaller and therefore less vigorous. ***Avoid injury at harvest*** and discard damaged corms or cormlets for future planting. Wash corms and cormlets after lifting and separate cormlets < 19 mm in diameter. ***An excellent summary*** is provided by Salinger, 1985: Green-clean corms, cure all planting material at 30^{o}C and 80-90% relative humidity for 1-2 weeks before storage, clean corms after curing (if not green-cleaned), cold store at 3-7^{o}C at 70-80% relative humidity with adequate ventilation.

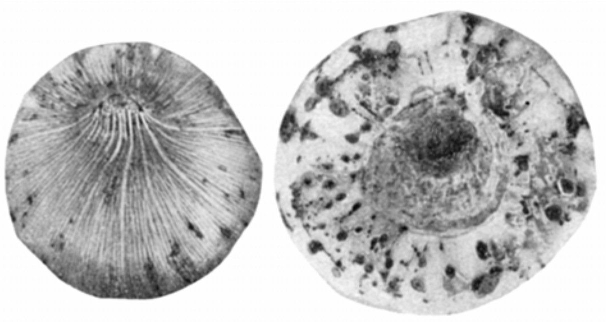

Fig. 78. Bacterial scab (*Pseudomonas gladioli* pv. *gladioli*) on gladiolus corms. Dept. of Agric., NSW.

Fig. 80. Collar rot on gladiolus caused by *Botrytis gladiolorum*. Rotting occurs at or just below ground level. Affected areas are usually covered with grey mould. Dept. of Agric., NSW.

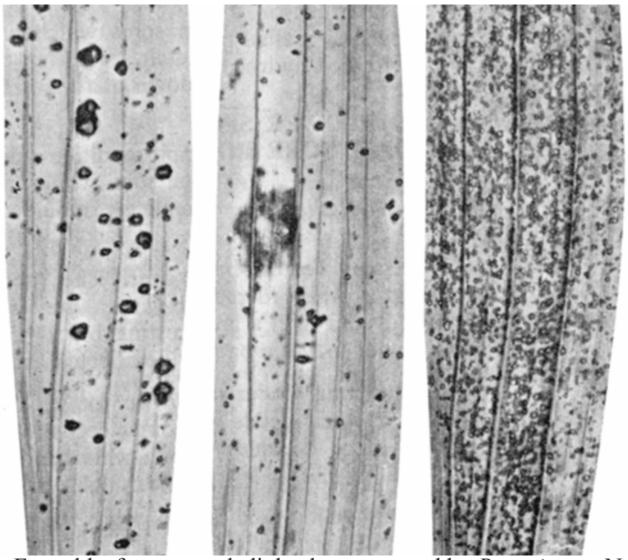

Fig. 79. Fungal leaf spots on gladiolus leaves caused by *Botrytis* spp. Note small reddish circular spots and large irregular lesions. Dept. of Agric., NSW.

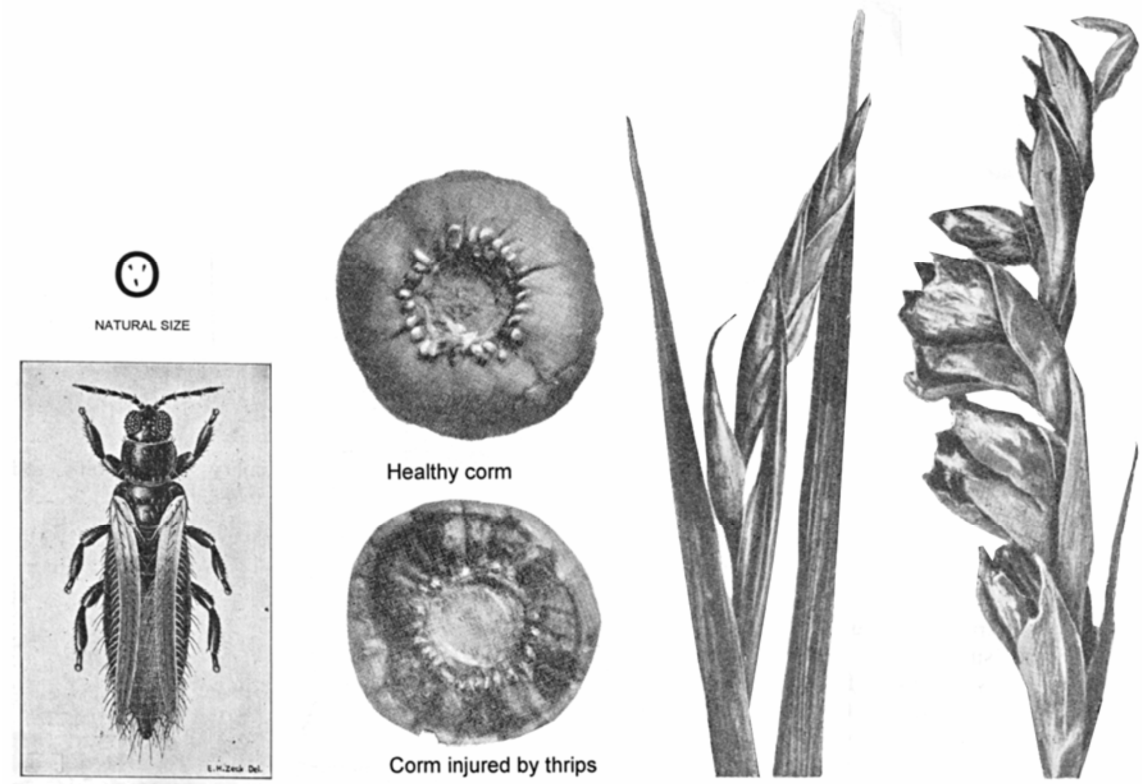

Fig. 81. Gladiolus thrips (*Thrips simplex*): ***Left :*** Adult thrips. ***Centre :*** Injury to corms (showing injured area and killed rootlets around basal plate. ***Right :*** Injury to foliage and flower spikes (silvering). Dept. of Agric., NSW.

Hyacinth

Hyacinthus spp.
Hyacinth (*Hyacinthus orientalis*)
Family Liliaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial soft rot
  - Bulb rot, yellow disease, yellow rot
- **Fungal diseases**
  - Grey mould, fire
  - Root and bulb rots
- **Nematode diseases**
  - Root knot
  - Stem and bulb nematode
- **Insects and allied pests**
  - Aphids
  - Lesser bulb fly

Non-parasitic
- Hyacinth itch

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Hyacinth mosaic virus affects *Hyacinthus* sp. causing leaf yellowing, stem spotting, and an occasional flower break. Symptoms shown by naturally infected plants persist. ***Spread*** by vegetative propagation, by green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphon euphorbiae*), by mechanical inoculation, not by contact between plants, not by seed, not by pollen.

Narcissus mosaic virus: Leaf symptoms range from faint yellow flecking, blotches and rings to severe distortion and death of tissue. In Australia yield of crops is not affected. There is no vector. See Daffodil C 19.

See Bulbs C 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*) may affect ***bulbs*** in the ***ground*** and in ***storage***. Bulbs may fail to produce ***flowers***. See Bulbs C 5, Vegetables M 5.

Bulb rot, yellow disease, yellow rot (*Xanthomonas campestris* pv. *hyacinthi*) occurs on *H. orientalis*. Yellowish water-soaked stripes begin near the ***leaf tip*** and extend downwards, these stripes later brown and die (Pirone 1978). ***Flower stalks*** brown and shrivel and ***bulbs*** rot. See Vegetables M 5.

FUNGAL DISEASES

Grey mould, fire (*Botrytis cinerea*) may affect the flowers especially some ***dark blue cultivars***. See Bulbs C 5, Greenhouses N 22.

Root and bulb rots

Blue and green moulds (*Penicillium* spp.) can be a problem during forcing if humidity is high and it attacks the ***basal plate*** (Larson 1992). See Fruit F 6.

Others:
Phytophthora root rot (*Phytophthora cryptogea*)
Sclerotium rot (*Sclerotium rolfsii*)

See Bulbs C 5, Vegetables M 6.

NEMATODE DISEASES

Root knot (*Meloidogyne* sp.) has been recorded on *Hyacinthus* sp. See Vegetables M 10.

Stem and bulb nematode (*Ditylenchus dipsaci*) has been recorded on *H. orientalis*, *Hyancinthus* spp. See Daffodils C 20.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphon euphorbiae*)
Aphids infest ***new leaves*** and transmit ***virus diseases*** of hyacinths. See Bulbs C 6, Roses J 4.

Lesser bulb fly (*Eumerus tuberculatus*) maggots may infest ***hyacinth bulbs***. See Bulbs C 7.

Non-parasitic

Hyacinth itch: Hyacinth bulbs contain a ***crystallised powder*** on their husks, which when ruffled by rough handling, can settle and enter the pores of the skin causing an ***itch*** (Frohne and Pfander 1983). Wear gloves when handling dried hyacinth bulbs. This effect can be neutralised by washing affected areas with soap and water.

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Grower Information Sheet No.2. Hyacinths
Growers Information Sheet No 7. Forcing Spring Flowering Bulbs
Grower Information Sheet No.8:Forcing Bulbs

See Bulbs, corms, rhizomes and bulbs C 9

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Hyacinth are popular spring flowering, perfumed bulbs available in a wide range of colours, grown for bedding displays, cut flowers and are ideal for container growing, both outdoors and indoors.

Resistant varieties: Some cultivars are ***more susceptible*** to grey mould (*Botrytis*) than others.

Disease-free planting material: All diseases and pests are carried over in the bulbs. Only purchase and plant certified virus and pathogen-tested bulbs.

Establishment and Maintenance

Propagation: By daughter bulbs.

Cultural methods ***(Tesselaar's Grower Information Sheet No. 2 : HYACINTHS*):*** ***1. On arrival:*** Unpack bulbs immediately and store at 20-30^{o}C in a well ventilated area in dry trays rather than in paper bags or cardboard boxes. Bulbs may be grown in pots and/or forced for early flower. See Bulbs C 10. ***2. Field planting*:** Hyacinths are gross feeders and require extra feeding to allow the bulbs to fully develop for the following season. Fowl manure at the rate of 70 m^3/ha or in very poor soil 120 m^3/ha may be used. This is applied to the soil before planting and also turned into the soil together with a green crop 1-2 months before planting time. Bulbs are planted in rows 300 mm apart, 100-120 mm deep and spaced 50-88 mm apart. Hyacinths, unlike tulips, are unaffected by high temperatures and so can be planted out into the soil from the beginning of March until the end of April. As with all bulbs, they prefer to be planted in moist soil and pH of 6-7 is required.

Pesticides: ***3. Spraying:*** When they commence flowering 2-3 fungicide sprays for grey mould (*Botrytis* spp.) at 10 day intervals may need to be applied.

Weed control: ***4. Weeds:*** Four weeks after planting and while bulb shoots are still more than ***30 mm below the soil*** spray the ground with a contact herbicide to kill existing weeds, and a pre-emergence herbicides to prevent weed seed germinating for up to 3 months. ***Never spray with herbicide once growth is within 5-10 mm of the soil surface or the shoots have emerged through the soil.***

Postharvest

Cut flowers: ***5. Flowers:*** ***Harvest*** flowers with a sharp knife as low as possible without damaging the leaves when top florets are still in bud and there is an even opening in the lower florets. ***Vase life*** is approximately 4-8 days, place stems in water containing preservative but no sugar (Nowak and Rudnicki 1990).

Lifting and storage of bulbs: ***Hyacinths and tulips*** are best lifted when the foliage completely dies down as our summers are too hot for them to flower well the 2nd year. ***Hyacinths*** should be kept in shallow containers after lifting and covered with peat moss in a cool dry place. ***6. After flowering*:** Keep weeds away from the plants to help the bulbs absorb as much of the available nutrients as possible. Keep the soil moist after flowering. It is during the next 8-10 weeks that the bulb develops for the following season. ***7. Digging*:** After the leaves have yellowed and started to die, dig the bulbs up and break off the foliage at the top of the bulb. The bulbs should then be air dried in the shade for 5-10 days. After this time they can be graded if necessary and then stored in an with plenty of fresh air. Hyacinths prefer a temperature range of 25-30^{o}C but will take a range of 20-35^{o}C during their storage season. Good ventilation is the key to their success. ***8. Dipping bulbs:*** Providing the roots are not yet developed, the bulbs should be dipped in a ***recommended effective disinfectant*** to promote a more healthy skin and less 'split bases' in the hyacinth bulbs. ***Make sure that this is done before the bulb starts rooting.*** Wear gloves when handling hyacinth bulbs.

Potted plants: ***Sell*** when buds start to colour (Nowak and Rudnicki 1990). For longest life, flowering plants should be kept at a cool temperature of 10-15^{o}C. Higher temperatures stimulate stem growth and cause rapid deterioration of inflorescences. Do not spray flowers with water as this causes flowers to become infected with grey mould (*Botrytis* spp.).

* *This information is given as a guide only. See Disclaimer, Page iii.*

Remember, always check for recent references

Iris

Iris spp.
Bulbous (Dutch, dwarf, English, Japanese, Spanish)
Rhizomatous (German, Siberian)
Family Iridaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Bulbous irises are ***more severely affected*** by virus diseases than rhizomatous irises. All viruses are spread by vegetative propagation, some also by insects, but not usually by seed.

Iris mild mosaic virus (IMMV) affects *Iris* spp. ***Leaves*** may be symptomless or show a light green mosaic, which is slightly more intense on flower bracts, ***flowers*** are usually unaffected. Symptoms are more obvious on irises grown under cover, and those shown by naturally infected plants vary cyclically over a few weeks. ***Spread*** also by aphids, eg cotton aphid (*Aphis gossypii*), potato aphid (*Macrosiphum euphorbiae*), green peach aphid (*Myzus persicae*), not by chrysanthemum aphid (*Macrosiphoniella sanborni*), not by seed (seed from iris bulbs will be virus-free initially). Because ***IMMV*** is less severe than ***ISMV***, growers have not attempted to control it to the same extent as they have ***ISMV***.

Iris severe mosaic virus (ISMV) affects *Iris* spp., overseas also *Crocus vernus* and *Belamcanda chinensis*. Outer and middle ***leaves*** have yellow-green stripes in mild infections. In severe infections, pale green and yellowish-green stripes and wide bands in irregular patterns extend upwards from below soil level. Plants may be distorted and stunted. ***Flowers*** may show a colour break, be reduced in size and twisted to one side. Plants die prematurely. Symptoms shown by naturally infected plants persist and vary cyclically over a few weeks. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), not by *Myzus pelargonii*, *M. circumflexum, Anuraphis tulipae, Rhopalosiphon tulipaella*, by mechanical inoculation, not by grafting, not by contact between plants, not by seed.

Others: Cucumber mosaic virus, lily symptomless virus, narcissus latent virus, narcissus mosaic virus.

See Bulbs C 4., Daffodil C 19,

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*), possibly other *Erwinia* spp. may also attack iris, especially ***rhizomatous irises***. Leaves turn yellow and collapse. When plants are lifted, rhizomes below the wilted foliage are rotted and have a foul smell. ***Lifting and dividing irises*** every 2-3 years helps reduce the incidence of disease. ***Rotate irises*** with non-susceptible crops. See Bulbs C 5, Vegetables M 5.

Others: ***Bacterial leaf spot*** (*Pseudomonas gladioli* pv. *gladioli*). See Gladiolus C 29.

FUNGAL DISEASES

Fungal leaf spots

Fungal leaf spot (*Cladosporium iridis* = *Heterosporium* spp. = *Mycosphaerella macrospora*) mainly affects ***rhizomatous irises***. Minute, brown elliptical spots with water soaked margins develop on leaves. Spots enlarge and turn grey with brown to red margins ***(eyespots)***. Spots may coalesce to form larger dead areas, leaves die prematurely and weaken the plant. Plant rhizomes in well ventilated, well drained sites, collect and destroy badly infected leaves and spray with a fungicide if necessary. Soak bulbs before planting for half an hour in a recommended fungicide. See Bulbs C 2 (Fig. 60).

Ink disease (*Dreschlera iridis*) may cause leaf spots on ***bulbous iris***.

See Annuals A 5, Bulbs C 5.

Root, bulb and crown rots

Blue or green moulds (*Penicillium* spp.) may develop on the fleshy ***bulb scales***. See Bulbs C 5.

Fusarium yellows (*Fusarium oxysporum* f.sp. *gladioli*) affects gladiolus, iris. See Gladiolus C 29.

Grey mould (*Botrytis cinerea*) rots the ***stem base*** as it emerges or just after the leaves develop. Greenhouses N 22.

Ink disease (*Dreschlera iridis*) causes black blotches on scales of ***bulbous iris***.

Rhizoctonia neck rot (*Rhizoctonia solani*) causes a brownish rot of the ***base*** of the leaves and flower stalks. See Vegetables M 7.

Sclerotium stem or crown rot (*Sclerotium rolfsii*) may attack both rhizomatous and bulbous irises initially rotting the ***base*** of leaves and flower stalks causing dieback. The rotting spreads into the rhizomes, killing plants. A white, cottony growth and later ***tiny brownish sclerotia*** develop on affected parts. See Bulbs C 2 (Fig. 62), Vegetables M 8.

See Bulbs C 5, Vegetables M 7.

Rust, leaf rust (*Puccinia iridis*) occurs mainly on ***rhizomatous irises*** during warm, humid weather. Rusty red, powdery pustules may develop on stems and on both sides of leaves which may yellow and die prematurely. Plants are not usually killed but ***vigour is seriously affected***. During the short period when no iris foliage is above ground, old foliage may be burnt off and new growth sprayed as soon as it emerges (Salinger 1985). ***Avoid*** overhead watering. ***Remove and burn*** old infected leaves. At first sign of disease apply a ***fungicide***. Several applications may be necessary depending on weather. Some fungicides may ***injure blooms***. See Annuals A 7.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) has occurred on iris in Australia. Vegetables M 10.

Stem and bulb nematode (*Ditylenchus dipsaci*) may attack ***bulbous iris***. In NZ bulbs scales are separated from the basal plate and subsequent above ground growth is very weak. ***Hot water treatment*** of bulbs at 44^{o}C for 3 hours with a prescribed disinfectant in the bath, and the incorporation of ***insecticide granules*** at planting and each autumn, should reduce their incidence and possibly give complete control (Salinger 1985). See Daffodil C 20.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cotton aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum euphorbiae*)
Tulip bulb aphid (*Dysaphis tulipae*)
Aphids cluster and suck sap from ***flowering shoots and bulbs*** and may multiply during ***storage*** on emerging shoots and under the scale leaves, infested dry bulbs feel sticky. Aphids transmit ***virus diseases*** of iris during feeding. See Bulbs C 6, Roses J 4.

Others: ***Bulb mite*** (*Rhizoglyphus echinopus*), ***gladiolus thrips*** (*Thrips simplex*), ***lesser bulb fly*** (*Eumerus tuberculatus*), ***mealybugs*** (Pseudococcidae, Hemiptera).

SNAILS AND SLUGS

Snails may be a serious pest of irises. See Bulbs C 8, Seedlings N 70.

VERTEBRATE PESTS

Cockatoos and other birds may randomly dig up and partially eat bulbs, above ground shoots are often not damaged. Some growers net plantings. See Fruit F 13

Remember, always check for recent references

Non-parasitic

Environment: ***Blasting*** (failure to produce a marketable flower after floral initiation has taken place) in Dutch iris and tulips is very complex. Known causes are low light intensity, high temperatures, insufficient watering and lack of fertiliser in the greenhouse. ***Blindness*** is a failure to flower, only 3 leaves are produced, and can be due to the use of small-sized bulbs, forcing too early, or improper programming of temperatures. ***Frost: Pre-cooled prepared bulbs*** planted outdoors without protection may suffer frost damage; ***flower buds*** fail to emerge from sheaths or if they do emerge, flowers may be at an angle to the stem due to a ***bent stem*** below the ovary. ***Weather-damaged flowers*** are unsaleable, but when the flower and ovary are picked off in the field, large bulbs are formed (Salinger 1985). Tall irises may need staking to protect them from ***wind damage***.

Failure to flower, in ***rhizomatous irises*** may be due to deep planting or congested clumps resulting in the sun being excluded from the centre. In some varieties of ***bulbous irises***, virus diseases prevent flowering. See Daffodil C 21.

Nutrient deficiencies, toxicities: Iris can suffer from ***calcium deficiency*** (weak neck) where flower stems cannot support flowers (Salinger 1985).

Pesticide injury: Glyphosate and other herbicides should not be applied to iris foliage even when it has ***apparently dried up***. Old stalks and leaves ***transport*** the material to the bulbs causing next year's crop to have bleached leaves.

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State/Territory Departments of Agriculture/Primary Industry eg
Diseases of Irises (NSW Plant Disease Bull.)
Associations, Journals etc.
American Iris Society
British Iris Society (The Iris Year Book 1981)
GrowSearch (database Qld DPI)
Handbook for Judges & Show Officials
Iris Society of Australia (Regional Newsletters)
The World of Irises

See Bulbs, corms, rhizomes and tubers C 9

MANAGEMENT

Selection

Horticultural requirements: ***Bulbous iris*** (Dutch, dwarf, English and Spanish) are undoubtedly popular for both gardens and containers, and for commercial cut flowers. ***Rhizomatous varieties*** (German, Japanese and Siberian) are mainly garden plants.

Resistant varieties: Some irises are more or less susceptible to snails, fungal leaf spots and other diseases.

Disease-free planting material: Plants derived from the seed of bulbous irises are virus-free, but insects must be controlled to maintain virus-freedom. Purchase virus-free bulbs. All diseases and pests are carried over in the bulb or rhizome.

Establishment and Maintenance

Propagation: By bulbs, division of rhizomes and by micropropagation. Irises, like tulips, produce annual bulbs, they are formed one season and if large enough, flower the following spring.

Culture: Soil should be well drained, bulbs rot in waterlogged soil in winter. ***Lighter soils*** are desirable as bulbs benefit from the summer warmth and are easier to lift. Lime is applied before planting to bring the pH up to at least 6.0. Irises are usually grown on ridges rather than on the flat as this improves winter drainage and makes bulb lifting 6-8 weeks after flowering more effective. Iris bulbs may be ***forced*** before planting (Larson 1992, Salinger 1985).

Sanitation: In NZ it is recommended that ***all surface plant material*** should be ***destroyed*** before the bulbs are lifted. If conditions are wet and there is weed growth (annual or perennial) go over with a flail mower or similar machine and allow material to dry so that a good clean burn can be obtained.

Pesticides: In commercial crops ***if aphids are present*** on the ***bulbs***, insecticide granules may be placed in the trench. Naturally clean and healthy bulbs are protected by ***fungicide and insecticide treatments***, before setting in the field. ***Fungicides*** may be applied routinely for fungal leaf spots, and if insecticide granules have not been used, ***aphicides*** for aphids.

Postharvest

Cut flowers: ***Harvest*** for direct sale when flower buds are well coloured, petals emerging about 30-50 mm but before starting to open. Smaller buds do not open in water. During winter, when light intensity is low, harvest when first bud begins to open. The cultivar Professor Blaaw should be selected when the edge of one petal is unfurled. Place in ***preservative solution*** (no sugar) to ensure that later buds develop and open out, and that colour is maintained in the 2nd bloom or subsequent flowers. ***Store*** upright as tips may bend upwards (geotropism) at 2-4^{o}C in solutions for 0-4 days, longer cool storage may inhibit later bud opening, whatever solutions the stems are placed in. Remove lower foliage and as flowers desiccate easily, keep at high relative humidity, away from draughts. ***Vase life*** is approximately 5-6 days and improves after prescribed conditioning. To open buds, recut stems, place in warm water (40^{o}C) and wrap stems but leave head unwrapped, put in disinfectant solution then put in cool room (Jones and Moody 1993). Bulbous iris are very sensitive to ***ethylene*** (greyish petals, bud sleepiness or blasting, hastening of senescence), ***do not place with daffodils*** (Nowak and Rudnicki 1990). ***Plant growth regulators*** delay senescence in iris flowers.

Lifting and storing bulbs: ***To minimise losses*** by reducing the incidence of disease, lift and divide irises every 2-3 years. Lift bulbs when foliage has completely dried off, about 6-8 weeks after flowering. Avoid injuring bulbs during lifting and storage. ***Inspect bulbs*** after lifting, before storage and again before planting, destroy any bulbs affected with root, bulb and crown rots and treat with ***fungicide*** before storage and again before planting. Remove and destroy surface plant material. Healthy bulbs have clean brown outer dry scales leaves, not stained black or showing green stains from ink disease or blue or green moulds. Remove and destroy diseased scales. Remove diseased portions of rhizomes with a sharp knife, then immediately drench with a suitable fungicide to reduce spread of the fungus in the soil. ***For cut flowers***, bulbs are graded into rounds, large flat, small flat side and smalls; all round and most large flat sided bulbs will flower satisfactorily (Salinger 1985). ***Store*** bulbs, treated with aphicide to protect from aphids.

Lily

Lilium spp.
Family Liliaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial soft rot
- **Fungal diseases**
  - Grey mould, fire (*Botrytis*)
  - Root and bulb rots
- **Nematode diseases**
- **Insects and allied pests**
  - Lily aphid
  - Lily caterpillar

Non-parasitic
- Pollen

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Leaf mosaics may involve several viruses.

Lily symptomless virus systemically infects *Lilium* spp. and *Iris* spp. Hosts differ in susceptibility, eg *L. longiflorum* displays a curl-stripe if ***seedlings*** are infected with this virus alone and grown at temperatures < 15.5^{o}C. Symptoms shown by naturally infected plants vary seasonally. ***Yield*** of crops is moderately affected in susceptible varieties. ***Spread*** by vegetative propagation, by aphids (Aphididae) and by mechanical inoculation.
Others: Cucumber mosaic virus, tulip breaking virus.

See Bulbs C 4, C 6.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) on lily (*Lilium* spp.), tiger lily (*Lilium lancifolium*). See Bulbs C 5, Vegetables M 5.

FUNGAL DISEASES

Grey mould, fire (*Botrytis cinerea, B. elliptica*) produces elongated spots on ***leaves*** during humid weather. A furry grey mould may develop. It may be necessary to apply ***fungicides*** regularly. See Bulbs C 5, Greenhouses N 22.

Root and bulb rots

Fusarium wilt and bulb rot (*Fusarium oxysporum* f.sp. undetermined) affects the ***bottom of the scales*** which separate from the base of the bulb. Leaves that grow from infected bulbs may go yellow or purple and die. If ***flowers*** are produced, they are small and of poor quality. This disease is much more likely to occur on ***damaged bulbs*** than on healthy undamaged bulbs. This disease may be controlled by soaking bulbs in warm water with a fungicide. See Bulbs C 5, Vegetables M 9.

Others:
Phytophthora root rot, basal stem rot (*Phytophthora nicotianae* var. *parasitica*)
Pythium rot (*Pythium* spp.)
Rhizoctonia rot, scale rot (*Rhizoctonia solani*)
Root and bulb rot (*Cylindrocarpon destructans*)
Sclerotium bulb rot (*Sclerotium rolfsii*)

See Vegetables M 7.

NEMATODE DISEASES

Various nematodes may attack lily.

Foliar nematode (*Aphelenchoides fragariae*) has been recorded on *L. longiflorum* and *Lilium* x *sulphurgale.* See Ferns E 2.
Root knot nematode (*Meloidogyne* sp.) occurs on *Lilium* spp. See Vegetables M 10.
Root lesion nematode (*Pratylenchus penetrans*) infests *Lilium* spp. in NZ and granular nematicides may be required at planting (Salinger 1985). See Vegetables M 11.

See Vegetables M 10.

INSECTS AND ALLIED PESTS

Lily aphid (*Aulacorthium circumflexum,* Aphididae, Hemiptera) infests lilies and other plants, eg chrysanthemum. Lily aphid can reproduce by parthenogenesis (no sexual forms) throughout the year. See Bulbs C 6, Roses J 4.

Lily caterpillar (*Spodoptera picta,* Noctuidae, Lepidoptera) feeds on Amaryllidaceae eg Kaffir lilies (*Clivea, Clivea miniata*), *Crinum* spp. and *Hippeastrum* spp., but not *Lilium* spp. ***Caterpillars*** are black and yellow. Young caterpillars feed in groups (which may provide them with some protection) and skeletonise ***leaves***. Older caterpillars feed singly on either leaf surface or bore into the heart of plants. ***Moths*** have a wingspan of about ***50 mm*** and red and black patterned forewings (McMaugh 1994). Eggs are laid in a group on a leaf of the host plant. ***Pruning off*** damaged leaves with caterpillars still feeding on them may provide sufficient control, otherwise an insecticide may be required, wetting agents are necessary. See Annuals A 8.

Others: Larvae of large native ground-dwelling ***weevils***, (Amycterinae, Curculionidae, Coleoptera) live in the soil and feed on ***underground stems, crowns, tubers or rhizomes*** of Liliaceae and Poaceae.

Non-parasitic

Pollen stains clothing and may be removed with sticky tape. It also ***stains*** cemented/rendered walls if flower arrangements are placed close to walls. Commercial growers cut anthers off.

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See Bulbs, corms, rhizomes and tubers C 9

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: There are various types of lilies which may be grown in the field or in pots in greenhouses. Choose varieties which have relatively short growing periods, the time taken from visible flower bud to flowering ***must be rapid***. Bulbs must have a short dormancy period which can be satisfied by cool storage. Flowers should face outwards or upwards and have short pedicels and preferably only 1 flower on each pedicel. Anthers should not produce excessive pollen or be heavily scented (Salinger 1985).

Resistant varieties: Varieties should have some ***resistance/tolerance*** to grey mould, fire (*Botrytis* spp.) and virus diseases.

Disease-free planting material: Viruses and other diseases are carried over in the bulblets and scales. Select virus and pathogen-free planting material. Usually seed is virus-free.

Establishment and Maintenance

Propagation: By bulbs, scales, tissue culture or by seed. Saleable or flowering bulbs should be obtained in 2 seasons from planting bulblets.

Cultural methods: Lilies require excellent drainage and protection from wind and excessive heat. Diseases and pests should be controlled. ***Weed control*** is essential where diseases are a problem.

Sanitation: Remove all ***plant debris*** after harvest, and any other plant debris which might encourage grey mould (*Botrytis cinerea*).

Pesticides: Pesticides are ***registered*** for the control of grey mould, fire (*Botrytis* spp.), aphids and other pests.

Postharvest

Cut flowers: There are ***US quality criteria*** for lily cut flowers. ***Harvest*** when at least 2 buds are fully expanded and about to open, with the other buds well coloured. There should be a minimum of 5 buds per stem, foliage turgid, dark green, free from mottling or yellowing, trumpets should be 80-120 mm long. Flowers are sensitive to ethylene so may be treated with an anti-ethylene agent by the grower before storage or transport. Anthers may be cut off to prevent them staining clothing and hastening withering (Matthews 1989). Cut flowers may be stored wet or dry but must be conditioned appropriately. ***After storage***, stem-ends should be recut and placed in a floral preservative solution (Nowak and Rudnicki 1990).

Potted plants: ***Sell*** Easter lilies when flower buds are white and puffy. ***Storage/Transport:*** For longest life, flowering plants should be kept at a cool temperature of 10-15^{o}C. Higher temperatures cause quick deterioration of the flowers. Plants need moderate watering. Plants may be stored by a range of methods. Overwatering during storage stimulates the development of grey mould, fire (*Botrytis cinerea*) and various root or bulb rots (Nowak and Rudnicki 1990).

Lifting and storing bulbs: Bulbs are lifted in April/May, stems may be removed beforehand to save the bulblets. After lifting, bulbs are washed, superficially dried and stored until sale or replanting in a cool place in a medium such as slightly damp sawdust (Salinger 1985).

Tulip

Tulipa spp.
Garden tulip (*T. gesneriana*)
Family Liliaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Fire, fire blight (*Botrytis*)
  - Root, stem and bulb rots
- **Nematode diseases**
  - Stem and bulb nematode
- **Insects and allied pests**
  - Aphids
  - Mealybugs
  - Wireworms

Non-parasitic
- Chimera
- Lack of flowering
- Tulip finger, tulip nail

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tulip breaking virus affects *Tulipa* spp. and some hybrids, *Lilium* spp and some hybrids (Liliaceae). A prominent ***colour break*** in the ***petals of flowers*** develops (Fig. 82): in red and orange varieties streaks of light or dark red, yellow or white develop; in yellow and white varieties, the streaks are much less obvious, being white or translucent. The colour break may be accompanied by serration of the petal margins, giving a tattered appearance to the flower, and this is the most obvious symptom in yellow or white varieties. ***Leaves*** may also show yellow or light green streaks but these symptoms are often very mild. See Bulbs C 2 (Fig. 57, 58). The virus also causes a reduction in ***bulb size and the number of bulbs produced***. Symptoms shown by naturally infected plants persist. ***Spread*** by vegetative propagation, by aphids, eg green peach aphid (*Myzus persicae*), cotton aphid (*Aphis gossypii*), potato aphid (*Macrosiphon euphorbiae*), tulip bulb aphid (*Dysaphis tulipae*), *Neomyzus circumflexus,* by mechanical inoculation, by grafting, not by contact between plants, not by seed, not by pollen. ***Forcing tulips*** to produce flowers early in the season may increase the risk of infection, forced tulips emerge late in autumn when aphid numbers are high, so that rapid virus spread may occur. If tulip breaking virus is a problem, tulips should be ***rogued*** as soon as leaf and flower symptoms appear. As yellow and white varieties do not produce a distinct flower break, they are difficult to rogue and are probably heavily infected with tulip breaking virus. They are a threat to coloured varieties which are easy to rogue and are almost virus-free. Growers who wish to propagate tulips should avoid yellow and white varieties or ***obtain virus-free stocks*** of these varieties.

Others: Overseas at least 13 viruses, eg cucumber mosaic virus, potato virus X and tobacco necrosis virus have been recorded on *Tulipa* spp. (Strider 1985). ***Tobacco necrosis virus*** causes elongated white to brown streaks to develop on ***leaves***, distortion may develop especially in ***forced tulips***. Plants may be stunted. If tobacco necrosis virus is a problem, practise ***crop rotation*** as this virus disease is spread by a soilborne fungi (*Olpidium*) and is prevalent where tulips have been grown on the same land for consecutive seasons.

See Bulbs C 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Corynebacterium* sp.)
Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*)

FUNGAL DISEASES

Fire, fire blight, *Botrytis* leaf and petal spot (*Botrytis* spp., *B. cinerea, B. tulipae*) may be a ***serious disease*** of tulips. ***Leaves*** become flecked with small brown spots, later large areas may be affected. The ***stem*** may rot off completely; in humid weather a grey mould (large numbers of spores) develops. At the base of the stems, many blackish or brown resting bodies (sclerotia) develop. ***Flowers*** are also attacked, spots are more noticeable on light coloured varieties. In moist weather, petals may develop a grey mould and completely collapse. If the ***bulb*** is affected the whole plant becomes dwarfed and turns a pale yellowish-green and the ***flowers are blasted*** (does not produce a marketable flower). Many sclerotia may develop on diseased areas on bulbs. See Bulbs C 5, Greenhouses N 22.

Root, stem and bulb rots
Blue mould (*Penicillium corymbiferum*)
Phytophthora bulb rot (*Phytophthora cryptogea*)
Pythium rot (*Pythium irregulare*)
Rhizoctonia rot (*Rhizoctonia tuliparum*)
Sclerotinia rot (*Sclerotinia* sp.)
Sclerotium crown (*Sclerotium rolfsii*)
See Bulbs C 5, Vegetables M 7.

NEMATODE DISEASES

Stem and bulb nematode (*Ditylenchus dipsaci*) is ***difficult to identify on tulips*** if infestation is slight, but after the nematodes have been feeding for a while there may be greyish or brownish patches on the outside of the ***bulbs***. When the plant is growing, pale streaks may appear on the ***upper stem*** and the ***flower***. The epidermis often blisters and splits. ***Stalks*** may be bent over and ***petals*** distorted. See Daffodils C 20.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Tulip bulb aphid (*Dysaphis tulipae*) infests bulbs and corms, eg crocus, daffodil, freesia, iris, gladiolus and tulip during cool moist weather. It is a ***major pest*** of tulips and transmits the ***tulip flower breaking virus***. ***Adult aphids*** are grey with a waxy appearance, and cluster under ***bulb coats***. Immature stages are greyish brown. Severe infestations of ***foliage*** may check growth. Infested young growth results in distortion of buds, shoots, foliage and flowers, and weakens the entire plant. Aphids tend to cluster under the bud. ***Bulbs*** may be attacked in the field and in storage.

Other species infest foliage and bulbs of tulip in store, eg ***bulb and potato aphid*** (*Rhopalosiphoninus latysiphon*) and ***violet aphid*** (*Neotoxoptera violae*).

See Bulbs C 6, Roses J 4.

Mealybugs (Pseudococcidae) feed and multiply on ***bulbs*** in the ***field*** and in ***storage***, if the temperature is 15^{o}C or above, causing them to shrink to such an extent that they may not grow, or if they do, they produce ***sickly plants***. See Greenhouses N 25.

Wireworms (Elateridae) are the larvae of ***click beetles***. Wireworms are long, smooth and segmented, yellow-brown and up to ***18 mm*** long. They live entirely in the soil, and burrow into ***bulbs***, hollowing out ***stems*** as they work their way up, and causing the plant eventually to fall over. See Seedlings N 69.

Others: ***Bulb flies*** (Syrphidae, Diptera), eg ***lesser bulb fly*** (*Eumerus tuberculatus*) and ***narcissus bulb fly*** (*Lampetia equestris*), and ***bulb mite*** (*Rhizoglyphus echinopus*) may also infest tulips. See Bulbs C 6, C 7.

Non-parasitic

Chimera: A chimera is commonly a plant part composed of ***two or more genetically different tissues***. In a sectorial chimera the different tissues lie side by side and commonly appear in tulips as different coloured segments on the ***flowers*** (Fig. 82). Different colour segments may also occur on ***fruit*** and occasionally on ***leaves and shoots***. In Greek mythology a chimera was a fire-breathing monster with the head of a lion, the tail of a dragon and the body of a goat, and the word chimerical is used to describe anything wild or fantastic.

Lack of flowering: Tulips are bulbous plants so failure to flower may be due to problems discussed under daffodils. See Daffodils C 21. Tulips prefer areas with ***long cold winters.*** Bulbs do not perform well for more than one season in warm-winter areas. New bulbs should be purchased each year and flowering induced by storing them under refrigeration for 5-6 weeks before planting. Bulbs ***< 30-40 mm*** across will not flower. Tulips prefer a shady more alkaline position than most other bulbs. ***Topple*** is when the flower falls over because the stem collapses due to ***calcium deficiency***; it is usually more of a problem on forced, rapidly grown tulips (Strider 1985). Exposure to ***ethylene***, eg *Fusarium*-infected bulbs, fruits, ethylene-producing flowers, etc, may result in leaves ***without flowers***; also production of ***green petals*** or coloured petals with white tips, distorted shoots, lack of roots and other symptoms. Symptoms depend on the ***stage of development*** at which the bulbs were exposed, concentration of ethylene and variety of tulip (Strider 1985).

Tulip finger, tulip nail: Tulip bulbs as well as other parts, especially the flowers, contain ***tuliposides*** which can cause severe ***dermatitis***. Symptoms usually only occur after prolonged contact with tulip bulbs or their juice (Frohne and Pfander 1983).

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State/Territory Departments of Agriculture/Primary Industry eg

Tulip Growing in Tasmania (Tas Farmnote)

Tesselaar's Padua Bulb Nurseries, Sylvan, Vic.

Grower Information Sheet No.3. Tulips

Grower Information Sheet No.7. Suggestions for Potting Spring Flowering Bulbs

Grower Information Sheet No.8. Forcing Bulbs for Early Flowering

Associations, Journals etc

GrowSearch (database Qld DPI)

See Bulbs, corms, rhizomes and tubers C 9

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: The tulip most commonly grown is the single late tulip, eg Apeldoorn.

Disease-free planting material: All diseases and pests are carried over in the bulb. Purchase virus and pathogen-tested bulbs.

Establishment and Maintenance

Propagation: By bulbs.

Cultural methods (Tesselaar's Grower Information Sheet No.3 : TULIPS*): Tulips are affected more by fluctuations in temperature than any other bulb. ***Forcing:*** Pre-chilling encourages earlier flowering and longer stems, but forced tulips may be more susceptible to virus diseases. See Bulbs C 10.

1. On arrival unpack the bulbs immediately and store in an area where they have moderate temperatures and are away from excessive heat, 17-20°C is ideal. They will tolerate up to 5°C higher in the daytime, but higher temperatures will delay flowering. Spread bulbs thinly in flat boxes or trays, no more than 60-80 mm thick, ensuring that there is good air circulation. ***2. Planting*:** Tulips are best planted in early May. They can be planted earlier, but only if the soil temperature has settled below 20°C. If planted in temperatures that are too hot, bud blast may occur prior to planting. It is beneficial to add some blood and bone or bone-meal or other complete bulb food to the soil and work it well in. Plant in a loose friable soil ***with the point facing upwards*** and about 50 mm of soil over the top of the tip. Rows should be a minimum of 300 mm apart and the bulbs 50-100 mm apart. Tulips grow well in most kinds of soils, providing the pH is not too acid, a pH of 6-7 is ideal.

Sanitation: Remove any damaged leaves and other parts as soon as observed, remove the first severely infected plants in a crop as soon as they are observed. Destroy infected bulbs before storage.

Pesticides: ***3. Dipping bulbs*** with a fungicide before planting protects bulbs against soilborne diseases, eg *Fusarium* and *Botrytis*. Preventative spraying for fire (*Botrytis*) and aphids is usually commenced once the plants are approximately 100-150 mm above ground level. ***4. Weeds*:** To help keep weeds at bay, about 4 weeks after planting and while the shoots of the bulbs are more than ***30 mm below the soil,*** spray the ground with a recommended post-emergence foliage herbicide and a pre-emergence herbicide. This will control existing weeds and prevent weed seed from germinating for up to 3 months. ***Never spray with a herbicide once the growth is within 5 mm of the surface or if one of the shoots has emerged through the soil.***

Potting spring flowering bulbs: See Bulbs C 10.

Postharvest

Cut flowers: ***Harvest*** when the bud is fully developed and the upper half of the petals well-coloured (50% colour, 50% green). Elongation (often caused by sugar in solution) can be a problem as tulips continue to grow in the vase. ***5. Pick*** the flowers by 'snapping' the stem just above the 2nd bottom leaf. Some varieties do not snap easily, so use a sharp knife, two leaves are always left to give energy back to the bulb for multiplication and next year's growth. Remove the white portion of the stem to improve water uptake and place in water (sugar in preservatives causes stem elongation). Keep flowers upright otherwise stems will bend (geotropism); to straighten stems, wrap firmly in dampened tissue paper then newspaper, leave for a few hours. ***Store*** at 0-2°C, after storage recut and place in cold water (Jones and Moody 1993).

Potted tulips: Sell when the bud is fully developed and the upper half of the petals well-coloured. Avoid heat which hastens flower senescence, hence the saying 'put the pot out at night with the cat'. Freesias, irises and tulips are of better quality when night temperatures are close to 10°C (Nowak and Rudnicki 1990).

Lifting and storage of bulbs: ***6. After flowering*** keep weeds away from the plants to allow maximum nutrients to be taken up by the bulbs. ***Tulips*** are best lifted when the foliage completely dies down as summer in Australia is too hot for them to flower well the 2nd year. The bulb makes its maximum growth after flowering, so water plants to help them continue their growth for as long as possible. Once the foliage has yellowed, lift the bulbs, break off the old stalk and 'air dry' the bulbs in a shed for 4-5 days. The old husks can be taken off the bulb at this stage. ***7. Store*** in trays that have air holes underneath to allow for maximum ventilation. Wooden trays with a wire mesh underneath are ideal. Do not stack the bulbs higher than 60 mm in each tray. Keep in a well ventilated area with a maximum temperature of 25°C until early January then store at 17-20°C until planting time. Bulbs 25-30 mm in diameter are large enough to flower the following spring, smaller bulbs may require 2-3 seasons of growing before they are of sufficient size to bloom. Cold temperatures are not desirable during the early stages of dormancy as the bulbs only remain dormant at temperatures above 15°C. The ideal storage temperature is about 18°C. When the temperature drops to around or below 10°C, growth within the bulb is stimulated and internal growth starts. A temperature increase of 6°C or more may cause formation of methane which can kill the flower or the last part formed.

* *This information is given as a guide only. See Disclaimer, Page iii.*



Fig. 82. *Left :* Tulip breaking virus. ***Centre :*** A sectoral chimera which is common in tulip.
Right : A 50% sectoral chimera which has about a 1 : 50 000 000 chance of occurring.

Remember, always check for recent references

Zantedeschia

Arum lily, calla lily

Zantedeschia spp.
Golden calla lily (*Z. elliotiana*)
White arum lily (*Z. aethiopica*)
Family Araceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus-like symptoms on ***leaves*** include yellow spots, streaking and distortion.

Dasheen mosaic virus may affect *Alocasia* spp., anthurium, dasheen (*Colocasia*), dieffenbachia, philodendron, *Xanthosoma* and zantedeschia, reducing yield. ***Leaves*** may show mosaic and distortion symptoms which vary seasonally. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), banana aphid (*Pentalonia nigronervosa*), cowpea aphid (*Aphis craccivora*), cotton aphid (*A. gossypii*), by mechanical inoculation, not by contact between plants, not by seed, not by pollen.

Others: ***Tomato spotted wilt virus*** causes spots and streaks on leaves of white arum lily (*Z. aethiopica*) (Fig. 83), the spots are smaller and more irregularly spaced than those on golden calla lily (*Z. elliostiana*). Also ***cucumber mosaic virus***. Overseas also alfalfa mosaic virus, arabis mosaic virus and potato virus X

Use ***virus-tested planting material***. Tissue culture techniques have been used to obtain virus-free plants of some varieties. Do not propagate vegetatively from infected plants. Routinely control aphids. See Bulbs C 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) causes rots of ***leaf stalks*** near ground level. In NZ, *E. carotovora* pv. *aroideae* causes similar rots. See Bulbs C 5, Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots (*Alternaria* spp., *Phyllosticta*, other species). Small, roundish, grey spots develop on ***leaves***, these enlarge until there are large irregular dead areas. Remove and destroy affected leaves. See Annuals A 5, Bulbs C 5.

Phytophthora foot rot (*Phytophthora* sp.) Yellow streaks, browning and death of the outer leaves first, newer ***leaves and flowers*** are infected later and, if pulled up, the ***root system*** will appear extensively decayed. Infected rhizomes can be cleaned and dipped in hot water for a prescribed time. Cool and dry. Do not plant back in the same area. See Trees K 6, Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne sp.*) has been recorded on *Zantedeschia* sp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Banana aphid (*Pentalonia nigronervosa*)
Cotton aphid (*A. gossypii*)
Cowpea aphid (*Aphis craccivora*)
Green peach aphid (*Myzus persicae*)
Aphids suck sap from ***new leaves*** and ***flowers*** and ***transmit virus diseases***. See Bulbs C 6, Roses J 4.

Caterpillars (Lepidoptera)
Grapevine hawk moth (*Hippotion celerio*)
Leafrolling moths (*Tortricidae*)
Vine hawk moth (*Thereta oldenlandiae*), *T. tryoni*
See Annuals A 8, Bulbs C 8.

Gladiolus thrips (*Thrips simplex*) is the ***most serious insect pest*** of calla lily. See Gladiolus C 31.

Mealybugs (Pseudococcidae) can sometimes be a problem. See Greenhouses N 25.

Thrips (Thripidae, Thysanoptera) may transmit ***tomato spotted wilt virus***. See Tomato M 96.

Twospotted mite (*Tetranychus urticae*) may seriously damage ***leaves*** of zantedeschia. See Beans (French) M 29.

Non-parasitic

Environment: Zantedeschia is intolerant of ***heat or dryness***, protect from strong sun (will tolerate light shade) and drying wind, plant in moist soil, with good drainage. New growth is ***frost*** sensitive but later growth will not be affected.

Poisonous properties All Araceae contain calcium ***oxalate crystals*** which play a part in the strongly irritant action on the skin and mucous membranes, berries are poisonous (Frohne and Pfander 1983).

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Associations, Journals etc.
GrowSearch (database Qld DPI)
See Bulbs, corms, rhizomes and tubers C 9

Remember, always check for recent references

MANAGEMENT

Selection
Horticultural requirements: There is a range of varieties grown for cut flowers, pot plants or as greenhouse ornamentals.
Disease-free planting material: Plant virus and pathogen-tested planting material.

Establishment and Maintenance
Propagated: By rhizome divisions, seed and by tissue culture.
Cultural methods: ***Crop rotation*** is essential due to the persistence of volunteer plants and to the buildup of corm rotting bacteria and fungi in the soil. Some plants are grown in pots to reduce these root and rhizome rots to which zantedeschia are very susceptible. ***Temperature:*** Night temperatures are usually 13-16°C (but varies with the cultivar), while day temperatures of 16-21°C are generally used for all cultivars. ***Irrigation:*** Adequate irrigation is essential, a well drained porous soil minimises root rot problems. Too much moisture when bulbs are dormant in winter may cause them to rot, so lift after foliage dies for replanting in late winter. Zantedeschia prefer a ***sunny*** but damp site with fairly rich soil.
Sanitation: ***Good hygiene*** both in the field and in storage will limit bacterial rots and *Phytophthora*. Rhizomes should be ***inspected*** for rot prior to planting, after harvest and before storage. Any found to be rotted should be discarded.
Biological control: Mealybugs and twospotted mites may be controlled biologically if necessary.
Pesticides: After rhizomes with soft rotted areas have been ***discarded***, the remaining ones should be treated with a ***fungicide*** prior to planting . ***Pre-emergence herbicides*** may be applied before tips of rhizomes have grown through the surface. ***Growth regulators*** may be used to reduce height and increase tuber production. ***Insecticides and miticides*** are registered for controlling aphids, mealybugs and twospotted mites.

Postharvest
Cut flowers: ***Harvest*** when flowers are completely open, just before the tip of the flower begins to turn downwards. Flowers are easily damaged (Jones and Moody 1993). ***Storage:*** At 4°C with a high relative humidity (90%). Suspend flowers from the neck with chicken wire to avoid stem bending. Flower stems are pulled not cut (to prevent stem curling) and brought into the shade or for cool storage at 5-9°C (Salinger 1985). ***Vase life:*** Recut stems, removing at least 20 mm and place in a clean container with a preservative.
Lifting and storing rhizomes: Rhizomes may be lifted when foliage dies down annually (dwarf forms) or every 3 years (*Z. elliotiana*). Where soil diseases are a problem they may be lifted annually. When lifted, rhizomes are washed free of soil and dipped in a ***fungicide***, then dried in an airy place and stored in a cool place just covered with dry peat and sawdust.

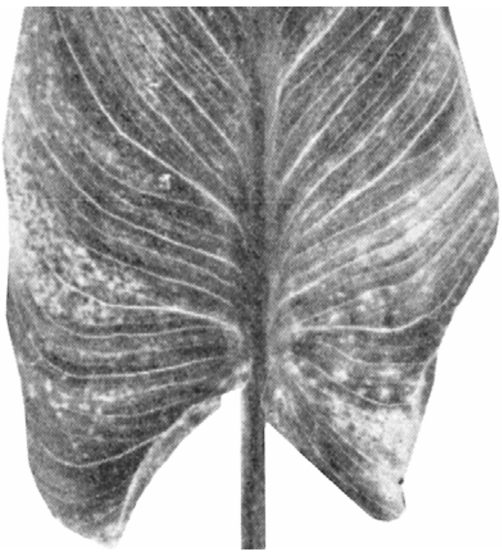

Fig. 83. Tomato spotted wilt virus infection of arum lily causes yellow spots and streaks on leaves. Dept. of Agric., NSW.

Cacti

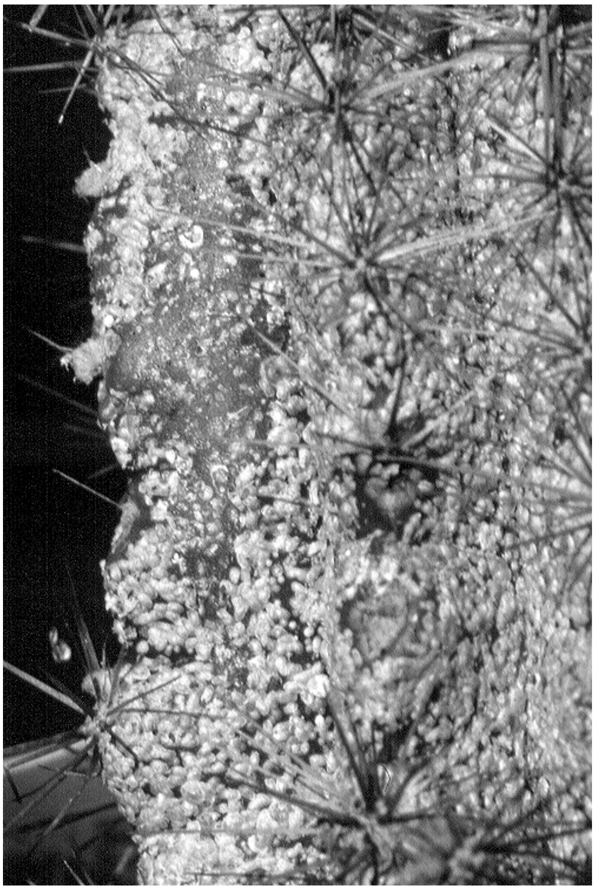

Fig. 85. Tiny armoured scales (Diaspididae) encrusted on a cactus.

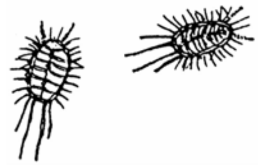

Fig. 84. Longtailed mealybugs (*Pseudococcus longispinus*) are 3-4 mm long.

Fig. 86. Twospotted mites (*Tetranychus urticae*) are 0.5 mm long, they can be seen with a hand lens.

Fig. 87. *Opuntia* spp. and many other cacti, are grown as ornamental plants both in the garden and in containers. However, some *Opuntia* spp., eg *O. inermis* and *O. stricta* in Qld, and *O. robusta* in Victoria, are declared noxious weeds**.**

Fig. 88. Weeds in containers.

Cacti

Family Cactaceae

PESTS AND DISEASES

Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial soft rot
- **Fungal diseases**
  - Root, crown and stem rots
- **Nematode diseases**
- **Insects and allied pests**
  - Mealybugs
  - Scales
  - Twospotted mite

Non-parasitic
- Ants
- Environment
- Nutrient toxicities
- Spines, bristles, size
- Weed potential

WEEDS

PESTS AND DISEASES

Parasitic

The most common pests of cacti are ***sucking insects***, eg mealybugs, scales and twospotted mite. These pests are more severe on potted plants where root systems are restricted and unable to obtain extra moisture to replace sap lost due to the sucking of the insects. Properly cared for plants grown in a garden situation are not so susceptible.

VIRUS AND VIRUS-LIKE DISEASES

Cactus X virus is found worldwide in cultivated cacti and has been identified in *Schulenbergia truncatus* in WA, but there is only one record. No symptoms develop on naturally infected host plants. ***Spread*** by grafting, by mechanical transmission, by contact between plants, not by seed, not by a vector.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) may rot damaged cacti under wet conditions. See Vegetables M 5.

FUNGAL DISEASES

Root, crown and stem rots

Grey mould (*Botrytis cinerea*) may cause ***crown and stem rots***. Wet rotting patches develop around the ***base of the stem*** and to a lesser extent higher up the plant. Plants may die. If possible cut out the infected area and treat with fungicide, otherwise remove undamaged sections and use as cuttings for fresh plants.

Bipolaris stem rot (*Bipolaris cactivora*) rots ***stems***; black fuzzy spore masses grow on affected areas.

Others: ***Phytophthora sp.*** causes a reddish basal stem rot of *Zygocactus* in Qld (Bodman et al. 1996). Also ***Fusarium wilt*** (*Fusarium oxysporum*), ***Pythium, Rhizoctonia.*** See Vegetables M 6, M 7.

Others: Various species of fungi may cause ***leaf spotting***. See Annuals A 5.

NEMATODE DISEASES

Cactus cyst nematode (*Cactodera cacti*) has been recorded in association with *Mammillaria erythrosperma* in NSW and ***root knot nematode*** (*Meloidogyne* javanica) on *Hoya carnosa* in Qld (Mcleod et al. 1994). Plants become unhealthy, yellowish and stop growing. Remove all the root system and wash all the soil from the base of the plant with a strong water jet. Use sterilised media only, wash and sterilise pots. For plants where roots cannot be cut, immerse the root system in hot water, eg 44^{o}C for 3 hours. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Mealybugs (Pseudococcidae, Hemiptera)

Longtailed mealybug (*Pseudococcus longispinus*) may feed on ***above ground parts*** (Fig. 84) and ***roots***.

Root mealybug (*Rhizoecus falcifer*) is common on older succulents and forest cacti.

Tuber mealybug (*Pseudococcus affinis*) feeds on all parts of the plant and is considered to be the ***most important root feeding mealybug*** in Australia. It feeds on many different plants.

Ants are attracted to the ***honeydew*** secreted by mealybugs. On small collections, individual mealybugs can be dabbed with a paint brush dipped in methylated spirits. Mealybugs can be removed from the roots by washing all the soil from the roots and repotting in a clean container with fresh soil. ***Predatory ladybird beetles*** and parasitic wasps may be purchased to control the mealybugs. ***Do not introduce*** infested plants to pest-free collections or ***propagate from infested plants***. Plants may be sprayed with ***insecticide*** outdoors but this does not control mealybugs on the roots. Insecticides may be applied to the soil as a drench or as granules (outdoors). ***Ants*** should be controlled. See Greenhouses N 25.

Scales (Hemiptera)

Armoured scales (Diaspididae) may be ***serious pests*** (Fig. 85), eg ***greedy scale*** (*Hemiberlesia rapax*) and ***oleander scale*** (*Aspidiotus nerii*).

Eriococccids (Eriococcidae), eg ***cactus mealybug*** (*Eriococcus coccineus*).

Soft scales (Coccidae) which produce honeydew are not usually common on cacti. ***Cottony pigface scale*** (*Pulvinariella mesembryanthemi*) frequently infests pigface (*Carpobrotus* sp.) and possibly other species in the same family, eg *Lampranthus* spp.

Scales only infest the ***above ground parts*** of cacti. For minor infestations a toothbrush can be used to remove scales. For larger infestations, ***biological control agents*** can be purchased and ***insecticides*** applied. See Citrus F 39, F 41.

Twospotted mite (*Tetranychus urticae*, Tetranychidae) may infest cacti under hot dry conditions giving them an ashy, yellowish or even whitish appearance. A ***hand lens*** will confirm their presence (Fig. 86). See Beans (French) M 29.

Other occasional pests include ***aphids*** (Aphididae), ***thrips*** (Thysanoptera) and ***slaters*** (Porcellionidae, Crustacea). ***Fungus gnats*** (Sciaridae, Diptera) and their adult flies may be nuisance pests in overwatered cacti. ***Several caterpillars*** (Lepidoptera) may cause damage to new shoots in leaf cacti, eg *Epiphyllum*, *Lepismium* and *Rhipsalis* (Common 1990, CSIRO 1991).

Non-parasitic

Ants may infest greenhouse and outdoor cacti. They are attracted to the ***honeydew*** secreted by mealybugs and soft scales, they also ***carry insect pests*** from plant to plant. See Turfgrasses L 8.

Environment: ***Bud drop:*** Premature dropping of buds may be caused by poor cultural conditions including lack of fertiliser, drying of the soil, and the use of very cold water for watering. ***Light:*** Most desert cacti need as much sunlight as possible especially in winter. Some cacti, however, are injured by overexposure to light. Although forest cacti like light they need to be shaded from direct sun. ***Oedema (corky scab):*** Irregular rusty or corky scabs are seen on stems of many species of cacti, especially *Opuntia* spp., and is associated with high humidities. The shoots may be thickly covered with these spots, only the young growth being scab-free. Severe attacks may destroy entire shoots. Milder attacks decrease the production of flowers. The cells of the epidermis dry and the epidermis breaks open and curls, the corky overgrowth then may be seen from below. The disease may be prevented by increasing the light and decreasing the humidity. See Camellia K 40, Geranium A 35. ***Temperature:*** During cold weather some cacti develop ***pinkish pigments***. Cacti may also suffer from ***frost injury***. ***Sunburn*** injury may result from watering in full sun during the heat of the day. Damaged areas become entry points for diseases. ***Ventilation:*** Good ventilation especially during the cooler months will reduce the likelihood of grey mould (*Botrytis*) and other diseases. ***Watering:*** Most cacti live in dry regions and are well suited to places with little rainfall. In most other plants, the food for the plant is made in the leaves which also give off water. Cacti have lost most of their leaves so that the plant can hold its moisture. Cacti stems have taken over the task of making food for the plant and these stems store water.

During the dormant season when the plant is not actively growing and unable to take up moisture, cacti should not be overwatered as this favours the development of bacterial and fungal rots.

During the growing season of spring and summer many cacti need as much water as conventional plants.

During summer water 1-2 times per week.

Nutrient toxicities: Cacti require fertilising regularly during the growing season in the same way as other plants but they ***should not be overfertilised*** as this promotes rapid soft growth and favours the development of fungal and bacterial rots.

Spines, bristles, size: Most cacti are protected by bristles and spines which prevent them from being eaten by animals that live in the desert. Cacti parts damaged by ***spines*** can act as entry points for rots under moist conditions. They should be promptly cut away and the rest of the plant allowed to dry out prior to resuming normal culture. Spines can also injure ***growers***. Some cacti, eg *Opuntia* spp., have ***minute bristles*** which attach themselves to clothes and gloves and can be very irritating. Bristles may also be inhaled so appropriate ***respiratory protection*** should be worn when handling such species. Some species grow ***very large***.

Weed potential: Some cacti have the potential to become ***noxious weeds*** in some areas of Australia. Some have already become noxious weeds, eg ***prickly pear*** (*Opuntia* sp.) (Fig. 87). Prickly pear has been successfully controlled in NSW and Qld by imported caterpillars of ***cactoblastis*** (*Cactoblastis cactorum*). This biological control program is arguably the best known example of biological control in Australia. Several ***cochineal scales*** (*Dactylopius* spp. Dactylopiidae) have been imported for use as biological control agents for prickly pear (*Opuntia* sp.) and other cacti, eg tiger pear (*Opuntia aurantiaca*), devil's rope (*O. imbricata*). Control of ***harrisia cactus*** (*Eriocereus* spp.) is being attempted by the ***harrisia cactus mealybug*** (*Hypogeococcus pungens*) and ***harrisia cactus weevil*** (*Eriocereophaga humeridens*).

WEEDS

Cacti, because of their spiny nature, can be difficult or almost impossible to hand weed (Fig. 88). Potting mixes should be ***weed-free*** prior to potting up. ***Persistent weeds*** such as oxalis, which develop later, may be wiped with a weeding wand or spot sprayed with glyphosate using a shielded nozzle. Pre-emergence herbicides effectively control weed seeds. See Containers N 20.

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The Spinette (Australia)
Wagga Cactus News
State/Territory Socs.

See Preface xii

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: There are cacti to suit everyone. Choose species that do not have ***large spines*** which can stab people or ***tiny bristles*** which adhere to clothes or can be inhaled. Choose species which do not grow ***too large***. Many species, eg rattail cactus (*Aporocactus flagelliformis*), are suitable for ***hanging baskets***. Some species are ***declared noxious weeds*** in some parts of Australia, eg prickly pear (*Opuntia* spp.), and should not be grown for sale in these areas. Many *Opuntia* spp. have ***edible fruits*** of varying degrees of palatability. Many others have edible fruit but few are grown outside the Americas (Glowinski 1991).

Resistant varieties: Some species are more ***tolerant of low temperatures*** and other conditions.

Disease-free planting material: Only purchase or propagate from pest or disease-free cacti.

Establishment and Maintenance

Handling cacti to minimise discomfort and facilitate maintenance and propagation: Wear appropriate ***clothing***, eg gloves, overalls, respirator (if handling cacti with fine hairs, eg *Opuntia* spp.). Use appropriate ***tools***, eg tongs are ideal for removing some weeds. Cacti pieces and weeds loosened with weeding tongs should be promptly dropped into a bag which can be placed directly in a bin for disposal. This avoids an unsuspecting person disposing of the material being accidentally injured. To facilitate ***handling*** of indoor cacti, they should not be allowed to become overgrown. Cacti known to grow extra large or to produce irritating hairs should be grown in appropriately ***small containers***.

Propagation is easy and this is one of the initial attractions for growers. Most can be propagated either vegetatively through cuttings, branches or leaves and through grafting or by growing from seed.

Monitoring pests, diseases and weeds: Regularly ***inspect*** plants for the presence of pests, diseases and weeds so that infestations can be treated promptly and effectively.

Cultural methods: ***Watering*** will vary with species but pots should be allowed to dry out between waterings. Generally water more frequently during summer, and reduce watering in winter, do not waterlog plants. ***Fertilise*** fortnightly at half strength during the growing season. Cacti are light loving plants (photophilic), they grow well in dry air and prefer a light and free draining mix with a pH of 5.5 - 6.5. Some cacti require special mixes. ***Repot*** routinely each spring. The exact conditions for establishment, eg potting mix, light, nutrition, temperature range, watering regime), will depend on the ***species***.

Sanitation: Often small infestations on cacti can be washed or lightly scrubbed clean with a toothbrush; however, spiny cacti can be difficult to clean and weed. If plants are so damaged that they have to be discarded, cuttings may be taken from an uninfected part, new plants should be kept separate until they are observed to be ***pest, disease and weed-free***.

Biological control: Where mealybugs and twospotted mites are serious problems in commercial plantings, ***biological control agents*** may be introduced.

Plant quarantine: All new purchases should be ***inspected carefully*** for mealybugs, scales and twospotted mites as this is the most common method of introducing pests and weeds to a collection. If infested, they should be placed in quarantine until pest-free.

Pesticides: ***Insecticides*** are registered to control mealybugs and other pests. Householders should only use one registered and labelled for ***indoor plant use*** and follow label instructions.

Postharvest

Standards are available for judging cacti and should be obtained from the relevant society. Cacti should be well established in pots ***at time of sale***; those that flower should be sold at the beginning of flowering. The conditions required after purchase depend on the species (Nowak and Rudnicki 1990). Edible cacti are usually despined and are ready to eat on harvest. They may be boiled as a vegetable (Glowinski 1991).

Ferns

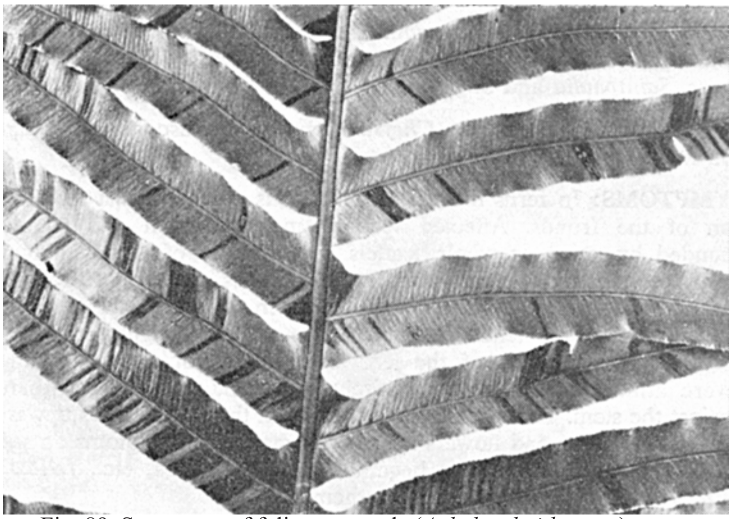

Fig. 89. Symptoms of foliar nematode (*Aphelenchoides* spp.) infestation on a fern frond. Affected sections are bounded by veins. NSW Dept. of Agric.

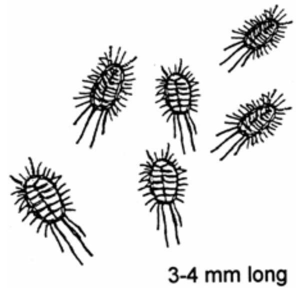

Fig. 90. Longtailed mealybugs *Pseudococcus longispinus*).

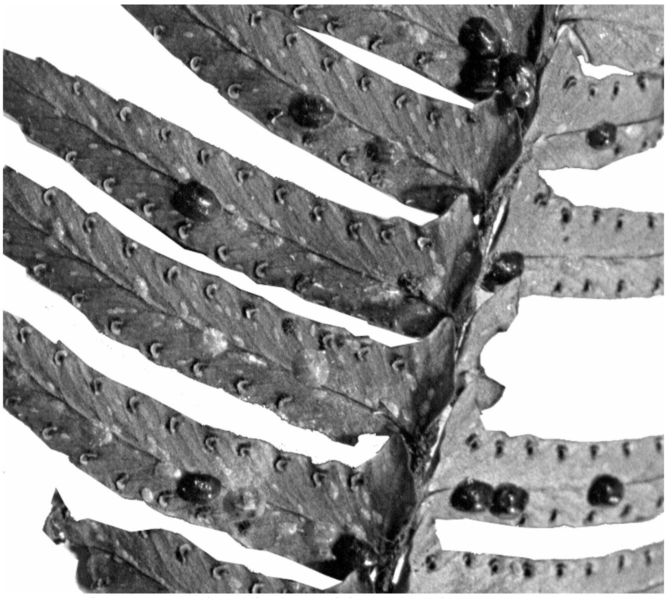

Fig. 91. A soft scale (Coccidae) on a fern.

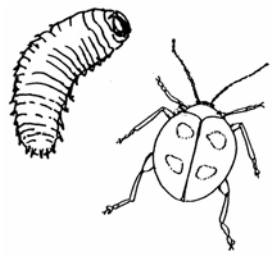

Fig. 92. Staghorn fern beetle (*Halticorcus platycerii*).
Left : Larva (about 8 mm long).
Right : Adult (about 3 mm long).

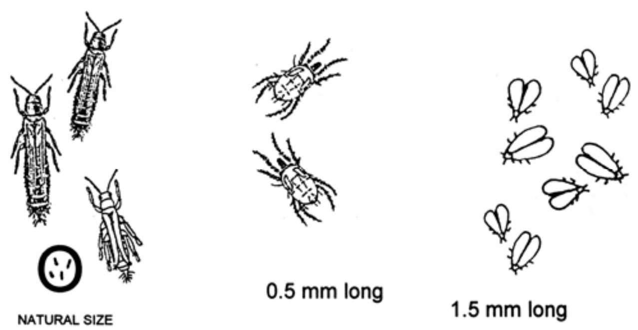

Fig. 93. ***Left :*** Greenhouse thrips (*Heliothrips haemorrhoidalis*).
Centre : Twospotted mite (*Tetranychus urticae*).
Right : Greenhouse whitefly (*Trialeurodes vaporariorum*)

Fig. 94. Typical tag on a soft tree fern (*Dicksonia antartica*).

Ferns

Filicinae, Pteridophyta

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial leaf spot, blight (*Pseudomonas* sp.) causes dark leaf spots or irregular large dead areas with watersoaked margins and can be damaging in very wet conditions (Bodman et al. 1996).

FUNGAL DISEASES

Damping off (various fungi): ***Grey mould*** (*Botrytis cinerea)* causes ***prothalli*** to rot. Spores should be sown in pasteurised media or in an equivalent disease-free media. See Greenhouses N 22, Seedlings N 66.

Fungal leaf spots (various species, *Botrytis cinerea, Myrothecium, Pseudocercospora)* develop on many ferns. ***Grey mould*** (*Botrytis cinerea*) may cause leaf spotting on a range of ferns and other plants. ***Pseudocercospora sp.*** causes circular brown leaf spots commonly on *Nephrolepsis*; leaflet drop may occur (Bodman et al. 1996). See Annuals A 5, Greenhouses N 22.

Root, crown and stem rots (various species) have been recorded on a range of ferns.

> ***Rhizoctonia blight*** (*Rhizoctonia solani*) causes brown irregular ***foliage rots*** of ferns in wet crowded conditions. Fine web-like fungal strands grow over affected areas.

> ***Others: Anthracnose*** (*Colletotrichum gloeosporioides*) is a severe disease of ***leatherleaf fern*** (*Rumohra adiantiformis*) overseas (Leahy et al. 1995).

See Annuals A 6, Vegetables M 7.

PARASITIC PLANTS

Parasitic ferns or epiphytes, eg *Davallia pyxidata* will grow all over *Platycerium superbum.*

NEMATODE DISEASES

Foliar nematodes

Scientific name: Nematoda:
Foliar or leaf nematodes (*Aphelenchoides* spp.)

Host range:

> ***A. fragariae:*** Strawberry, ***ferns*** (> 100 species worldwide, eg maidenhair fern (*Adiantum*), *Blechnum,* brake fern (*Pteris*)); also African violet, anemone, kangaroo paw (*A. manglesii*), begonia, bergenia, *Bouvardia*, cyclamen, fuchsia, gloxinia, *Helleborus, Streptocarpus*, fig (*Ficus carica*), Moreton Bay fig (*F. macrophylla*), rubber plant (*F. elastica*), mainly Liliaceae, Primulaceae and Ranunculaceae.
> ***A. ritzembosi***, eg African violet, chrysanthemum, coleus, impatiens.

Symptoms: ***Nematodes*** are microscopic, worm-like and feed in leaf tissues. ***Leaf symptoms*** vary with the host. Initially, leaf spots are produced but later they may become triangular and bordered by veins. Dead areas (stripes) enclosed by leaf veins may develop on fronds of some species (Fig. 89). Fronds may die prematurely, disease progresses from lower leaves upwards. Do not confuse early symptoms with those caused by fungal leaf spots or cold. ***Flowers*** of African violet, begonia, coleus and chrysanthemum, often decay only on one side.

Overwintering: In soil and debris from infested plants. Infected cuttings, tubers, perennial plants.

Spread: By vegetative propagation from infested plants. Healthy plants become infested by planting in infested soil; soil becomes infested by introduction of infested plants or soil in pots, on machinery, tools, footwear. Nematodes swim up outside of stems in a film of water and are splashed by rain or irrigation on to leaves or adjacent plants.

Conditions favouring: Overcrowded conditions. Moisture on leaves, overhead irrigation. Extended showery weather especially in the cooler months (conditions under which ferns themselves thrive).

Control:

Cultural methods: ***Avoid*** overhead irrigation. ***Mulch*** soil to prevent nematodes overwintering in old infested leaves and from entering lower leaves in spring. Practise ***crop rotation***.

Sanitation: ***Prune out*** affected leaves from mildly infested plants, destroy severely infested plants unless of special value. ***Sanitation practices*** are important in the control of foliar nematodes on plants such as ferns and African violets which may be injured by the nematicidal sprays used on hardier plants, eg chrysanthemums.

Biological control: Nematodes are controlled to some extent in nature by **natural enemies**, eg parasitic fungi.
Resistant varieties: Species vary in **resistance**.
Plant quarantine: **Isolate new stock** until nematode-freedom is confirmed.
Disease-free planting material: Purchase nematode-free plants. **Do not propagate** from infested plants, if this is unavoidable, take tip cuttings from the tops of long vigorous shoots or treat infected plant parts in hot water (some plant damage may occur). Plant **nematode-free** plants, tip cuttings or treated setts in **nematode-free** media/soil.
Physical and mechanical methods: To prevent nematodes swimming from pot to pot in drainage water, hold pots on **wire-mesh bench tops**. Benches, tools and soil should be **disinfected**. **Pasteurise** cutting beds.
Pesticides: Affected parts should be **pruned out** and destroyed before treatment. Some ferns are **sensitive to pesticides**, always test on a few plants prior to large scale treatments. Systemic granular **nematicides** may be scattered over the soil surface of potted plants outdoors, or sprays applied to the foliage, at the first sign of infestation. Regular follow up treatments may be necessary to keep plants free of nematodes.

Others:
Spiral nematode (*Helicotylenchus dihystera*), ***root lesion nematode*** (*Pratylenchus brachyurus*) and other species have been associated with ***bracken fern*** (*Pteridium esculentum*). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Bracken aphid (*Shinjia orientalis*) infests crosiers, deforming fern fronds.
Maidenhair fern aphid (*Idiopterus nephrelepidis*) is dark green (almost black), with white legs and feeds on many fern species and possibly also cyclamen and Cape primrose (*Streptocarpus* sp.) causing **fronds** to curl up and turn black.

See Annuals A 7, Roses J 4.

Caterpillars (Lepidoptera) chew fern fronds and crosiers, most have a wide host range.

Common caterpillars:
- Cutworms (Noctuidae)
- Ivy leafroller (*Cryptoptila immersana*)
- Lightbrown apple moth (*Epiphyas postvittana*)
- Looper caterpillars (*Chrysodeixis* spp.)
- Painted apple moth (*Teia anartoides*)

An Australian butterfly (*Hypochrysops theon medocus*, Lycaenidae): Young caterpillars feed in galleries in rhizomes of the fern (*Drynaria quericifolia*) occupied by colonies of a small ant (*Iridomyrmex cordatus*). Older caterpillars feed at night on fronds and shelter during the day at fern bases. Pupae are found amongst debris or partly concealed in the rhizomes. This fern is the only known food plant of an Australian butterfly outside the Angiospermae and Gymnospermae (Common 1981).

Elkhorn spore caterpillar (*Calicotis crucifera*, Oecophoridae) webs the sporangia of staghorns and elkhorns (*Platycerium* spp.). Caterpillars are tiny, and tunnel and feed inside the brown spore pads causing **frond tips** to brown and shrivel. Caterpillars are difficult to find and if exposed quickly cover themselves with spore cases. Damage is often mistaken for a fungal disease. The fully-fed caterpillars pupate under cover of the spore cases. Control measures may be necessary.
Other moths: **Caterpillars** of *Callopistria maillardi* and *Musotima* spp. may defoliate **maidenhair fern** (*Adiantum aethiopium*) and swordfern (*Nephrolepsis*). **Caterpillars** of *Hedraea quadridens*, *Hemichloreis exoterica* and *Idiodes apicata* feed on **bracken fern** (*Pteridium esculentum*).

See Annuals A 8.

Fern mirid (*Felisacus glabratus*, Miridae, Hemiptera) is a minor and sporadic pest of ferns, eg *Pteris* spp. and *Hyolepsis* spp. **Adult bugs** are slender, active with a green body (sometimes brownish), narrow, and about ***4 mm*** long. Antennae and legs are long and thin. Antennae and eyes are dark brown, legs and head are a shiny, pale yellowish-brown. The head may have small red markings. A solitary insect. **Fronds** are damaged by the injection of saliva and the sucking of sap from the developing crosiers resulting in papery patches. Tropical to subtropical regions, mainly coastal. Control is not usually warranted. Hand picking is successful. See Vegetables M 12.

Fern weevils (Curculionidae, Coleoptera)
Large fern weevil (*Syagrius fulvitarsus*)
Maidenhair fern weevil (*Neosygagrius cordipennis*)
Larvae of these weevils tunnel in **stems** causing fronds to wilt and die. See Vegetables M 17.

Mealybugs (Pseudococcidae, Hemiptera):
Longtailed mealybug (*Pseudococcus longispinus*) and also probably **root mealybug** (*Rhizoecus falcifer*) and **tuber mealybug** (*P. affinis*). Tuber mealybug attacks many plants and is found on all parts of the plant; it is considered to be the most ***important underground mealybug*** in Australia. Mealybug populations also often go unnoticed until large numbers build up (Fig. 90) They are difficult to control and are the ***most common and serious pests of ferns indoors.*** See Greenhouses N 25.

Scales (Hemiptera) occur in sheltered parts and on fronds (do not confuse scales with fern sporangia).

Armoured scales (Diaspididae): **Fern scale** (*Pinnaspis caricis*) is a ***destructive scale*** found amongst the brown sporangia and can cause ferns to die within one season. ***Adult females*** are white and about 1.5 mm long. Fronds of staghorn, elkhorn and birds nest fern develop yellow spots and dieback. **Oleander scale** (*Aspidiotus nerii*) infests ferns and other plants. ***Adult females*** are white to brownish, circular and 1-2 mm in diameter. See Citrus F 39, Oleander K 104.
Soft scales (Coccidae) are common on ferns (Fig. 91). **Nigra scale** (*Parasaissetia nigra*) is a leathery, oval, raised, black waxy scale about 5 mm long. Nymphs settle on young shoots and along the midribs of leaves. Young scales frequently lodge on adult coverings. Nigra scales are easily dislodged so can be removed

by hand. See Custard apple F 52. ***Soft brown scale*** (*Coccus hesperidium*) is perhaps the ***most common and destructive scale*** of ferns, they feed on midribs, leaf stalks and stems. ***Others:*** ***Hemispherical scale*** (*Saissetia coffeae*), ***white wax scale*** (*Gascardia destructor*). See Citrus F 41.

The most serious damage caused by soft scales is the ***sooty mould*** which grows on the vast quantities of ***honeydew*** produced and which also attracts ***ants***. Scales are attacked by ***many natural enemies*** which restrict populations. After infested parts have been pruned out, ferns may be sprayed/washed with soap or other ***insecticides***. Oil sprays may damage fronds. Pots may be treated with granular soil treatments (outside during the warmer months). See Citrus F 40.

Staghorn fern beetle (*Halticorcus platycerii,* Chrysomelidae, Coleoptera) damages staghorn and elkhorn (*Platycerium* spp.) especially during late summer and autumn. ***Beetles*** are hemispherical, black with 4 orange spots, and are about ***3 mm*** long (Fig. 92). Females insert eggs into fronds. ***Larvae*** are orange and about ***8 mm*** long with a black head and legs. ***Fronds:*** Beetles eat out regular cavities usually on the upper surface of fronds, spoiling their appearance. Larvae cause more serious damage tunnelling inside fronds, especially near the tips, until most of the internal tissues are eaten. ***Soft rot bacteria*** invade injured tissue and fronds die and fall prematurely. ***Sanitation:*** Search periodically for adults, remove by hand. While larvae are still inside frond tips, cut off and destroy affected tips early in summer as soon as damage is noticed. ***Insecticides*** do not kill larvae feeding internally and are directed towards killing the beetles. See Trees K 14.

Thrips (Thripidae, Thysanoptera): ***Greenhouse thrips*** (*Heliothrips haemorrhoidalis*) and ***onion thrips*** (*Thrips tabaci*) may infest ***frond undersurfaces*** (Fig. 93) which become silvery and covered with black dots of excreta. See Greenhouses N 24, Onion M 68.

Twospotted mite (*Tetranychus urticae*) can ***seriously damage ferns*** if unnoticed for a time (Fig. 93). ***Fronds*** become sandy coloured and webbing may be visible. See Beans (French) M 29.

Whiteflies (Aleyrodidae, Hemiptera) ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*) and other species may infest ***frond undersurfaces*** (Fig. 93). See Greenhouses N 24.

Others: ***Staghorns*** in particular are very susceptible to attack by ***European earwig*** (*Forficula auricularia*), ***millipedes*** (Diplopoda), and ***slaters*** (Crustaceae) as in addition to providing food and shelter, they provide attractive breeding places. ***Also*** ***black field cricket*** (*Teleogryllus commodus*), ***black vine weevil*** (*Otiorhynchus sulcatus*) and ***passionvine hopper*** (*Scolypopa australis*) may infest ferns.

SNAILS AND SLUGS

Various species feed on ferns, eg ***common garden snail*** (*Helix aspersa*), ***brown slug*** (*Deroceras parnormitanum*), ***reticulated slug*** (*D. reticulatum*), ***garlic snail*** (*Oxychilus alliarus*), ***orchid snail*** (Zonitidae), a ***small spiral snail*** (*Cochlicella ventricosa*) and ***red triangle slug*** (*Tribinophorus graeffei*) (Hocking 1980). See Seedlings N 70.

VERTEBRATE PESTS

Birds may feed on soft succulent fern growth and ***possums*** may eat young crosiers of tree ferns (*Dicksonia*).

Non-parasitic

Environment: ***Light:*** Most ferns prefer dappled or filtered light. Leaves are easily damaged by too much sun. ***Temperatures:*** Sudden exposure to low temperatures, eg during transport, or being near heaters, may cause fronds to brown and die. Avoid temperature extremes of hot and cold, transport between 15-21^{o}C. The first fronds of tree fern (*Dicksonia antartica*) may be damaged by ***wind*** but those produced later usually remain green and healthy. ***Underwatering*** causes ferns to die, water frequently but provide good drainage, avoid overwatering especially at lower temperatures. ***Humidity:*** Mist ferns to maintain humidity (even hardy ferns prefer a humid atmosphere). Ferns do not like ***sudden changes*** in conditions, draughts, light, temperature. Hanging baskets on exposed verandahs may be damaged by sun, wind, lack of water and low humidity.

Exploitation: The intention of various Wild Flowers and Native Protection Acts is to ***prevent excessive removal*** of tree and other ferns from public and private land (Fig. 94). Tree ferns may be collected only after permits have been issued to land owners by the appropriate government authority, eg the Forests Commission in Victoria. Departments issuing the permits keep records of the number of ferns removed from bushland areas (Watson and Patzopoulos 1993). ***Soft tree fern*** (*Dicksonia australis*) is heavily exploited because it can be chain-sawed off at the base (adventitious roots regrow from the base when planted) and they show the least stress in the short term after planting ***but may die slowly over months***.

Nutrient deficiencies, toxicities: Ferns are ***more adaptable*** to a ***range of acid/alkaline pHs*** than is often realised (Handreck 1991).

Weed potential: Although some ferns are delicate and difficult to grow, some are ***weeds***, the worst in Australia being the ***native perennial bracken*** (*Pteridium esculentum*). Stock may be ***poisoned*** by eating fresh fronds or rhizomes, or when large amounts are included in hay (McBarron 1983). ***Poisonous effects*** include unknown factors affecting cattle and sheep causing haemorrhages, thiamine deficiency in horses and pigs and cancer-producing factors in cattle and sheep. New fronds and spores of bracken contain ptaquiloside, a cancer-producing chemical (Emsley 1994). British health authorities have issued warnings that people living near bracken should wear face masks when bracken is shedding spores (O'Neill 1996).

Others: ***Fungus gnats*** (Sciaridae) and ***ants*** (Formicidae) are attracted to ***honeydew*** produced by aphids, mealybugs, soft scales and whiteflies.

WEEDS

Weeds are not a major problem in fern plantings as most ferns like filtered light which is usually unsuitable for broadleaved and grass weeds. However, ***mosses*** and ***liverworts*** may grow. See Turfgrasses L 15, Greenhouses N 27 respectively.

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State/Territory Departments of Agriculture/Primary Industry eg
Bud and Leaf Nematodes (Vic Agnote)
Ferns and Allied Plants (SA Adel. Bot. Gard. Leaflet)
Leatherleaf Fern (Qld Farmnote)
Propagating Ferns from Spores (Vic Agnote)
Propagation of Ferns by Tissue Culture (Vic Agnote)
The Foliar Nematode in Ferns (Vic Agnote)
Association, Journals etc.
Fern Societies of various States/Territories (various Bulletins)
GrowSearch (database Qld DPI)
Society for Growing Australian Plants (Fern Study Group)

See Preface xii, House plants N 35, Nurseries N 51

MANAGEMENT

There is such a great number of different ferns it is not possible to generalise, eg there are large and small ferns, some are hardy, others are very susceptible to frost or drying out. They cover quite a wide range of preferred temperatures. In general, fine foliaged ferns, eg *Nelphrolepis* and *Pteris*, need intermediate conditions of 13-18^{o}C. Ferns with coarser foliage, eg *Platycerium,* need more warmth, eg 15-21^{o}C. It also depends on where they are to be grown, eg indoors or outdoors. Only propagate vegetatively from ***plants free*** from scale, mealybugs and other pests and diseases. Ferns may be ***propagated*** by ***asexual propagation***, eg division (rhizomes or sections of runners), bulbils (small plants that form on the surface of mature fronds) and by tissue culture or by ***sexual propagation***, eg spores. Soft tree fern (*Dicksonia antartica*) is propagated by cutting the trunk and by spores. ***Provide appropriate cultural conditions***, eg humidity, light, ventilation, potting mix, fertiliser, watering. ***Sanitation*** measures include pruning out infested fronds, eg ferns such as *Blechnum,* may be ***pruned*** back to the rhizome. Rhizomes should be ***monitored*** regularly, especially the very hairy ones, for insects such as aphids and scale which are hidden among the hairs and cause considerable damage. Pests overlooked on a rhizome can later reinfest fronds. Remove all dead material from plants and greenhouses regularly to reduce buildup of *Botrytis*. ***Biological control agents***, eg predatory ladybird beetles and parasitic wasps, may be purchased to control mealybugs, which are probably the ***worst pest of ferns***. Fern fronds are very sensitive to ***pesticides***. Granular insecticides may be used outdoors. For cut foliage ***harvest*** when fronds are green and healthy, cut off any woody stem bases present and place in water with ***preservative*** (asparagus fern does not like sugar). Replenish water regularly. Ferns may be misted regularly during hot weather (Jones and Moody 1993). Individual ferns require specific care (Nowak and Rudnicki 1990).

CHECK CURRENT
REGISTRATION
OF PESTICIDES
PRIOR TO USE

Transverse ladybird
(*Coccinella transversalis*)
5 mm long

Common spotted ladybird
(*Harmonia conformis*)
7 mm long

Fruit and Nuts

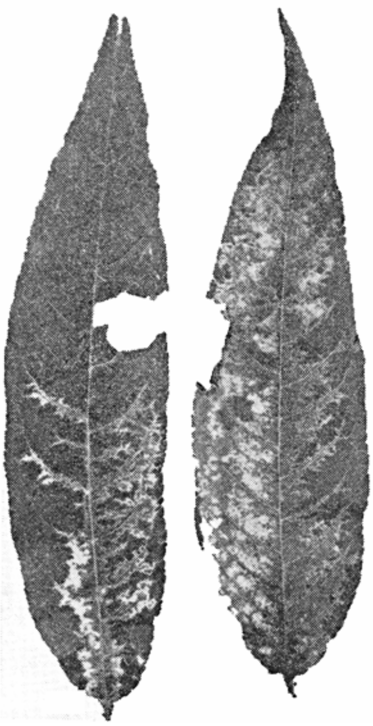

Fig. 95. *Left* : Line patterns on Halford peach leaves caused by *Prunus* necrotic ringspot virus. ***Right :*** Symptoms of russet ring virus on Granny Smith apple. Dept. of Agric., NSW

Fig. 96. Anthracnose (*Colletotrichum musae*) on banana.

FRUIT AND NUTS F 1

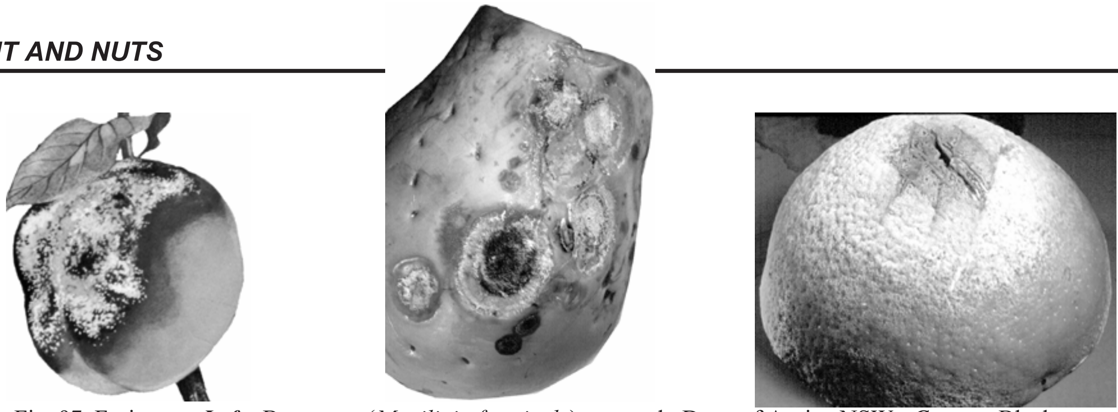

Fig. 97. Fruit rots : ***Left :*** Brown rot (*Monilinia fructicola*) on peach. Dept. of Agric., NSW. ***Centre :*** Black rot (*Phoma caricae-papayae*) on ripe pawpaw. ***Right :*** Penicillium mould (*Penicillium* spp.) on citrus.

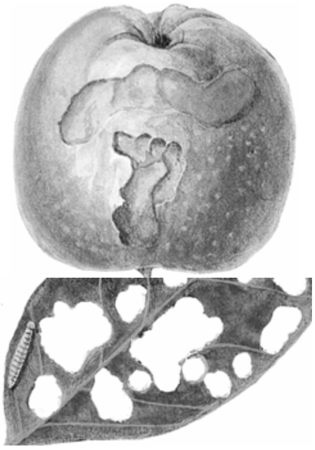

Fig 98. Lightbrown apple moth (*Epiphyas postvittana*) caterpillars feed on fruit surfaces and leaves. Dept. of Agric., NSW.

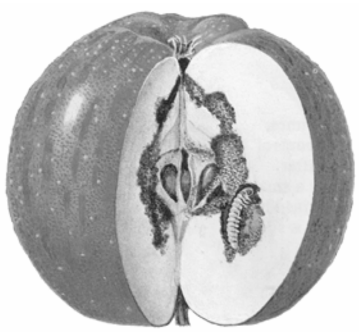

Fig. 99. Internal-feeding caterpillars, eg codling moth (*Cydia pomonella*) caterpillars feed inside fruit. Dept. of Agric., NSW.

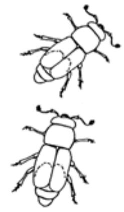

Fig. 100. Driedfruit beetles (*Carpophilus* spp.) about 3 mm long.

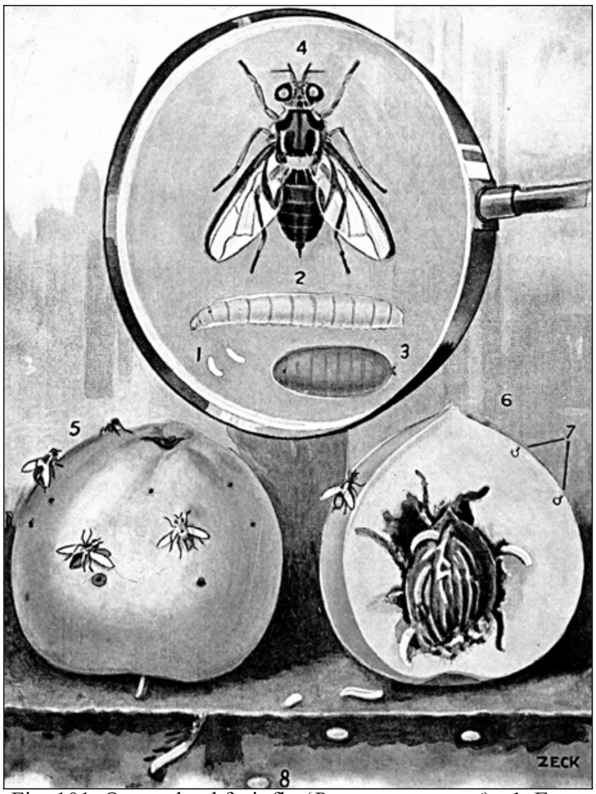

Fig. 101. Queensland fruit fly (*Bactrocera tryoni*). **1**. Eggs. **2.** Larva or maggot. **3.** Pupa. **4.** Adult fly. **All enlarged x 5.** **5.** Apple showing punctures or stings where eggs have been deposited. **6.** Peach showing decay and tunnels of the maggots. **7.** Egg clusters beneath the skin. **8.** Pupa in the ground. All actual size. Dept. of Agric., NSW.

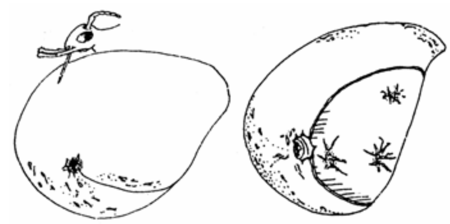

Fig. 102. Fruitpiercing moth (Noctuidae) (with a wingspan of about 100 mm), sucks juice from fruit.

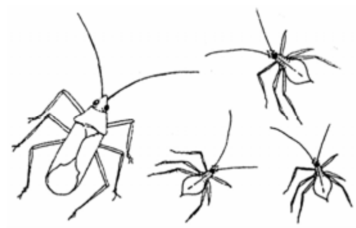

Fig. 103. Fruitspotting bug (*Amblypelta nitida*), about 15 mm long, and nymphs.

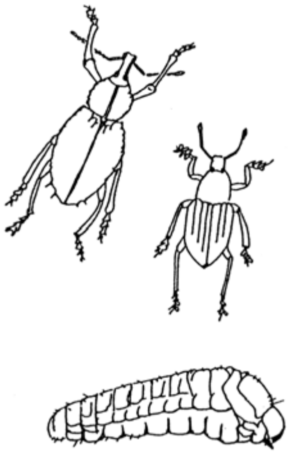

Fig. 104. Fruit-tree root weevil (*Leptopius squalidus*) 20 mm long) and larva (up to 25 mm long).

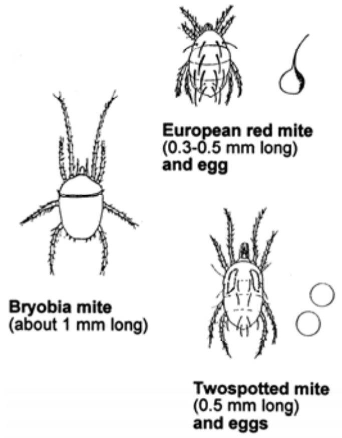

Fig. 105. Bryobia mite (*Bryobia rubrioculus*), European red mite (*Panonychus ulmi*), twospotted mite (*Tetranychus urticae*).

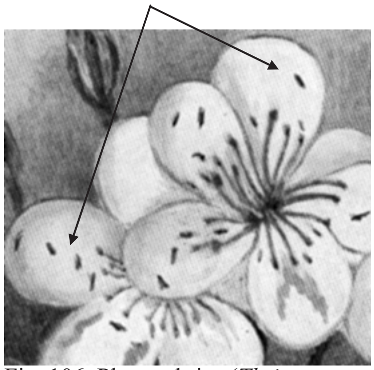

Fig. 106. Plague thrips (*Thrips imaginis*) on apple blossom. Dept. of Agric., NSW.

Fig. 107. Frosted scale (*Eulecanium pruinosum*) on plum twigs. Dept. of Agric., NSW.

Fig. 108. ***Left :*** Apple damaged by birds. ***Right:*** A fruit bat.

Fig. 109. Frost damage to Santa Rosa plums.

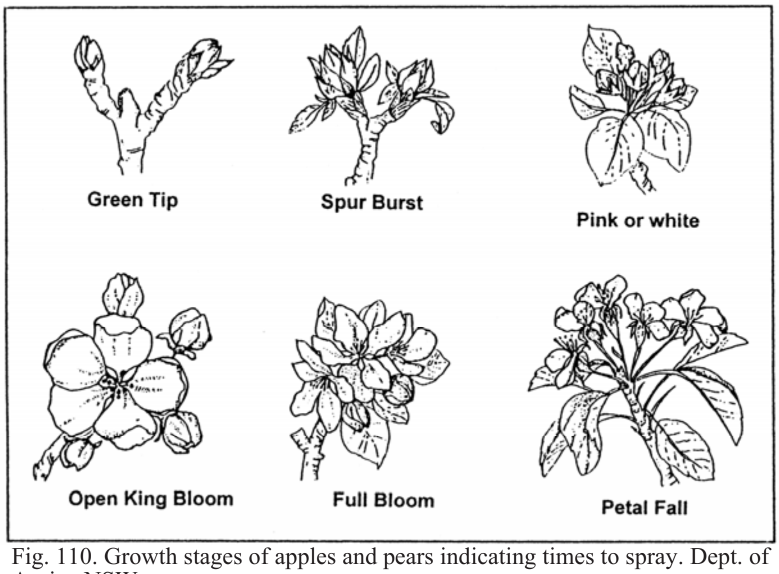

Fig. 110. Growth stages of apples and pears indicating times to spray. Dept. of Agric., NSW.

Fruit and Nuts

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Host range: Most fruit crops may be infected with one or more virus or virus-like diseases. They tend to be host specific but a few, eg *Prunus* necrotic ringspot virus, extend their host range to closely related ornamental species.

Symptoms: In addition to the development of symptoms on ***leaves, trunks and fruit***, virus diseases reduce both ***fruit quality and yield***. Symptoms (Fig. 95) vary with the virus, cultivar, growth stage and temperature, and these are described under individual fruit crops.

Overwintering: In infected hosts, propagation material, nursery stock. Generally seed is virus-free, but there are exceptions, eg *Prunus* necrotic ringspot is sometimes seedborne.

Spread: All viruses are spread by ***vegetative propagation material***, eg infected buds, grafts, cuttings, or rootstocks. Also by natural ***root grafts*** within an orchard. By ***introduction*** of infected plants, plant parts (buds, grafts, clonal rootstocks) into orchards. Occasionally by ***seed*** used to grow rootstock (*Prunus* necrotic ringspot is sometimes seedborne). Occasionally by ***pollen*** (*Prunus* necrotic ringspot). Not usually by contact between plants and not usually on secateurs. Virus diseases of deciduous fruit trees are not usually spread by insects. ***Some viruses*** of ***some fruit crops***, eg herbaceous fruits such as strawberry, and citrus, are spread by ***insects***.

Conditions favouring: Symptoms are often more apparent, or only apparent, during cooler weather in spring or autumn. Later growth may be symptomless.

Control: There is no cure for infected plants, the aim is to prevent infection and minimise losses.

Sanitation: Remove and destroy infected plants in herbaceous fruit crops, eg strawberry.

Resistant varieties: Cultivars vary in ***resistance***.

Disease-free-planting material: Only plant ***certified virus-tested planting material***, eg fruit crops propagated from certified virus-tested sources. The Fruit Variety Foundation ***(FVF)*** provides such material to state departments which supply budwood for foundation stocks for some fruit crops. If virus-tested material is not available then use the best available which is visibly free from diseases and pests. Because there are no known vectors of virus diseases of ***deciduous fruit trees*** in Australia, virus-tested planting material will remain free for life from the viruses for which they have been tested, unless they are reworked with infected material or root grafts develop in orchards. On other fruit crops, if viruses are spread by insects, certified virus-tested planting material will become infected after planting out. However, the ***increased yield and quality*** from the use of certified virus-tested planting material justifies its use if it is available.

Pesticides*:* The use of insecticides to control any insect vectors of virus diseases of tree crops is impractical. There are exceptions.

BACTERIAL DISEASES

Bacterial canker (*Pseudomonas syringae* pv. *syringae*) is a ***major disease*** of stone fruit trees but may also affect pear, citrus, ornamentals and other plants. The most characteristic symptom, although not always the most common, is the formation of cankers and gumming on branches and trunks. See Stone Fruits F 124.

Bacterial soft rot (*Erwinia* spp.) may cause rotting of fruit, eg avocado and banana. See Vegetables M 5.

Crown gall (*Agrobacterium* sp.) may be a ***serious disease*** of stone fruit nursery stock causing large ***galls*** up to the size of a football to develop at the ***base of stems***. It may also affect other fruit crops, eg currants, grapevine, raspberry, trailing berries. See Stone Fruits F 125.

FUNGAL DISEASES

Anthracnose

Scientific name/Host range:

Ascomycetes: *Glomerella cingulata, Diplocarpon, Elsinoe* and *Gnomonia* on ***ornamentals***, eg camellia, ***fruit***, eg avocado, apple, grape, walnut.

Imperfect stage: *Colletotrichum* (*Gloeosporium*), *Coryneum, Marssonina, Melanconium* and *Sphaceloma,* cause anthracnose diseases of ***ornamentals***, eg anemone and ranunculus, ***vegetables***, eg bean, brassicas, celery, cucurbits, tomato, ***fruit***, eg citrus, custard apple, grape, mango, passionfruit, pawpaw, stone fruit, ***field crops***, eg cotton. Some anthracnose diseases are host specific.

Symptoms: Anthracnoses are diseases of ***leaves, stems or fruit***, and appear as small or large dark spots or slightly sunken lesions with a raised rim. Plants may be attacked any time from the ***seedling*** stage to ***maturity*** in the ***field*** and ***postharvest. Leaf spots*** are oval or circular and at first yellow-green to dull white with a narrow brown border. Small black spots, the fruiting bodies of the fungus, are formed later on affected areas. Stem cankers may girdle plants causing ***twig dieback.*** In some ***fruit***, spots with raised corky surfaces appear. One or more of these may become active and enlarge rapidly in the skin (Fig. 96) and underlying flesh, and within a few days the fruit may rot and drop. Depending on the host, a range of spore types may be produced on the fruit or vegetable, eg avocado, beans and cucurbits, may develop pink spores on spots. ***Some fruit and vegetable spots are dormant, and only become active after harvest when fruit ripens or is injured, even though infection took place in the field***.

Overwintering: As a ***saprophyte*** (using dead organic matter for food) in cracks of immature bark, fruit bearing twigs, in dead leaves or twigs, mummified fruit on the tree and on the ground. Also in infected hosts, crop debris, dead leaf bases, bulbs from earlier seasons and seed. Anthracnose can be isolated from orchard plants even though there are no visible symptoms. In spring surviving mycelium produces spores.

Spread: Spores are spread by rain/irrigation, wind, insects, by adherence to animals, clothes, machinery and tools moving through wet crops, and possibly birds from fruit to fruit and from tree to tree. Propagation from infected plants, introduction of infected planting material, eg seed, seedlings and vegetative propagation material.

Conditions favouring: Surface moisture (dew, rain) that persists for 10 or more hours, and by air temperatures > 15°C. Closely planted crops with dense canopies. Prolonged wet warm weather in ***the field, during harvest and postharvest.*** Fruit from older, unsprayed orchards (leaves, twigs and fruit are readily infected and produce spores).

Control: Do not market vegetables from diseased crops, as vegetables unblemished when picked may develop disease postharvest in transit. ***Monitor*** disease regularly in field and postharvest.

Cultural methods: For herbaceous crops practise ***rotations*** of 3-4 years. Provide infected debris time to break down between crops. Ensure good ***drainage and ventilation***, and rapid drying of foliage by pruning lower limbs so that the canopy is at least ***500 mm*** above ground level. Avoid unnecessary wetting of foliage and fruit and working in fields when wet. Time overhead irrigation to minimise periods of leaf wetness, which favours infection. ***Harvest fruit*** when recommended so it will ripen evenly and at the correct rate. Keep harvested fruit out of direct sunlight to prevent flesh overheating.

Sanitation: Destroy or incorporate crop debris by deep ploughing or burning, destroy alternative hosts and unmarketable produce. During winter or before flowering, ***prune out*** and destroy any dead wood, foliage and mummified fruit on the tree. ***Collect and destroy*** any mummified fruit on the ground. During the growing season regularly remove infected fruit both on the tree and fallen fruit on the ground .

Resistant varieties: Varieties vary in ***resistance***.

Plant quarantine: On some hosts, eg anemone, anthracnose may be a ***quarantinable disease***.

Disease-free planting material: Plant ***certified anthracnose-free planting material*** (cuttings, seed, tubers) if available, otherwise select vegetative propagation material and seeds only from symptom-free plants, and hot water treat seed and tubers. Store and handle seed to ***avoid contamination***.

Physical and mechanical methods: Cool fruit, transport and store at appropriate temperatures.

Pesticides: If anthracnose has been a problem previously, ***regular protectant field sprays*** may be needed for economic control. Before packing treat products with appropriate fungicide. ***Control insect pests***, eg fruit fly and fruit spotting bugs, which may damage fruit.

Cankers

Cankers (*Botryosphaeria*, *Glomerella* and other fungal species) may cause dead sunken localised cankers on ***branches, twigs or trunks*** of tree fruits. See Trees K 5.

Downy mildews

Downy mildews (Peronosporaceae) may be ***serious diseases*** of some fruit crops, eg grapevine. Pale yellow lesions develop on ***leaf uppersurfaces*** while corresponding lesions on leaf undersurfaces produce a downy growth. ***Flowers, fruit, stems*** may also be affected causing crop loss. See Annuals A 5, Grapevine F 59.

Fruit rots:

Fruit rots: Most fruit rotting fungi have a wide host range. Some only attack a particular species. ***Postharvest diseases*** are described by Beattie et al. (1989).

Alternaria rot (*Alternaria alternata*) affects citrus, mango, ***many other fruit***, and causes many other diseases of a wide range of plants.

Anthracnose diseases (*Colletotrichum* spp. etc) in the ***field*** and ***postharvest*** (see above).

Aspergillus fruit rot, black mould (*Aspergillus niger*) causes soft watery spots on stem ends of fruits eg cashew before harvest. Dark purple to black powdery spores develop on the spots, fruit may fall prematurely or mummify on the tree. It can multiply in ***spent flowers*** caught in foliage or in caterpillar webbing. Fruit infection occurs through ***wounds*** or by ***direct penetration*** when dead flowers or tissue from flowers are in contact with fruit.

Brown rot (*Monilinia fructicola*) affects ***stone fruits*** (Fig. 97). See Stone fruits F 125.

Grey mould (*Botrytis cinerea*) may attack many fruit crops eg strawberry, in the ***field*** and ***postharvest*** in cool wet conditions. ***Flowers, fruits and fruit stalks, and twigs*** may rot. In humid conditions patches of grey powdery spores develop on the surface of affected areas. Black hard sclerotia may develop. Postharvest the fungus can spread to other fruit in containers ***(nesting)***. See Greenhouses N 22.

Mucor rot (*Mucor piriformis, Mucor* spp.) initially causes a light brown soft watery ***postharvest*** rot and later a white whiskery fungal growth soon covered with black spores. A similar disease to *Rhizopus* but may develop at 0°C while *Rhizopus* cannot develop at < 4°C. It is a soilborne fungus, infecting ***fallen fruit during*** and ***after harvest.***

Penicillium moulds, blue or green moulds (*Penicillium* spp.) appears as soft pale brown watery spots, which enlarge rapidly to rot the whole fruit. Under warm moist conditions ***blue-green spore masses*** develop on affected areas (Fig. 97). Fruit has a ***musty smell***. Fruit is contaminated during harvesting or packing, infections usually occur through ***wounds*** caused by sunburn, chilling or prolonged storage under cool conditions. *Penicillium* spp. infect damaged or fallen fruit on the orchard floor. Spores develop on these fruit, contaminate the soil and are blown by ***wind*** to fruit on the trees.

Rhizopus soft rot, transit soft rot (*Rhizopus stolonifer, R. oryzae,* Eumycetes) is a minor disease of greenhouse crops. These species together with *R. nigricans* and *R. arrhizus* may attack many fruits ***postharvest*** especially stone fruit causing a soft rot, white fungal growth and black spore heads. Storage organs may also be attacked. ***Petals*** collapse with a wet rot which extends into the heart of the flower. The fungus invades flowers and fruit through ***injuries***. Inoculum builds up on flower trimmings if these are left in or around packing sheds.

Yeasty rots: Geotrichum candidum affects citrus, cucurbits, tomato, ***Saccaromyces sp.*** affects pineapple, cucurbits, tomato.

Others: Phytophthora sp. affects citrus, pineapple, ***black rot*** (*Phoma caricae-papayae*) infects papaw (Fig. 97), ***thielaviopsis paradoxa*** affects pineapple.

Overwintering: Most are common inhabitants of ***decaying organic matter***, eg crop debris, discarded rotting fruit, and air. The main source is diseased fruit in and around packing sheds.

Spread: Spores are spread by wind and air currents, by water splash, and on dust. By mycelium growing from fruit to fruit ***(nesting)*** during storage and transport.

Conditions favouring: ***Fruit injury*** during harvesting and handling, prolonged warm, moist conditions during harvesting, transport and storage (packaging in plastic bags), decaying fruit. Heavy rain just before or during harvest may favour fruit cracking, soil adhering to fruit. High storage temperatures also favour disease development.

Control: Avoid skin injury or bruising of fruit.

Cultural methods: Harvest during ***dry weather***. ***Cool fruit promptly*** after harvest to restrict disease development. Provide cool conditions for transport and storage. Market fruit quickly. Avoid prolonged storage. Do not store fruit from infected crops.

Sanitation: Remove and destroy debris from crops, eg prune out brown rot mummies regularly. Remove rejected fruit daily from packing sheds, bins and surrounds as it produces spores which are spread by air currents and on dust. ***Fruit, soil and bulk bins are the major source of infection.*** During harvest contaminated soil is transported with the bulk fruit to the packing shed and loaded into fruit dumps, dips or recirculating drench solutions, and these are a major source of spores during and between seasons. ***Fruit infection can occur*** during harvesting, grading, packaging and storage as a result of infection through ***wounded skin*** or an open calyx cavity. Discard fruit with growth cracks and other injuries. Remove and clean waste fruit and moulds from bins, then disinfect bins to kill remaining fungal spores before fruit harvest. Use orchard trailers to carry fruit to packing sheds then restrict entry of machinery into sheds to reduce soil and dust contamination. Clean and disinfect sheds and equipment regularly with steam or high pressure water. Keep graders clean to avoid fruit injury and avoid overhandling fruit.

Biological control: Various ***yeasts***, eg *Pichia guilliermondii*, ***bacteria***, eg *Bacillus subtilis*, *Pseudomonas cepacia*, and ***other microorganisms***, are antagonists of blue mould (*Pencillium* sp.), *Rhizopus* rot (*Rhizopus stolonifer*) and other postharvest diseases of fruit and vegetables (Wisniewski and Wilson 1992).

Physical and mechanical methods: Cool fruit as recommended immediately after harvest. Store and transport at recommended temperatures and humidity in the correct atmosphere and packaging system. ***Controlled atmosphere (CA)*** aims to keep fruit alive but reduces the rate of living processes. ***CA*** storage helps prolong shelf life of some fruit and can control some insects pests. ***CA*** storage aims to hold fruit under refrigeration at low oxygen and/or high carbon dioxide levels. ***Modified atmosphere packaging (MAP)*** is a flexible ***small scale means*** of extending shelf life of fresh foods. The is no active control over the atmosphere composition, which starts from a defined initial gas composition, but is subject to changes due to the products of physiological activity and characteristics of gas atmosphere, temperature and relative humidity. ***Vacuum packaging (VP)*** is a special type of ***MAP***. ***MAP*** and ***VP*** slow down metabolic activity of a product and any microorganisms present both spoilage and pathogens by limiting the oxygen supply and applying an elevated level of carbon dioxide. Some ***packaging materials***, eg wood wool, should not be used when some fruit, eg mango, are to be cooled, as it can act as a source of infection. It can also cause surface scratching. ***Food may be coated*** with an edible material that protects it from oxygen and moisture, seals in aromas while excluding unpleasant ones.

Pesticides: For some fruit rots, eg grey mould, it may be necessary to ***spray during blossoming*** if wet weather occurs. For other fruit rots it is necessary to apply registered postharvest fungicide treatments. Many postharvest fruit rots have some resistance to fungicides. ***It is necessary to seek advice*** on how to use fungicides to reduce/delay fungicidal resistance. See Postharvest N 61.

Fungal leaf spots

Fungal leaf spots (*Alternaria*, *Fabraea, Mycosphaerella, Septoria, Venturia,* other species) attack a range of fruit, eg mulberry. In addition to affecting ***leaves*** they may also attack ***fruit and canes***. If many spots are present, leaves appear brown and scorched and will fall prematurely. Plant vigour is reduced. The fruit may also become infected and fall. Yields for the current and next season are reduced. See Annuals A 5.

Powdery mildews (Erysiphales, Ascomycetes) affect many ***fruit crops***, eg apple, grapes. Greyish-white spores typical of powdery mildew develop on ***leaves, shoots, stems, flowers and fruit***. See Annuals A 6, Grapevines F 60.

Root and stem rots, wilts

Armillaria root rot (*Armillaria luteobubalina*) may cause ***serious loss*** of orchard trees of all ages, causing slow decline and death. A whitish creamy fungal growth with a strong mushroom smell is usually present beneath the bark of ***major roots*** and ***trunk base***. Black fungal strands resembling shoe-strings may be visible on roots. In cool wet weather small ***honey-coloured mushrooms*** may form at the base of affected trees. This disease can be serious in ***new orchards*** established on newly cleared land. For some fruit trees ***resistant rootstock*** may be available, eg walnuts. See Trees K 4.

Ashy stem blight, charcoal rot (*Macrophomina phaseolina*) attacks many species. It attacks gooseberry bushes from the top down, branches are attacked one by one, leaves yellow and fall, fruit stops growing and the bush dies. Roots do not seem to be affected. ***Favoured*** by any circumstances that might reduce vigour. See Vegetables M 7.

Damping off (*Cylindrocladium, Fusarium, Phytophthora, Rhizoctonia*, other species) may cause damping off diseases. See Seedlings N 66.

Phytophthora collar, crown and root rot (*Phytophthora* spp., *P. cinnamomi, P. cryptogea, P. nicotianae*) affects ***many fruit***, eg avocado, citrus. Crown rot has a white mouldy appearance in the ground. It can move up into the centre of the tree and cause it to fall over in a few years. ***Avoid excessive moisture*** around the trunk, including saturated soils with poor drainage, mounding soil up around the trunk, excessive weed growth or sinking of the tree after planting to below the level of the soil in the nursery. Keep the ground clean around tree and plant high. Herbicides may be used around the base of the tree. Some varieties are ***resistant***. See Trees K 6.

Rosellinia root rot, white root rot (*Rosellinia necatrix*). See Pome fruits F 110.

Sclerotinia rot (*Sclerotinia* spp.) may affect many species including strawberry. If wet or humid weather persists, watersoaked areas become covered initially with a white fluffy mycelium typical of the disease and eventually with ***irregular black sclerotia*** up to ***10 mm*** across. See Vegetables M 7.

Sclerotium stem rot (*Sclerotium rolfsii*) may attack ***stems*** of various fruit at ground level, eg apple. A white fungal mat grows over affected parts. ***Round sclerotia***, about ***1-2 mm*** across, are produced on the surface of the mycelium, these later turn brown and are hard to see. See Trees K , Vegetables M 8.

Thielaviopsis black root rot (*Thielaviopsis paradoxa*) affects pineapple. See Pineapple F 103.

Wilts: Fusarium wilt (*Fusarium oxysporum*) may attack some fruits, eg banana. See Banana F 23. ***Verticillium wilt,*** black heart (*Verticillium dahliae*) causes wilting and death. ***Woody tissue*** in stems is discoloured. It is usually an economic problem only in young trees 3-6 years old, eg where apricots have been planted after, or interplanted with, infected tomatoes or potatoes. Do not plant ***susceptible crops*** in land that previously grew strawberries, potatoes, tomatoes. See Stone fruits F 127, Vegetables M 9.

Others: Pythium root rot (*Pythium* spp.).

See Vegetables M 7.

Rusts (Uredinales, Basidiomycetes) may affect ***many fruit***, eg stone fruits, especially prunes, trailing berries. Rust pustules may develop on ***leaves, twigs and fruit***. See Annuals A 7.

Wood rots, heart rots (Basidiomycetes)

Pink limb blight (*Corticium salmonicolor*)
Red wood rot (*Trametes cinnabarina*)
Silver leaf (*Stereum* spp.)
Tinder punks (*Phellinus* spp.)
Yellow heart rot (*Schizophyllum commune*)
Yellowish wood rot (*Polystictus versicolor*)

Many wood rot fungi are ***weak pathogens*** which only attack fruit trees suffering from stress and are only important in ***older orchards*** where there may be neglect, borer damage, sunburnt trunks and branches, broken limbs, poor nutrition and pruning techniques, overworking of trees or drought. See Trees K 8.

NEMATODE DISEASES

Many nematodes have been found associated with particular fruit and nut trees. ***Root knot nematodes*** (*Meloidogyne* spp.) may cause lack of vigour and low yields, ***roots*** are covered with small galls about 1 mm across. Roots may branch above the swellings and be a ***tangled mass***. Root systems are reduced in size. ***Other nematodes***, eg ***citrus nematode*** (*Tylenchulus semipenetrans*), ***foliar nematodes*** (*Aphelenchoides* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Black peach aphid (*Brachycaudus persicae*)
Cherry aphid (*Myzus cerasi*)
Citrus aphids (*Toxoptera* spp.)
Green peach aphid (*Myzus persicae*)
Strawberry aphid (*Chaetisiphon fragaefolii*)
Woolly aphid (*Eriosoma lanigerum*)
See Roses J 4.

Borers

Beetle borers (Coleoptera)
Fruit-tree pinhole borer (*Xyleborus saxeseni*)
Longicorn borers (Cerambycidae)
Moth borers (Lepidoptera)
Fruit-tree moth borers (Oecophoridae).
See Fruit F 10.

See Trees K 10, K 11, K 12.

Bugs (Hemiptera)

Many bugs suck juice from ***fruit***, which may become so ***pitted*** and disfigured with exudations of ***gum*** that they are ***unmarketable*** both as fresh and canning fruit. Some also damage ***new growth*** causing wilting and considerable damage.

Coon bug (*Oxycarenus arctatus*)
Fruitspotting bugs (*Amblypelta* spp.) (see Fruit F 10)
Green mirid bug (*Creontiades dilutus*)
Green stink bug (*Plautia affinis*)
Green vegetable bug (*Nezara viridula*)
Harlequin bug (*Dindymus versicolor*)

Leptocoris bug (*Leptocoris mitellata*)
Metallic shield bug (*Scutiphora pedicellata*)
Pale cotton stainer (*Dysdercus sidae*)
Rutherglen bug (*Nysius vinitor*)
Many other bugs, eg ***tea bugs*** (*Helopeltis* spp.), are serious pests of many fruit and nuts in Asia (Com. of Aust., 1996). See Stone fruits F 130, Vegetables M 12.

Caterpillars (Lepidoptera)

Noctuids (Noctuidae): ***Corn earworm*** (*Helicoverpa armigera*) is about 35 mm long, pale green, creamy, red-brown, sparsely hairy with longitudinal stripes. Caterpillars damage ***young shoots and flowers*** and bore into ***young fruit***, eg strawberry. See Sweetcorn M 89. ***Cluster caterpillar*** (*Spodoptera litura*) when fully-grown is about ***40-50 mm*** long and is green to greyish with longitudinal stripes and prominent black triangular markings on each side of the body. Young caterpillars ***skeletonise leaf undersurfaces***, older ones are more solitary and damage ***flowers and fruit***. See Vegetables M 13. ***Cutworms*** (*Agrotis* spp.) are a serious pest of ***herbaceous fruit***, eg strawberry runners. They are greyish-green to brown, about ***45 mm*** long, hide at the base of the plant or in the soil during the day and feed at night and curl up if disturbed. Caterpillars sever stems of ***young heart leaves*** near ground level and may cause heavy losses. They also eat holes in leaves and ***ripening fruits.*** Spraying affected plants and surrounding soil should be effective, See Seedlings N 68. ***Looper caterpillars*** (*Chrysodeixis* spp.) bend their bodies ***into an arch*** when moving. They chew irregular holes, and are difficult to see as their colour resembles that of their food plant. Their presence is usually indicated by the dark brown cylindrical pellets of ***excrement*** on the leaves below them. See Vegetables M 13.

Leafroller moths (Tortricidae): ***Ivy leafroller*** (*Cryptoptila immersana*) is a ***pest*** of many fruit and other crops. See Ivy K 88. ***Lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars are pale green and ***wriggle*** when touched or disturbed, often dropping off the leaf or plant on a ***silken thread***. They form webbing on ***leaves, flowers and fruits*** and can be ***very destructive*** (Fig. 97). See Pome fruits F 112. ***Codling moth*** (*Cydia pomonella*) is the ***major pest*** of pome fruits (Fig. 97). See Pome fruits F 113. ***Orange fruitborer*** (*Isotenes miserana*) is a ***major pest*** of citrus and other plants. See Citrus F 37. ***Oriental fruit moth*** (*Grapholita molesta*) is a ***major pest*** of stone fruits. See Stone fruits F 132.

Others: Painted apple moth (*Teia anartoides*), ***yellow peach moth*** (*Conogethes punctiferalis*).

Caterpillar pests must be ***monitored***. See Annuals A 8, Trees K 13, Vegetables M 13..

Driedfruit beetles

Scientific name: Nitidulidae, Coleoptera: Driedfruit beetles (*Carpophilus* spp.)

Host range: ***Most fruits***, eg apple, apricot, fig, nectarine, peach, trailing berries, and ***vegetables***, especially while they are drying.

Description and damage: ***Beetles*** are small, dark brown elongated, flattened and about ***3 mm*** long with short paler wing covers that do not reach the tip of the abdomen (Fig. 100). They run or fly readily when disturbed. ***Larvae*** are yellowish, slender and up to ***6 mm*** long, light brown head and forked tail. They have 3 pairs of short legs and move quickly when disturbed. ***Fruit loss*** is caused primarily by beetles burrowing and feeding ***within ripening fruit***. At the same time they spread ***fruit rot fungi***, eg brown rot of stone fruit, causing up to ***25%*** crop loss. Beetles rarely penetrate the exposed surface of fruit.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with many overlapping generations each season. All stages can be found at most times of the year. Beetles migrate long distances to ***rotting fruit or vegetables*** and lay white eggs in rotting fruit which is either still hanging on the tree or on the ground. Less commonly they are laid in skin breaks, caused by the attacks of other insects, in hanging fruit.

Overwintering: All stages can be found at most times of the year. Beetles may overwinter as adults in cracks, crevices, under bark; as adults and larvae in rotting fruits, eg citrus on the ground or still on trees, or as larvae, pupae or adults in soil.

Spread: Beetles are strong fliers. Movement of infested fruit.

Conditions favouring: Warm wet seasons with an abundance of fermenting fruit. Optimum temperatures range from 16-22 C. Fermenting tree fruits, and dried fruits.

Control:

Sanitation: Destroy waste fruit. Beetles in fallen fruit can be destroyed by burning or boiling it, or by putting it in an insect-proof pit.

Biological control: Little is known about the natural enemies of dried fruit beetles.

Pesticides: An efficient program to control fruit fly and various caterpillars greatly reduces the volume of damaged and fermented fruit available to the beetles. Insecticide may be sprayed over the trees at intervals of a few days while fruit is attractive to the beetles.

Ferment flies, vinegar flies (Drosophilidae, Diptera)

infest ***ripe fruit***, eg grapes, tomatoes. ***Flies*** are brown and grey with reddish eyes, and are about 3 mm long. They lay eggs in fruit damaged by birds or rain split. Small white ***maggots*** up to 4 mm long develop causing fermentation and breakdown. They pupate in the drier areas of the food. ***Do not confuse with fruit flies***. ***Complete metamorphosis*** (egg, maggot, pupa, adult). ***Overwinters*** as flies in sheltered places or as pupae. ***Spread*** by adults flying. Flies are ***attracted*** in great numbers to acetic acid produced by large quantities of rotting fruit or liquid. Ferments flies are ***difficult to control*** when conditions favour them. They breed quickly and it is important to remove/destroy possible ***breeding sites***, eg decaying, nearby overripe fruit and tomatoes, which may be sprayed frequently. Temporary relief may be obtained by applying non-residual insecticides to control adult flies. ***Waste fruit*** can quickly produce enormous swarms of flies which invade packing sheds and canneries becoming a nuisance. The quantity of waste must be kept to a minimum in the field and in the cannery to reduce breeding. Damaged and infested fruit should be dumped in one place and sprayed as prescribed.

Fruit flies

Fruit flies are the world's ***worst fruit pest***.

Scientific name: Tephritidae, Diptera:
More than 80 species are found in Australia, the most economically damaging species include:
Queensland fruit fly (*Bactrocera tryoni*) (native)
Mediterranean fruit fly (*Ceratitis capitata*) (exotic)
Other fruit flies include:
Banana fruit fly (*B. musae*)
Cucumber fly (*B. cucumis*)
False oriental fruit fly (*B. opiliae*)
Halfordia fruit fly (*B. halfordia*)
Island fruit fly (*Dirioxa pornia*)
Jarvis's fruit fly (*B. jarvisi*)
Lesser Queensland fruit fly (*B. neohumeralis*)
Newman fly (*B. newmani*)
Northern Territory fruit fly (*B. aquilonis*)
Mango fly (*B. frauenfeldi*)
Papaya fruit fly (*B. papayae*)
Solanum fruit fly (*B. cacuminatus*)
Many other fruit flies occur overseas, eg ***Oriental fruit fly*** (*Bactrocera dorsalis*) and ***melon fly*** (*Dacus cucurbitae*), which are probably the greatest risk as they occur in the countries to the north of Australia (Drew and Hancock 1994). Exotic fruit flies are monitored in northern Australia.

Host range: Introduced and native fruit.

Description and damage: ***Queensland fruit fly (QFF)*** is red-brown and about 7 mm long. ***Mediterranean fruit fly (MFF)*** is smaller, usually yellow and wings have noticeable brown bands. ***Flies*** lay eggs in fruit (Fig. 101). The ***papaya fruit fly*** which is a recent arrival in Australia is important because it lays eggs in ***green fruit*** (at a much earlier stage of fruit development than other fruit flies). ***Maggots*** of ***QFF*** and ***MFF*** are cream and up to ***8-10 mm*** long. When mature they jump from the fruit to reach the soil and burrow down into the soil to pupate. ***Pupae*** are brown and up to 10 mm long. Egg laying ***'stings'*** on ***fruit*** appear as small black marks on the skin. Maggots do not always develop; a corky layer may form round the egg batch preventing them from hatching. Maggots burrow in the ***flesh of the fruit***, ***secondary rot organisms*** invade the tunnels and surrounding tissue; tissue breaks down.

Pest cycle: Complete metamorphosis (egg, maggot, pupa, adult) with several general generations each year (Fig. 101). Females lay eggs just beneath the skin of fruit. Maggots feed on flesh, destroying it then pupate in soil.

Overwintering: As adults in sheltered places, they become active in spring. Pupae die in cold winters.

Spread: By adults flying, wind, also by movement of ***infested fruit***, fruit cases. Climate changes.

Conditions favouring: Warm weather. Unharvested ripening fruit, seedling summer fruits, tomatoes close by. They may breed in large numbers in wild fruits in banana-growing areas.

Control: Control fruit fly on nearby hosts, eg citrus, guavas, loquats, peaches, tropical fruits. ***Legislation*** regulates ***sanitation, quarantine and pesticide procedures*** for controlling fruit flies.

Cultural methods: ***Prune trees*** to manageable size so they can be safely and effectively ***sprayed***, eg espaliered, or use dwarfing rootstock.

Sanitation: Remove ***unwanted fruit trees*** from boundaries, etc and ***late hanging fruit*** missed during harvest. Infested fruit should ***not be buried*** as flies can emerge from fruit buried to a depth of 1 m. Home gardeners can collect unwanted or infested fruit and destroy maggots and flies by placing in a sealed plastic bag and leaving in sun for a few days before disposal.

Biological control is difficult. ***Parasites*** of the ***QFF*** include ***wasps*** (*Opius* spp.). ***Sterile male fruit flies*** have been released in some areas, eg in WA in eradication programs.

Resistant varieties: Late ripening fruits are very susceptible. Early ripening fruits can act as a source of infestation for later ripening fruits.

Plant quarantine: Receiving states/territories or countries have ***legislation*** regulating the import of produce which may be infested with fruit flies.

Pesticides: ***Foliage baiting*** using an attractant (protein hydrolysate), carrier (water) and an insecticide at regular intervals is commenced the recommended number of weeks prior to anticipated harvest. ***Foliage sprays*** may be applied at recommended intervals prior to anticipated harvest, on some fruit. They do not necessarily protect fruit against stinging. ***Fruit treatment postharvest*** (dipping, flood or spray which may be combined with washing of fruit or fungicidal dipping) may be required ***Other postharvest treatments***, eg cold storage, fumigation and ionising energy may also be required. ***Monitor*** fruit flies and stung fruit, before making a decision to bait or spray. ***Male lure traps*** (Dakpot®) can help indicate increases in fly activity providing there are no other breeding sources of flies within 500 m. Count traps weekly and spray/bait when an average of 14 or more flies per trap occur per week (Brough et al. 1994).

Fruitpiercing moths

Fruitsucking moths

Scientific name: Noctuidae, Lepidoptera:
Fruitpiercing moth (*Othreis fullonia*)
Fruitpiercing moth (*O. materna*)
and *Eudocima salaminia*

Host range: ***Moths*** feed on ripening fruit, eg citrus, lychee, mango, ***caterpillars*** develop on vegetation in areas of rainforest or along the banks of creeks (Common 1990).

Description and damage: ***Moths*** are large, stout, wingspan is about 100 mm, forewings are dull, but hindwings are brightly coloured. Moths enter orchards at ***night*** and drill a neat hole in the ***skin of ripening fruit*** with their proboscises and suck the juice, sometimes causing considerable fruit loss (Fig. 102). The ***feeding hole*** is obvious but may be mistaken for damage by other insects, eg ***fruit fly stings***. ***Secondary organisms***, insects and mites may then invade fruit. After a few days rot develops at the puncture site and fermenting fruits may be visited by secondary moth feeders. Internal injury in mango resembles a honeycomb. Moths may cause major and frequent damage to lychee in Qld. Fruit damaged the ***night before harvest*** may escape detection but may spoil a whole pack as fermentation proceeds and juice leaks onto other fruit. The holes are neat and the flesh beneath is opaque compared to undamaged taut, opaque translucent flesh. If moth-damaged fruit is squeezed, juice will squirt out.

Spread: By moths flying.

Conditions favouring: Moonless nights favour moth activity, moths attack fruit during the week or so before harvest, late maturing varieties.

Control: No satisfactory control measures as damage is so close to harvest.

Cultural methods: Harvest fruit as soon as sugar levels reach market standards.

Biological control: ***Various parasites*** exert some control on caterpillars in their natural habitat. Moths may be attracted to ***fermenting fruit lures*** and killed manually next morning.

Physical and mechanical methods: Protective ***nets*** exclude moths from fruit. Nightly spotting with ***torches*** (red eyes of moths reflect light, aiding detection) when fruit is nearly mature and ***swatting*** with tennis racquets kills moths.

Fruitspotting bugs

Scientific name: Coreidae, Hemiptera:
Banana-spotting bug (*Amblypelta lutescens lutescens*)
Fruitspotting bug (*A. nitida*)
Fruitspotting bug (*Dasynus fuscescens*)

Host range: ***Banana-spotting bug*** damages native hosts, eg white cedar, rough-leafed fig, umbrella tree, coffee apple, corky passionvine, ***fruit***, eg avocado, banana, citrus, custard apple, guava, lychee, macadamia, passionfruit, pawpaw, pecan. ***Fruitspotting bug*** (*A. nitida*) also damages macadamia, pecan, lychee mainly in the south-east of the State. Bugs also breed on bauhinia, frangipanni and hibiscus so avoid planting these.

Description and damage: ***Adult bugs*** are slender, ***yellow-green*** and about ***l5 mm*** long. If disturbed they fly away or hide on the plant. They are ***difficult to find*** on a tree (Fig. 103). Banana-spotting bugs are usually ***slightly lighter green***. ***Nymphs of fruitspotting bugs*** are ***ant-like*** (Fig. 103), red-brown with prominent antennae and have paired button-like scent glands on the upper side of the abdomen, later stages are greener with wing buds. ***Nymphs of the banana-spotting bug*** are stouter, pink above, have pale antennae and more prominent, button-like scent gland openings. Nymphs are paler red than the fruitspotting bug nymphs. The ***2nd last joint of the antennae*** of nymphs is black and flattened. Adults and nymphs suck juice from preferably ***young fruit,*** causing sunken spots with internal damage (Fig. 103), fruit are ***unmarketable***. Fruits damaged early often fall, injured fruit on trees are unmarketable. Injuries a few weeks old appear as dark, often watersoaked spots, sometimes accompanied by gumming, which dries to form white powdery masses causing severe callused blemish in the skin. The more shallow injury can be ***difficult to distinguish*** from that caused by ***Queensland fruit fly***. On some hosts, eg papaws, bugs may also suck sap from ***growing points and leaf stalks***.

Pest cycle: Gradual metamorphosis (egg, 5 nymphal stages, adult) with 3-4 overlapping generations (during spring, summer, autumn). Females lay more than 150 pale green oval eggs about 2 mm long singly on ***fruit or foliage***.

Overwintering: As adults.

Spread: By winged bugs flying.

Conditions favouring: In Qld during summer especially in coastal orchards, especially those ***close to rainforest or scrub*** where insects breed.

Control: Control bugs when they occur. Remove affected fruit when observed during monitoring so that new damage will be seen at each sampling. Apart from orchard sanitation little can be done to alleviate the situation.

Cultural methods: Avoid growing susceptible fruits close to rainforest.

Biological control: No effective parasites or predators, spiders or assassin bugs have been observed. Numbers collected have been insufficient to have any effect on total bug populations. Up to 84% eggs may be ***parasitised*** by a wasp egg parasite (*Anastatus*).

Resistant varieties: Varieties vary in resistance.

Pesticides: When damage is first observed, ***insecticides*** may be applied, repeat applications may be necessary. If possible, treat heavily infested areas within the orchard rather than spraying the entire orchard. ***Monitor*** bug damage on ***susceptible fruit*** at regular intervals before making a decision to spot spray with an insecticide, usually during January and February (Brough et al. 1994).

Fruit-tree borers

Scientific name: Oecophoridae, Lepidoptera:
Fruit-tree borer (*Maroga melanostigma*)
Small fruit-tree borer (*Cryptophasa albacosta*)

Host range: ***Ornamentals***, eg especially wattle, banksia, *Prunus*, elm, grevillea, hakea, NSW Christmas bush (*Ceratopetalum gummiferum*), plane, willow, *Pistacia*, crepe myrtle, jacaranda, *Cassinia,* eucalypt *Helichrysum* (shrubby spp.), *Leptospermum,* melaleuca, *Prostanthera.* ***Fruit***, eg stone fruit especially cherries, peaches, nectarines, plum, prune.

Description and damage: Although this is probably the most frequently noticed borer, many other borers cause more serious damage. ***Moths*** are satiny white about 50 mm across with darker hind wings. ***Caterpillars*** are fleshy, grey/red, sparsely hairy and up to ***50 mm*** long. During the day they hide in tunnel entrances, coming out to feed on surrounding bark at night. ***Trunk:*** Tunnels are vertical ***(only 80-100 mm deep)*** and are usually made in the forks of trees or between main branches (see Trees K 2, Fig. 205). Caterpillars feed on ***callus tissue*** which grows around tunnel entrances. Damaged areas and tunnel entrances are neatly covered with ***chewed wood, bark, webbing and droppings*** which protect caterpillars from predators, eg ants. Some trees, eg cherries, ooze gum from damaged areas. Attack weakens branches and may ringbark and kill small branches or small trees and allows ***entry of wood rot fungi***.

Pest cycle: Complete metamorphosis (egg, caterpillar, adult) with 1 generation each year. Eggs are laid on bark in summer and caterpillars burrow into wood. When fully grown they pupate inside their tunnels which have been sealed with a silken pad. Moths emerge the following summer.

Overwintering: Probably as caterpillars or pupae in tunnels in trunks and branches.

Spread: By moths flying.

Control: As caterpillars do not tunnel far into the wood, ***this borer is the easiest to control*** (other borers are not usually noticed until they have done considerable damage and larvae may have penetrated deep into the wood).
Cultural methods: Fertilise and irrigate trees.
Sanitation: Remove and destroy ***black wattle*** thickets within 50 m of commercial plantings to prevent the build up of moth populations. Pull away webbing and expose caterpillars, they can then be ***squashed***. If small twiggy growth on shrubs or trees has been attacked, prune off.
Physical and mechanical methods/Pesticides: Control when infestation is first noticed. ***Inspect*** deciduous trees during dormancy in winter when damage is easily observed. ***Cut back*** severely infested branches well below infested sections and paint the cut surface with a fungicide paint if recommended. ***Remove webbing and sawdust-like material*** and either poke a thin wire down the short tunnels to kill caterpillars or paint the area with an insecticide, or inject/squirt kerosene or insecticide into tunnels. It may be necessary to spray trunks, branches and leaves. ***Smooth damaged wood***, then plug tunnels with putty or similar material. ***Monitor*** effectiveness of treatment. See Trees K 12.

Fruit-tree root weevil
Apple root borer

Scientific name: Curculionidae, Coleoptera: Fruit-tree root weevil *(Leptopius squalidus*) native *L. tribulus* also attacks roots of wattles.

Host range: Adults and larvae feed on the same species. ***Ornamentals***, eg wattles, eucalypts and swamp gum (*Eucalyptus amplifolia*) are probably its natural food. ***Fruit***, eg deciduous fruit trees, apple, citrus, ***weeds***, eg dock (*Rumex* spp.).

Description and damage: ***Female weevils*** are dull grey, slow moving and about ***20 mm*** long with a typical weevil snout (Fig. 104). Males are smaller. ***Larvae*** are fat, creamy, legless and up to ***25 mm*** long. ***Adults*** feed on young ***leaves*** causing insignificant damage, and ***larvae*** tunnel in ***deep roots*** (about 1 m below the surface) causing the main damage. Deep furrows are eaten out of the thicker roots, heavy infestation will kill roots. The pest can ***destroy an orchard*** if conditions are suitable and no control measures are employed. ***Trees become*** thin and sickly and show general dieback and excessive leaf-drop.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with 1 generation per year. Eggs are laid at night in summer in groups of 40-50 covered by a silky film between two leaf surfaces glued together. Young larvae drop to the ground, bore down to roots and begin to feed in late winter. Larvae pupate in earthen cells close to roots. In spring, adults dig their way out and climb the trees.

Overwintering: As larvae in or on roots.

Spread: Weevils cannot fly, but they can crawl long distances to host plants. Also by flood water.

Conditions favouring: Temperate coastal regions, river flats subject to periodic flooding, which encourages deep-rooting, also heavy soils, newly-cleared land. Seldom found on sandy soils.

Control: ***Monitor*** situations favourable to this pest, and begin control before damage causes permanent injury.
Cultural methods: ***Good soil preparation*** before planting can prevent the risk of beetles and larvae being present in newly-cleared land.
Biological control: Natural enemies have not been recorded in NSW.
Physical and mechanical methods: Trees in poor health and adjacent to healthy trees should be ***banded***, as high on the trunk as possible, with sticky material or fly screen wire traps. Sticky bands should be 'freshened' up regularly to prevent weevils from crossing them. Inspect all bands weekly in spring and summer, collect and destroy weevils. ***Sustained trapping*** will reduce the weevil population and lead to the ultimate recovery of trees. ***Trim limbs*** to prevent them touching the ground and control weeds to force weevils to climb the trunk to reach the tree. ***Examine deeper roots*** of some affected trees for furrowing, larvae and pupae.
Pesticides: Applying ***insecticides*** to the trunk, lower foliage and soil under trees in spring, to kill the adults and young larvae falling from the leaves, has been successful.

Grasshopper, katydids, locusts
(Orthoptera)

Grasshoppers and locusts (Acrididae): ***Giant grasshopper*** (*Valanga irregularis)* is one of the largest grasshoppers, feeds on leaves of trees and shrubs and may damage fruit and nut trees. ***Wingless grasshopper*** (*Phaulacridium vittatum*) chew holes in ripening fruit of strawberry, pome fruit and stone fruit in the tableland areas. ***Also Australian plague locust*** (*Chortoicetes terminifera*), ***migratory locust*** (*Locusta migratoria*), ***spur-throated locust*** (*Nomadacris guttulosa*). See Vegetables M 13.
Katydids (Tettigoniidae): ***Citrus katydid*** (*Caedicia strenua*), ***inland katydid*** (*C. simplex*) may be ***pests*** of ***citrus***. See Citrus F 38.

See Vegetables M 13.

Leaf beetles, flea beetles
(Chrysomelidae, Coleoptera)

Redshouldered leaf beetle (*Monolepta australis*) feeds on avocado, citrus, lychee, macadamia. ***Beetles*** are ***6-7 mm*** long, creamy-yellow, strong fliers, with a red spot on each wing cover. In spring and summer swarms commonly attack ***blossoms, buds and young foliage*** and later graze on soft skins of ***fruits***. Some trees look scorched, while others nearby may be hardly damaged. ***Monitor*** for swarms, and if detected quickly, lightly spray buds, blossoms and young growth (Brough et al. 1994). Plant susceptible windbreak trees, eg *Eucalyptus torelliana*, to aid detection. See Trees K 15.
Swarming leaf beetles *(Rhyparida* spp.) are about ***3-5 mm*** long, shiny, brown or black and may appear in swarms in summer and autumn. Beetles skeletonise ***new leaves*** and ***blemish fruits***. They prefer new leaves and young shoots and may totally defoliate young plants and tops of shrubs and trees. The effect on growth of young fruit trees and ornamentals and justifies spraying swarms. Older plants usually recover from attacks. See Trees K 15.

Mealybugs (Pseudococcidae, Hemiptera)

may attack apples, citrus and other fruit crops. See Greenhouses N 25.

Mites (Acarina)

Spider mites (Tetranychidae): ***Bryobia mite, brown almond mite*** (*Bryobia rubrioculus*) infests ***deciduous fruit and ornamental trees*** eg hawthorn. ***Adults*** are nearly ***1 mm*** long and are purplish brown to greenish grey with 4 pairs of legs, the ***front pair is very long*** (Fig. 105). There is no webbing. ***Nymphs*** look like adults but are smaller, are bright red and feed on ***new leaves*** which become pale and may fall. Tree vigour, fruit size and number are reduced. Mites gather on twigs during the day and spread out at night to feed on leaves. Several generations occur each season. ***Overwinters*** as eggs (minute, globular, ***red***) on bark or branches and twigs which may take on a red tinge. ***Spread*** by mites crawling, introduced to orchards on nursery stock. Wet cold weather and frequent rain ***destroy large numbers***. Nitrogenous fertilisers are thought to be unfavourable. Predators include ladybirds (*Harmonia, Stethorus*), and lacewing larvae. Oil sprays may be applied during dormancy. ***European red mite*** (*Panonychus ulmi*) may injure deciduous fruit and shade trees including pome and stone fruits, elm, grapevine, hawthorn, raspberry, rose, strawberry. ***Females*** are brown-red, oval and about ***0.3-0.5 mm*** long with ***4 rows of long stiff curved spines*** on the back, males are smaller and paler (Fig. 105). Mites suck sap and lay eggs on ***leaf undersurfaces,*** causing speckling of leaves, ***no webbing is produced.*** Leaves may become pale, bronzed, and may fall. ***Fruit buds*** may not form, fruit may be small and of poor quality. There are many overlapping generations each year, each cycle is about 1-2 weeks. Eggs hatch in spring and nymphs move to new leaves to feed. ***Overwinters*** as masses of ***red eggs*** on a distinct stalk at the apex of twigs and small branches or as orange inactive fertilised females in debris at the base of plants. ***Spread*** like twospotted mite (see below). ***Favoured*** by hot dry weather and severe water stress. A strain of ***predatory mite*** (*Typhlodromus pyri*) which is resistant to many pesticides has been introduced to Australia (Swaine et al. 1991). Dormant sprays of winter oil may be applied as close to green tip growth stage as possible (Fig. 110). ***Twospotted mite*** (*Tetranychus urticae*), bean spider mite (*T. Iudeni*) and banana spider mite (*T. Iambi*) may infest fruit crops. ***Adult female twospotted mites*** are about ***0.5 mm*** long and can easily be seen with a hand lens. They are pale green-grey to yellowish, with ***distinctive markings on either side of the body*** (Fig. 105). Nymphs and adults suck sap mostly from ***leaf undersurfaces*** but in heavy infestations also suck from upper surfaces causing leaf mottling or speckling. Mites, eggs and webbing are found on undersurfaces. ***Leaves may fall***. On some hosts, eg apple, leaves may be bronzed with uprolled leaf margins. Growth and cropping of plants may be retarded. Severely infested plants may be killed. ***Fruit*** may be attacked, and sunburned due to defoliation. Fruit with an excessive number of mites may be ***refused entry*** to certain countries. ***Trunks and branches*** may become ***sunburnt*** due to defoliation. Damage is more severe if trees suffer from moisture and other stresses. Twospotted mite is hard to ***control*** chemically because it readily develops resistance to pesticides. See Beans (French) M 29.

Eriophyid mites (Eriophyidae), eg ***grapeleaf blister mite*** (*Colomerus vitis*), tend to be host specific. See Grape F 62.

Others: A ***flat false spider mite*** (*Brevipalpus,* Tenuipalpidae) may affect strawberry.

Plague thrips (*Thrips imaginis*):

In some seasons huge numbers of tiny brown insects swarm on ***flowers*** of many kinds of plants including fruit, eg apple, raspberry, strawberry (Fig. 106). ***Petals*** brown and wither. Adults and yellow nymphs feed on ***stamens, pistil and ovaries***, partly or wholly preventing ***seed setting***. ***Fruit*** may be misshapen with few seeds and unmarketable as fresh fruit. Control is difficult. ***Monitor*** thrips prior to applying insecticides. Spraying may be started when numbers of thrips are first seen on flowers and when fruit set is just beginning. If spraying then do so in the evening when bees are not present. See Roses J 6.

Scales (Hemiptera)

may reduce ***fruit size*** and give fruit a ***pock marked appearance***, making them unfit for either picking or oil production. Soft scales secrete ***honeydew*** which attracts ***ants*** and encourages a dense growth of ***sooty mould*** which excludes light, reduces vigour, causes leaf yellowing and fall and retards fruit growth. Fruit is unsightly. Scales may gather on ***stems*** and ***leaves***.

Armoured scales (Diaspididae)
- Oleander scale (*Aspidiotus nerii*)
- Orchid parlatoria scale (*Parlatoria proteus*)
- Red scale (*Aonidiella aurantii*)
- Ross's black scale (*Lindingaspis rossi*)
- San Jose scale (*Quadraspidiotus perniciosus*)

Soft scales (Coccidae)
- Black scale (*Saissetia oleae*)
- Frosted scale (*Eulecanium pruinosum*) (Fig. 107)
- Nigra scale (*Parasaissetia nigra*)
- Soft brown scale (*Coccus hesperidum*)

Overwinters on infested hosts, cuttings and nursery stock. ***Monitor*** scale, and parasite and predator populations. Small infestations may be removed by hand. The presence of some scales may make fruit subject to overseas ***quarantine regulations***. ***Deciduous plants*** may be sprayed with ***insecticide***, eg winter oil, ***during dormancy***. ***Evergreen plants*** when they are not flowering and when crawlers are present. See Citrus F 39, F 41.

Scarab beetles (Scarabaeidae, Coleoptera)

African black beetle (*Heteronychus arator*) is about ***12 mm*** long, shiny black and oval. In spring, on land recently under paspalum, beetles bore into ripening strawberry ***fruit on the ground*** from underneath. Young strawberry plants and banana suckers may have ***stem bases and crowns*** chewed ragged, causing them to wilt or die. See Turfgrasses L 7 .

Scarab beetle larvae, eg Christmas beetles (*Anoplognathus* spp.), *Rhopaea* spp., are white, C-shaped, plump, with hard, brown heads and strong jaws, and up to ***50 mm*** long. They eat off ***roots*** of peanut, pineapple, strawberry and other plants, up to the crown, especially if planted out in recently ploughed grassland. Plants stop growing and in dry weather soon wilt and die. Affected plants can easily be ***pulled from the ground***. Roots of nursery stock planted ***into old pastures*** may also be attacked.

Established infestations are difficult to control. ***Careful land preparation*** is essential. Scatter baits lightly through crops, do not contaminate fruiting plants. If beetles are moving in from nearby pasture, a deep steepsided furrow can be ploughed around the crop area and the bait scattered in this. Young plants may be protected by jetting soil around them. See Turfgrasses L 11.

Weevils (Curculionidae, Coleoptera) attack ***low lying plants***, eg English gooseberry, strawberries. Foliage may be chewed by the adults and roots and crown eaten by the larvae.

Black vine weevil, European strawberry weevil (*Otiorhynchus sulcatus*) chew ***roots and foliage***. See Grapevine F 63.
Fruit-tree root weevil (*Leptopius squalidus*) damage ***roots and foliage***. See Fruit F 11.
Fuller's rose weevil (*Asynonychus cervinus*) may chew ***leaves*** of pome fruits, strawberry and other fruit crops along the edges to give a ***saw-toothed appearance***. Infestations are usually severe in weedy orchards. The use of clover and grass cover in the interrow space ensures that alternative hosts are readily available. See Roses J 6.
Spotted vegetable weevil (*Desiantha diversipes*) may feed on strawberry stems, leaves and runners in spring and autumn. See Vegetables M 17.
Strawberry weevil (*Rhinaria perdix*) may chew foliage, larvae feed on ***roots, crowns and stalks***. See Strawberry F 142.
Whitefringed weevil (*Graphognathus leucoloma*) larvae gouge strawberry roots. Adult weevils may attack strawberry foliage. See Vegetables M 17.

See Vegetables M 17, Trees K 17.

Others: ***Driedfruit mite*** (*Carpoglyphus lactis*, Carpoglyphidae, Acarina) is a pest of ***drying fruit***. Also ***whiteflies*** (Aleyrodidae).

SNAILS AND SLUGS

Snails and slugs may damage ***leaves, fruit, stems and seedlings***. Sometimes only tiny holes are made in the fruit but they favour ***mould development***. Slugs graze the ripest part of the berry, so one slug may damage several berries on one plant. Young snails graze on the surface of fruits, older snails may eat into ripening fruits, gouging out circular holes. See Seedlings N 70.

VERTEBRATE PESTS

Birds, especially blackbirds, finches, silver eyes, sparrows, starlings may damage fruit (Fig. 108). ***All native birds***, eg parrots, honeyeaters, are protected by legislation and permits to destroy them must be obtained from the appropriate government department. Birds must be controlled before fruit becomes attractive to them. Many growers use a ***combination of methods*** to ensure satisfactory results. ***Deterrent devices***, eg rotating flashing acrylic mirrors, flags, hawk replica, humming lines and scarecrows usually have to be used with acoustic devices. ***Electronic devices*** probably produce the best results. 'Eagle' is a remote controlled aerial bird scarer. ***Netting*** which drapes over crops is available but is expensive. ***Bat netting*** is used for fruit bats and larger birds, and ***bird netting*** for all birds and some insects. ***Hail netting*** is used for hailstones, it enables better use of chemicals, reduces drift, breaks up rain into fine mist, reduces evapo transpiration, wind and sunburn damage, increases temperature and prevents frost damage. 'Vine-net' was originally for vines but is now also used for protecting tropical fruit, eg lychees, persimmon, from insects, eg fruit-piercing moths, and birds. Whole crops may be covered with mesh, which also reduces hail damage. Individual fruit bunches, eg bananas, may be ***bagged***. ***Acoustic devices*** are the most widely used eg rotating gas guns, which produce loud explosions at variable intervals. ***Repellent sprays*** are no longer registered for use on fruit crops. Maximum residue levels have been reviewed. ***Alternative food sources and water*** may prevent damage. Identify the problem birds and plant a diversionary crop. About one third of the birds that attack grapes are thirsty so the provision of drinking water saves more fruit. ***A canopy of foliage*** prevents birds getting in as they do not like going into dense vines because they fear ambush. Prune to provide leaf cover and concealment.

Fruit bats, flying foxes (*Dobsonia* spp., *Pteropus* spp.) live in colonies in trees during the day. At night they leave to feed on mostly native fruits but will also feed on soft ***cultivated fruit*** (Fig. 108). They are native animals and control is difficult. Research has indicated fruit bats may carry viruses, eg the equine (horse) morbillivirus and a new strain of the lyssavirus (bat lyssavirus), which may infect humans.

Others: ***Possums*** may feed on buds, fruits and nuts. ***Goannas*** may feed on strawberries. ***Rabbits,*** hares, kangaroos and wallabies graze on newly planted nursery stock. ***Rats*** eat macadamia nuts.

Non-parasitic

Ants (Formicidae), eg ***coastal brown ant*** (*Pheidole megacephala*) and ***meat ants*** (*Iridomyrmex* spp.), are ***major and sporadic pests***. They protect sucking insect pests which produce honeydew, eg aphids, soft scales, by disrupting their important natural enemies. Treat when there are noticeable numbers of ants observed on trees, especially in association with a developing pest population of sucking insects. ***Insecticide*** sprays or baits may be applied to the base of the trunk ***Sticky material*** at the trunk base may trap ants. Each season after harvest ***prune the tree skirt*** to at least 1 m clear of the ground. ***Keep weeds down*** and vines and branches off the ground.

Biennial fruit bearing: Some fruits, eg some varieties of apricots, apples, pears, have a tendency to bear a heavy crop one year and a light crop the next. Biennial bearing causes variations in total crop and fruit size. It can be reduced to some extent, by judicious thinning of fruit and pruning. ***Thin heavy crops*** to increase fruit size and discourage biennial bearing. The ***earlier the thinning*** the greater will be the control of biennial bearing. Later thinning in December to January helps to improve fruit size but does not overcome biennial fruit bearing. All trees in an orchard are not usually on the same cycle, though if they are from the same clone they may be.

Environment: Blossoms are less ***frost*** tender than ***young fruit***, the most susceptible part of which is the ***seed***. Once the seed is killed, growth of that fruit stops and it usually falls a few days later. Frost injury may be ***minimised*** by having smooth, weed-free and moist soil in the orchard. The soil acts as a heat reservoir and moist soil can store more heat than a dry one. At night the heat is slowly released (Baxter 1990). Sprinkling trees with a ***fine spray of water*** during a frost releases the latent heat of water which is released when water freezes. As the water freezes into ice it protects the delicate blossoms. ***Special materials*** may be sprayed onto plants to protect them from frost injury. Various ***heating devices*** may also be used in orchards. Crops may be covered with ***shade clothe*** to protect fruit from frost injury, hail damage, sunburn, wind and birds. Do not confuse ***hail*** injury to ***young shoots*** with cankers caused by shot-hole, brown rot or other agents, eg egg laying of some insects. Do not confuse ***hail*** injury to ***fruit*** with that caused by oriental fruit moth. Fruit, leaves, limbs and trunks may be ***sunscorched***. Appropriate ***irrigation*** and ***drainage*** are essential for the production of most fruit crops. Many fruit consist of ***85%*** water.

Nuisances to pickers: ***Paper nest wasps*** (*Polites* spp.) nest in trees and can sting fruit pickers when disturbed. Spray nests at night with a pyrethrum aerosol and remove the nests when wasps are dead. Alternatively, nests may be flamed at night to disable the adults and allow nests to be removed. ***Twospotted mites*** (*Tetranychus urticae*) may irritate pickers. ***Webbing spider*** (*Ixeuticus longinquus*) is small and gregarious and in inland areas it webs foliage of citrus trees together. This webbing interferes with normal development of foliage and fruit and protects black scale and mealybugs. Spiders in webs may annoy ***pickers***, spiders may be sprayed, webs can be broken mechanically to allow better penetration of spray.

Nutrient deficiencies, toxicities: With the range of fertilisers available, and rapid analytical tests ***(plant tissue analysis and soil and water analyses)***, deficiencies, toxicities and nutrient imbalances should not occur in commercial orchards. Fertilisers or animal manures are essential to maintain tree vigour and soil fertility in most orchards but they can only help if trees are adequately watered, kept free from weeds during summer and are free of diseases and pests. ***Fertiliser requirements*** vary from crop to crop and during different stages of the crop, ie establishment, non-bearing and bearing and age. ***Before planting, soil analysis*** is the only reliable means of forecasting crop nutrient needs. Providing the soil test is calibrated to both the crop and the soil type, a soil test predicts the ability of the soil to supply nutrients. ***After planting,*** diagnosis may be from ***visual symptoms*** (see Citrus F 43), which often requires skill and experience, or ***plant tissue analysis*** (usually leaves), which gives the current nutrient status of the crop. Leaf analysis must also be ***calibrated*** for fruit trees. (Weir and Cresswell 1993, 1995).

Pesticide injury: Many fungicides, insecticides and herbicides may injure ***some fruit crops***. Follow label instructions carefully. ***Injury*** may be ***acute***, eg leaf browning or leaf fall, or ***take longer to show its effects***, eg reduced fruiting the following season.

WEEDS

Most fruit crops are more productive when they do not have to compete with grass and weeds. Weed control is important and in some areas ***legislation*** requires that some weeds must be controlled, eg to assist control of banana weevil borer, weeds within 2 m of a banana plant must be controlled. Weed control varies with the ***age*** of the planting.

Types of herbicides: Post-emergence herbicides may be contact or systemic for annual weeds, and systemic for perennial grass and broadleaved weeds, there are ***selective*** grass herbicides. ***Prevent spray drifting*** on to lower hanging leaves or green trunks of ***young trees***, as it may kill them. ***Post-emergents*** may be used around some ***established trees***. On some species, eg grapevine, fit a Sisalation® collar around the stem to avoid risk of damaging bark, it should be kept in place for 3-4 seasons. ***Pre-emergence herbicides*** will give up to 4 months control of weed seeds. Some herbicides are only registered for ***non-bearing fruit crops***.

Pre-plant: Control perennial weeds ***before planting out*** by physical removal or application of post-emergence sprays, eg glyphosate.

Row weed control: ***During the 1st year***, weed control either by mulching, cultivation, herbicide or by a combination of these, is important. Later, areas under tree canopies should be kept weed-free either by using ground cover, mulch or herbicides. ***Mulches*** of sawdust, bark and weed mat, assist control of annual weeds and protect fine shallow roots of some fruit crops, eg blueberry and strawberry. Mulch must be kept well clear of trunks. Any annual or perennial weeds that do grow through the mulch can be spot sprayed or removed by hand. Coarse mulches can interfere with mechanical harvesting of macadamia, at harvesting time it is recommended that there be a minimum of coarse material on the soil surface. ***Groundcovers*** under trees compete with trees for moisture. They need to be shade tolerant, non-climbing, persistent and possibly tolerant to recommended rates of herbicides used. If nuts are collected from the ground under trees, growth should be mown and raked away from under and around the trees before nuts start to fall. ***Pre-emergence herbicides*** are usually used from the 2nd season onwards, however, some are registered for use after planting. Herbicides may be applied to a strip or band along the tree rows, the width of strips may be increased as trees age, eg from approximately 1 m on each side initially to a maximum of 2 m when trees are in production.

Inter-row weed control: Distance between rows will depend on the size of harvesting and other machinery. Areas between rows can be ***sown*** to grass, annual pasture and ***mown*** to protect soil from erosion, to control weed growth and to prevent moisture loss. ***Cultivation or herbicides*** can also be used to control weeds. Take care not to cultivate too deeply as some fruit, eg blueberries, have shallow roots (60-80 mm). Weeds in ***pathways*** can be controlled by ***mulches***, eg sawdust, straw or wood shavings.

Herbicide injury: Some ***pre-emergence herbicides*** may injure foliage of some fruit crops, eg persimmon. Some ***crops***, eg grapevines, are very sensitive to ***hormone herbicides***, eg 2,4-D. ***Care must always taken to avoid drift of all herbicides*** on to foliage of all fruit trees.

See Annuals A 9, Trees K 21.

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Bordeaux Mixture
Fruit & Vegetable Prices & Receivals (avail. from Johima Books, Paramatta, NSW.
Handling Fruit & Vegetables in Retail Stores
Home Fruit Growing (book)
Orchard & Vineyard Plant Protection Guide for Inland NSW
Postharvest Disease Control in Stone Fruits
Queensland Fruit Fly
Rat Control in Macadamia Orchards
Rutherglen Bug
Storage Conditions for Fruit and Vegetables
Testing Fruit & Vegetables for Pesticide
Transporting Fresh Produce in Refrigerated Trucks
Virus Diseases of Deciduous Fruit Trees
Wood Rots of Fruit Trees & Other Plants

NT Agnotes

Control of Fruit Flies by Commercial Producers of Fruit & Vegetables
Fruit Flies in the Home Garden
Mediterranean Fruit Fly

SA Fact Sheet

Espaliers for Fruit in Small Gardens
Fruit Flies
Fruit Fly Eradication : What Happens in Home Gardens
Orchard Pest and Disease Handbook (book)
San Jose Scale

Tas Farmnotes

Orchard Mites (1):Chemical Control
Rootstocks for Fruit and Nut Trees
Timing Orchard Sprays
Weed Control in Pome and Stone Fruit Orchards

Vic Agnotes

Armillaria Root Rot
Bird Control in Fruit Crops
Budding Deciduous Fruit Trees
Budding Fruit Trees
Cause of Fruit Drop
Certified Propagating Material for Tree Fruits
Control of Pests and Diseases in Home Orchards
Chemical Control of Weeds in Pome & Stone Fruit
Citrus and Avocado Kit
Deciduous Fruit Crops Kit
Fertiliser Programs for Home Orchards
Fertiliser Programs for Orchards
Frost : Its Nature & Control
Fruit Tree Borer Moth
Grafting of Fruit Trees
Honeybee Pollination of Fruit Tree Crops
Integrated Control of Twospotted Mite in Orchards
Irrigated Scheduling for Regulated Deficit Irrigation (RDI)
Mineral Deficiencies in Fruit Trees
Nuts, Berries & Speciality Fruits Kit
Planting & Caring for Young Fruit Trees
Pollination of Fruit Trees
Orchard Nurseries : Site Selection and Preparation
Orchard Nutrition 1 : NPK Fertiliser Programs for Mature Orchards
Orchard Pest and Disease Handbook
Pruning in the Home Garden
Queensland Fruit Fly in Victoria
Rhizopus Rot & Transit Rot of Fruit & Vegetables
San Jose Scale & Oystershell Scale
Silver-leaf Disease of Fruit Crops
Soil Preparation for Fruit Trees & Grapevines in Southern Victoria & the Goulburn Valley
Storage Conditions Affecting the Life of Fruit
Handling Fruit & Vegetables in Retail Stores
The Dried Fruit Beetle
The Fruit-tree Root Weevil, Leptopius squalidus
Using Lime in the Orchard
Verticillium Wilt of Deciduous Fruit Trees
Why Water Trees?
Wood Rots of Fruit Trees and Other Plants

WA Farmnotes

Fruit Fly Control in Backyard Orchards
Mediterranean and Queensland Fruit Fly
Sites, Layout and Irrigation for Nut Orchards
Storage Conditions for Fruit and Vegetables
Wound Dressings for Fruit Trees

Associations, Journals etc.

Apple and Pear Growers Assoc. of SA
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Australian Dried Fruits Board (ADFB)
Australian Fruit Juice Assoc. (AFJA)
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Australasian United Fresh Fruit & Vegetable Assoc.
Canned Fruits Industry Council of Australia
Central Tableland Nutgrower's Association Tom Ellis Ellco Farm Supplies
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Horticultural Research Development Corporation (HRDC)
International Rare Fruit Council
Many Overseas Fruit Growing Groups
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Rare Fruit Council of Australia
Tasmania Nut Growers Association, P.O. Box 303 Devonport, Tasmania 7310
The Australian Dried Fruit Assoc. (ADFA)
The Australian Nurserymen's Fruit Improvement Co. Ltd (ANFIC),
The West Australian Nut & Tree Crop Assoc. (WANATCA)
Tree Crop Centre, Subiaco, WA
Victoria Nut Growing Association, P.O. Box 69 Wangaratta Vic 3677
WA Nut and Tree Crop Association, P.O. Box 27, Subiaco WA 6008 (WANATCA) (Quandong Yearbooks)

See Preface xii, Postharvest N 61, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Management and spray guides are available for most commercial fruit crops for particular regions.

Selection

Horticultural requirements: Check ***pollination requirements*** for your particular area. Cross-pollination is necessary for production of some fruit and nuts, eg almonds. Varieties will not pollinate each other if they do not flower at the same time.

Resistant varieties: Select varieties with some ***resistance*** to key problems, eg powdery mildew of apple. Select ***resistant rootstock*** for key root problems, eg woolly aphid, grape phylloxera.

Disease-free planting material: ***Certification schemes*** operate for strawberry, citrus and deciduous fruits. The Fruit Variety Foundation (FVF) will guarantee stock (citrus, stone fruit, grapes, avocadoes) to be virus-free. The planting material provides to growers by these schemes is free from specified diseases and pests and should be used whenever possible. Planting material may need to be treated prior to planting, eg roots of peach may need to be dipped in insecticide to control black peach aphid.

Pesticides: There is still a need for pesticide applications to many crops to ensure the production of a healthy marketable crop. Routine pesticide applications are still frequently used rather than on a needs basis, this is considered to be due partly to poor pest recognition. Also new pests continually enter Australia.

Establishment

Legislation: Some crops, eg bananas, can only be grown in certain prescribed areas.

Propagation: Grafting on to dwarfing rootstock, budding, by tissue culture. Rootstocks confer many advantages, eg size control over scion, pest resistance and effects on yield and quality. Plants on their own roots may not have such advantages; however, they may produce high density plantings designed to have a short production life and permit the use of highly automated equipment. Some caution is necessary about the performance of tissue cultured fruit trees.

Cultural methods: ***Site and layout selection*** for particular fruit is important. Consideration must be given to temperature, aspect, air currents and wind, drainage, time of ripening (market demand, fruit fly); freedom and/or protection from frost, salinity, strong winds, diseases and pests, open, not shaded, soil structure and acidity. ***Pre-plant preparation*** includes soil preparation, soil and water analyses, construction of irrigation systems, shade and other protective devices. Pre-plant fertilising, etc may be required. Cultivation may be used to control weeds pre-plant.

Sanitation: All debris from previous crops must be destroyed.

Biological control: Some nursery stock may require treatment prior to planting, eg peach rootstock may be dipped in *Agrobacterium* sp (Nogall®) to protect against crown gall.

Plant quarantine regulates the movement of propagation material of fruit and nuts between regions/states/ territories within Australian. Imports must comply with Commonwealth regulations.

Pesticides: If the site has been cropped before it may be necessary to ***pre-plant*** treat/fumigate the soil to eliminate any soilborne diseases and pests and weeds. It depends on the crop. ***Pre-plant weed control*** involves controlling ***perennial weeds*** with post-emergence herbicides such as glyphosate at least a month prior to cultivation and planting.

Organic Standards: Three main associations certify some fruits, eg banana, based on production standards which details allowable practices and inputs. ***National Association for Sustainable Agriculture Australia*** (NASAA) has 2 organic levels. ***Biological Farmers of Australia*** (BFA) administers two similar levels and the ***Biodynamic Research Institute*** administers the 'Demeter' biodynamic trade mark, with 2 levels. The ***Organic Produce Advisory Committee*** settled in 1991 the national standard for organic and biodynamic produce. This is an export standard which became a domestic standard. It limits the use of the words ***organic and biodynamic*** to produce which has been certified by an approved certifying organisation (Madge 1995).

Maintenance

Cultural method: Deficiencies may be avoided by regular ***tissue analyses*** and the regular application of fertilisers. Appropriate irrigation, pruning and other required processes must be carried out.

Sanitation: ***Prune out*** diseased and infested shoots and fruit during normal pruning. For some problems it may be necessary to prune out diseased material ***during the growing season***. ***Remove all diseased fruit*** from trees and dispose of all fruit on ground, in packing sheds and storage areas. Clean machinery, etc.

Biological control: Several problems, eg red scale, twospotted mite, may be biologically controlled.

Physical and mechanical methods: Insect traps are often used for ***monitoring pests*** but some are used to reduce numbers of some insect pests, corrugated cardboard tied around trunks of apple trees trap ***codling moth caterpillars*** looking for a place to pupate. Caterpillars and ***other easily seen insects*** may be collected by hand on small plantings.

Pesticides: ***Non-bearing and bearing trees*** have different key pests, eg non-bearing apple trees do not require spraying for codling moth. All key diseases, pests and weeds of bearing and non-bearing trees should be ***monitored*** prior to applying pesticides. Many ***less hazardous pesticides*** are being researched, eg petroleum oil sprays for the control of twospotted mite, European red mite, powdery mildew of pome fruits. Guides are available on how to use pesticides to avoid the development of ***resistance***. ***Plant growth regulators*** are used in fruit growing for reducing shoot growth, dwarfing trees, delaying flower opening, thinning excess fruit, decreasing and increasing fruit size, improving colour, shaping, inducing roots in cuttings, inhibiting suckering and preventing pre-harvest fruit drop. Pesticides must be applied at the correct ***growth stage***, eg green tip (Fig. 110).

Postharvest

Harvest: Fruit must be harvested at correct stage of ripeness for the intended market. Cool as soon as possible to the recommended temperature. International quality standards (OECD cur. edn.) are available for many fruit and vegetables.

Plant quarantine: Some pests, eg fruit fly and Fuller's rose scale on citrus, are ***not accepted*** by overseas countries or even within Australia, eg papaya fruit fly in Qld. Various ***disinfestation treatments*** may be used, eg pesticides, heat and hot water treatments. ***Heat treatments*** may be applied after harvest for fruit that is to be sold soon after harvest rather than stored.

Storage/Transport: ***Ethylene*** is a naturally occurring gas produced by all fruit, to initiate its own ripening process. It may be used to ripen green fruit to add uniformity of ripening. The rate at which ripening occurs depends on the ***temperature***. Control of postharvest diseases depends on ***temperature*** (usually involving cooling produce to recommended temperatures), ***relative humidity*** (usually 90-95%) to prevent dehydration and the ***atmosphere*** (carbon dioxide, oxygen and ethylene). Various ***controlled atmospheres (CA)*** are used to control postharvest diseases and pests. ***Package*** as recommended. See Postharvest N 63.

Avocado

Persea americana
Family Lauraceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-DISEASES

Avocado sunblotch viroid is a minor disease of avocado, incidence is low. ***Leaves*** may have white or yellow variegation. ***Bark and fruit*** may show yellow streaks and spots (sometimes white to red). No fruit may form or it is small and deformed. Many infected trees never show symptoms but produce seed which, when used for rootstocks, infect the scion and cause severe disease symptoms. Vigorous water-shoots often grow from buds below the affected scion but rarely produce fruit. ***Spread*** by infected seed, by grafting wood, pruning and cutting implements, by natural root grafting between trees and pollinating insects. ***Destroy affected trees***. Keep a set of pruning, injecting and harvesting tools for use only on virus-tested trees, or disinfect tools. Plant seeds and budwood from certified ***sunblotch-free*** propagation sources or labelled trees derived from the Australian Avocado Growers' Federation ***(AAGF) Virus-tested Tree Registration Programs (VTRP)*** at least 15 m from untested avocado trees to avoid natural root graft transmission of sunblotch (Broadley 1991). ***Other viruses***, eg potato spindle tuber viroid, affect avocado overseas. See Fruit F 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia* sp.) may occur in association with anthracnose in the ***field*** and ***postharvest***. ***Fruit*** has a dark metallic sheen, flesh is brown, liquid-soft, with a rancid smell. Fuerte and Sharwil appear to be more ***susceptible*** than Hass. See Vegetables M 5.

Others: ***Bacterial leaf spot*** (*Pseudomonas syringae* pv *syringae*), also ***stem canker***. (unknown, probably bacterial).

FUNGAL AND ALGAL DISEASES

Fruit rots

Anthracnose, ripe rot (*Glomerella cingulata*) and *Colletotrichum gloeosporoides* are serious diseases of avocado ***fruit***. Fruit damaged by insects, eg caterpillars, are readily infected. ***Many other fungi*** may occur in association with anthracnose, eg *Botryosphaeria, Botryodiplodia, Pestalotiopsis, Phomopsis,* and ***grey mould*** (*Botrytis cinerea*). See Fruit F 5.

Stem-end rot (*Dothiorella* sp.) lives on dead twigs and leaves on plants, spores are splashed onto ***fruit*** during wet weather. The fungus remains ***dormant*** until fruit is mature and begins to ripen when a dark brown to black firm rot starts at the stem end and gradually progresses down the fruit. Clip fruit from the tree and avoid bruising it. Prune out any dead twigs or branches on a regular basis and store fruit in cool, well ventilated place. See Trees K 5.

See Fruit F 5.

Fungal leaf spots

Cercospora leaf or fruit spot (*Pseudocercospora* sp.): Angular brown spots 1-2 mm across, surrounded by a halo develop on ***leaves***. Raised black spots about 2-5 mm across (later sunken, dark and cracked), develop on ***fruit***. Secondary bacteria and fungi may invade cracks. Fuerte and Sharwil are ***more susceptible*** than Hass (Persley 1993).

Red rust, algal spot (*Celphaleuros virescens*) develops on ***twigs and leaves*** in wet conditions. The algal spots are whitish or yellowish, but do not seem to damage plants. Copper sprays may control it.

Others: ***Anthracnose*** (*Colletotrichum*, *Glomerella*) may also cause leaf spots (see above).

See Annuals A 5, Fruit F 6.

Root rots, stem cankers, wilts

Phytophthora root rot (*Phytophthora cinnamomi, P. citricola*) is the ***most serious disease of avocado*** (Fig. 111). On average, 10% of all avocado trees die each year from root rot often as they begin to bear fruit. Orchards may die after 1 season of heavy rainfall, many do not survive > 10 years. Fruit remain small. ***Fruit*** may shrivel on the tree or may fall as it matures. Later ***leaves*** curl, droop and slowly yellow. Leaf margins and veins brown. Plant rootstocks with some ***resistance*** to *Phytophthora*, and fertilise to maintain root tolerance. Only plant grafted trees from ***phytophthora-free nurseries*** accredited under the ***AAGF's*** Avocado Nursery Voluntary Accreditation Scheme ***(ANVAS)***. Trunk injections have been used to regenerate diseased trees (Piccone et al. 1987). The application of ***fosetyl-al*** on heavily scraped stem cankers was found to be the most effective method for controlling *P. citricola* (El-Hamalawi et al. 1995). See Nursery N 54, Trees K 6.

Others: ***Armillaria root rot*** (*Armillaria luteobubalina*), *Colletotrichum*, *Cylindrocladium* spp., *Fusarium*, ***pythium root rot*** (*Pythium* spp., ***verticillium wilt*** (*Verticillium dahliae*).

See Vegetables M 7.

Others: Various ***wood rots***, eg ganoderma butt rot (*Ganoderma* spp.), may affect avocado.

NEMATODE DISEASES

Many nematodes may be associated with avocado roots, eg ***dagger nematodes*** (*Xiphinema* spp.), ***root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* spp., *Rotylenchus* sp.), also *Boleodorus*, *Paratrichodorus porosus*, *Scutellonema*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Leafrollers (Tortricidae): ***Avocado leafroller***, tea tortrix (*Homona spargotus*), may be a ***serious pest*** of avocado, also custard apple, tea and other crops. ***Caterpillars*** are ***greenish*** and up to ***25 mm*** long. They web ***leaves and fruit*** together and feed on rind to a depth of 4 mm. Damaged areas develop scar tissue. Edranol, Wurtz, Reed and Hass, which either have large leaves in clumps or dense fruit clusters, are most affected. ***Ivy leafroller*** (*Cryptoptila immersana*) is a minor pest and causes similar damage to avocado leafroller. Caterpillars are ***yellowish-green*** with 4 prominent black wedge-shaped marks on the white head capsule. See Ivy K 88. ***Orange fruitborer*** (*Isotenes miserana*) is a minor, sporadic pest of Haas and causes damage similar to avocado leafroller. Caterpillars are ***brown-striped*** and cause severe ***fruit*** skin blemish. See Citrus F 37, Pome fruits F 112.

Loopers (Geometridae) feed on young foliage, flowers and fruit rind during summer. ***Bizarre looper*** (*Anisozyga pieroides*) is a minor pest of avocado, guava and macadamia ***fruit skins***. Loopers are brown, flattened, about ***40 mm*** long. ***Brown looper*** (*Lophodes sinistraria*) when young, is velvety black with several white rings around the body. They grow up to ***60 mm*** long and are light brown. When disturbed mature caterpillars remain motionless and stretch out like a twig. They feed on ***leaves and fruit skin***. ***Ectropis looper*** (*Ectropis savulosa*) feeds on leaves and fruit skin. Defoliation causes sunburn. ***Grey looper*** (*Cleora inflexaria*) caterpillars when young are velvety black with 6-7 white rings around the body. They grow to about ***40 mm*** long and feed voraciously on ***foliage*** and gouge irregular holes in ***fruit rind***. When disturbed, loopers remain still and straight like a stick.

Saunders's case moth (*Oiketicus elongatus*) caterpillars chew ragged holes in ***leaves*** of individual trees (Fig. 112). See Trees K 13.

Others: Budworms (*Helicoverpa* spp.), ***omnivorous tussock moth*** (*Acyphyas leucomelas*).

Damaged fruit may be invaded by ***anthracnose***. ***Natural enemies*** include hover fly larvae, parasitic wasps, tachinid flies, egg parasites, predatory bugs and a microsporidian disease. ***Monitor*** caterpillar populations regularly before applying insecticides (Brough et al. 1994). See Annuals A 8, Fruit F 8.

Fruit flies (Tephritidae, Diptera) may ***'sting'*** all varieties of avocado. Maggots rarely develop in the usual commercial varieties, but may cause severe skin blemish. Freshly punctured unripe ***fruit*** exude a clear gum which dries to form a small ***white powdery mass***. Later, a star or T-shaped slit (3-7 mm across with raised edges) develops at the puncture sites. A hard lump of discoloured tissue about the size of a pea is seen if the fruit is cut open, damage is superficial. Taste is not affected but fruit may be downgraded because of appearance. Avocados ***picked green for marketing***, will be free of fruit fly larvae. Fruit left on the tree and picked in ripening conditions could be infested. Thin-skinned, early and mid-season varieties, eg Fuerte and Rincon, and seedling fruits, are the most ***susceptible*** to maggot development. Some varieties may be heavily infested by maggots in autumn. See Fruit F 9.

Fruitspotting bugs (*Amblypelta* spp.) may ***seriously damage*** preferably young ***fruit***. Damage a few weeks old appears as watersoaked areas from which sap exudes and dries white causing a severe callused skin blemish. Brown pockets of damaged tissue 7-15 mm deep are seen when fruit is cut open. Very shallow injuries can be difficult to distinguish from ***fruit fly damage.*** Fruits damaged before December may fall, injured fruit remaining on the tree are usually unmarketable. All varieties are attacked but heaviest losses occur in the early and mid-season thin-skinned varieties, eg Fuerte and Rincon. ***Monitor*** bug damage at regular intervals before applying an insecticide (Brough et al. 1994). See Fruit F 10.

Leaf beetles, flea beetles
(Chrysomelidae, Coleoptera)

Metallic flea beetles (*Altica* spp.) may chew holes in ***leaves*** of nursery trees. Insecticides may be necessary. See Hibiscus K 82.

Leaf beetles (Chrysomelidae) are minor and sporadic pests of foliage and fruit, eg ***redshouldered leaf beetle*** (*Monolepta australis*), ***swarming leaf beetles*** (*Rhyparida* spp.). ***Monitor*** swarms on adjacent trees where they could be controlled prior to them entering crops (Brough et al. 1994). See Fruit F 11, Trees K 15.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus,* Tarsonemidae) may distort ***new leaves*** of ***nursery stock***. ***Monitor*** populations. See Greenhouses N 26.

Spider mites (Tetranychidae): ***Sixspotted mite*** (*Eotetranychus sexmaculatus*) sucks sap from ***leaf undersurfaces*** causing yellowish speckling and later leaf fall. Adult mites are translucent with ***3 dark spots*** on either side of the abdomen. Natural enemies of twospotted mite also assist control of six-spotted mite. ***Tea red spider mite*** (*Oligonychus coffeae*) feed on avocado, camellia, castor-oil plant, coffee, grevillea, mango, tea. Mites are about ***0.4 mm*** long and their feeding causes midribs and veins and eventually whole leaves to turn reddish-brown. Under water stress, leaves, especially of Wurtz, may fall. Mites suck plant sap preferably from the ***upper surfaces*** of older leaves during hot dry periods. ***Gradual metamorphosis*** (egg, nymph, adult) with many generations each year. Rain may wash mites off leaf uppersurfaces. Mites are usually controlled by predatory ladybird, eg *Stethorus* spp., lacewing larvae and predatory mites. Mites mostly damage leaves if predators have been killed by misuse of pesticides. ***Monitor*** mite populations, damage and predators at regular intervals before applying an insecticide (Brough et al. 1994). See Beans (French) M 29.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Fiorinia scale*** (*Fiorinia fioriniae*): Adult female scale cover is shield-shaped, ***1-1.3 mm*** long and yellowish brown to orange-brown in colour. There is a pale yellow terminal marking. ***Latania scale*** (*Hemiberlesia lataniae*) is a minor and sporadic pest of avocado (fruit, twigs, limbs and trunk), banana, papaw, kiwi, also *Albizia* spp., hakea, liquidamber, poplar, privet, willow. ***Adult females*** are circular, about ***2 mm*** across, convex and dirty white. They have a large, pale brown, central to sub-central marking. Males are smaller and more slender. Scale-infested fruit is edible but must be cleaned before marketing. There are several generations each year. Smooth-skinned varieties may be brushed off in the packing shed. ***Natural enemies*** keep scale in check but may be suppressed by misuse of chemicals. If chemicals are needed, apply white oil on Hass when 4 scales are producing crawlers per fruit (Brough et al. 1994). ***Spanish red scale*** (*Chrysomphalus dictyospermi*) cover (female) is circular, ***1.5-2 mm*** across, slightly convex, and grey with a clear central ring. Males are smaller. Scales may seriously damage trees. Even a few scales disfigure dark fruit. Some growers clean scales from smooth-skinned fruits by hand. Natural enemies are not effective enough to prevent economic damage to fruit. See Citrus F 39.

Soft scales (Coccidae): ***Indian white wax scale*** (*Ceroplastes ceriferus*), ***pink wax scale*** (*C. rubens*), ***soft brown scale*** (*Coccus hesperidum*), ***white wax scale*** (*Gasgardia destructor*). See Citrus F 41.

See Citrus F 39.

Others: ***Coon bug*** (*Oxycarenus arctatus*) may swarm on ***flowers*** causing them to fall. ***Plague thrips*** (*Thrips imaginis*) feeds in ***flowers*** and ***redbanded thrips*** (*Selenothrips rubrocinctus*) on ***leaves*** and ***fruit***. ***Also aphids*** (Aphididae), ***avocado bark beetle*** (*Paleticus* sp.), ***planthopper*** (*Siphanta galeata*), ***whiteflies*** (Aleyrodidae, Hemiptera), ***crickets*** (Gryllidae) and ***wingless grasshopper*** (*Phaulacridium vittatum*), ***leafhoppers*** (Cicadellidae);

VERTEBRATE PESTS

Rats and birds may damage fruit on the tree. ***Hares*** may eat the bark of young trees. Fruit F 13, Seeds N 77.

Non-parasitic

Environment: Prevent ***sunburn*** of top branch surfaces and fruit. Avocado is sensitive to ***frost***, so either choose a frost-free site, or plant a frost-tolerant variety, eg Bacon or Fuerte. ***Chilling injury*** is caused by exposing ripening avocados to temperatures < 12^{o}C. Shelter from strong ***winds*** as wind rub of leaves, twigs and branches may damage fruit and slow tree growth. ***Water stress*** causes leaf wilting, reduces fruit size and numbers, fruit may elongate, crack and fall. ***Oxygen deficiency*** in soil may cause ***feeder roots*** to become translucent from fermentation products. ***Leaves*** wilt, but may remain bronze-green and hang for a week or more. ***Favoured*** by heavy rainfall, poor drainage, and heavy irrigation.

Genetic: ***Albinism*** results from planting immature seed. 1st leaves on seedlings are white and distorted. ***Chimera*** may occur in Fuerte (sectors of yellowish skin). Do not propagate from affected branches. See Tulip C 43.

Nutrient deficiencies, toxicities: Various ***deficiencies***, eg boron, copper, iron and zinc (little leaf, mottle, rosette), may occur. Nitrogen levels determine yield. ***Toxicities*** may also occur, eg ***tipburn*** from excess mineral salts. ***Leaf analysis standards*** are available for avocados (Weir and Cresswell 1995).

Pesticide injury: ***Copper sprays*** may leave a deposit on fruit, ***herbicides*** may injure young trees.

Others: Although avocado is evergreen, ***heavy leaf fall*** is common during flowering. ***Sooty blotch*** (fungus) is a minor disease which reduces photosynthesis causing black superficial marks on stems, leaf veins and fruit in humid weather.

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State/Territory Departments of Agriculture/Primary Industry eg

NSW Agfacts

Avocado Diseases
Avocado Growing
Avocados : Cultural & Financial Aspects
Avocados in the Garden
Latania Scale in Young Macadamia Orchards (NSW Agnote)

Qld Dept of Primary Industries (videos)

Insects & Mite Pests of Avocados
Managing Phytophthora Root Rot in Avocados

SA Bulletins

Growing Avocados in South Australia

Vic Agnotes

Avocado Root Rot
Avocados : Recommended Varieties for Sunraysia
Citrus and Avocado Kit
Increasing Fruit Set in Feurte Avocados by Cincturing
Orchard Management to Prevent & Control Avocado Root Rot
Production of Trees Free From Avocado Root Rot
The Avocado

WA Farmnotes

Irrigation Requirements of Avocado
The Avocado in Western Australia (Bulletin 4077)

Association, Journals etc.

Atherton Tableland Avocado Growers' Assoc.
Australian Avocado Growers' Federation (AAGF)
Avocado Improvement Schemes
Avocado Nursery Voluntary Accreditation Scheme (ANVAS)
Virus-tested Tree Registration Programs (VTRP)

See Fruit and nuts F 15, Nurseries N 56, Postharvest N 62, Preface xii

Remember, always check for recent references

MANAGEMENT

An overview of the industry has been presented by Coombs (1995). ***Management programs and guides*** for avocados are available (Broadley 1992, Coombs 1995). The ***Avoman*** computer package available from Qld Dept. of Primary Industries features a series of modules covering every aspect of farm management. Avocado is an evergreen fruit tree. Although it is tropical it can be grown in temperate regions in sheltered sites. Flowers function as females for a few hours, close then re-open as male flowers the following day. Planting pollinating varieties maximises cropping. Some varieties are ***cold tolerant***, eg Fuerte, or ***wind tolerant***, eg Rincon. Plan to use cultivars with ***Phytophthora-resistant*** rootstocks. Purchase ***virus-tested nursery stock*** from the Avocado Nursery Voluntary Accreditation Scheme ***(ANVAS)*** which guarantees its stocks to be free from *Phytophthora* and other diseases and pests. ***Propagated*** by grafting on to seedling rootstocks. Grafted trees begin to bear fruit after 3 years. ***Cultural methods:*** Provide excellent surface and subsoil drainage, frost-free sites and shelter from wind. Reduce *Phytophthora* by planting on a gentle slope to allow free drainage; maintain high levels of organic matter, magnesium, calcium and nitrogen in soil. ***Little pruning*** is required. ***Sanitation*** practices are required for fruit fly and other pests. ***Biological control*** programs may be used to reduce mite infestations. ***Monitor*** pest insects, eg examine 5 trees at each of 6 widely spaced locations in the crop and only apply ***pesticides*** when damage is observed (Brough et al. 1994). ***Harvest*** cultivars at the correct time, early in the morning preferably before temperatures exceed 21^{o}C and avoid damaging the skin of fruit. Avocados may be marketed with a given oil content. Apply ***postharvest fungicidal dips*** to control anthracnose and other diseases and cool as required.

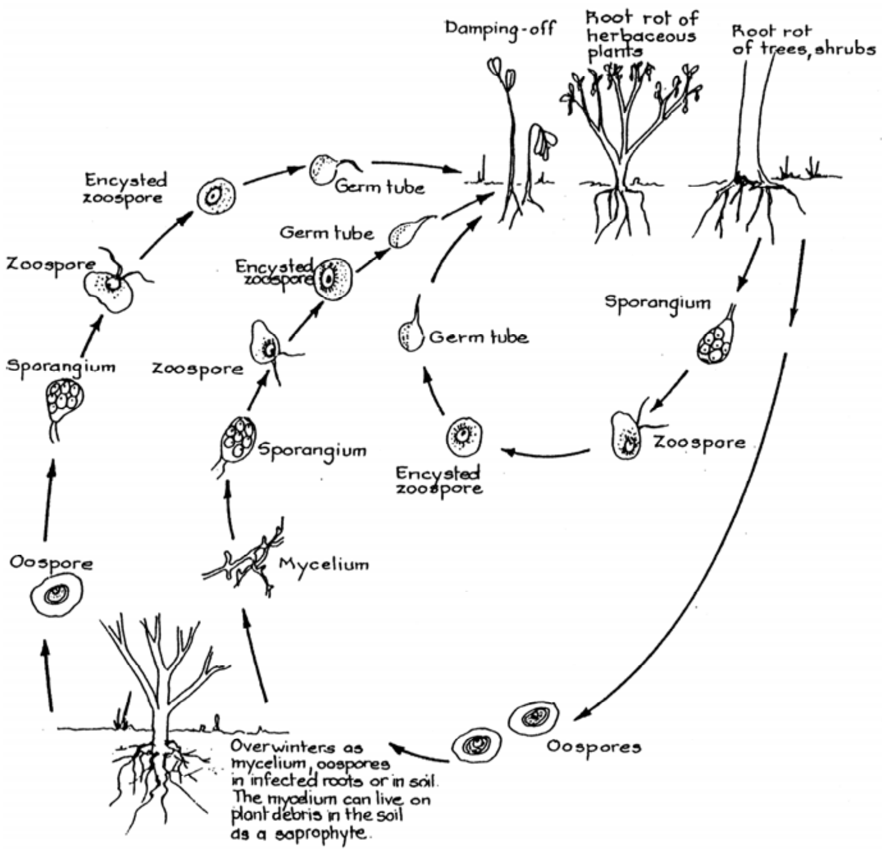

Fig. 111. Disease cycle of *Phytophthora* spp.

Fig. 112. Caterpillar case of Saunders's case moth (*Oiketicus elongatus*) is up to 130 mm long.

Banana

Musa sapientum, *Musa* spp.
Family Musaceae

Bananas are probably the world's most widely traded fruit and are next to rice as a source of energy (Griggs 1994).

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Banana bunchy top virus: Broken, dark green streaks develop along ***leaf veins***, ***leaves are short*** with wavy margins, upright, narrow and brittle ***(bunchy top)***. Plants affected when young rarely produce bunches, those affected later produce bunches which point upwards. ***Spread*** by banana aphid (*Pentalonia nigronervosa*), by introduction of infected planting material, sometimes by tissue culture. Local departments of agriculture must be ***notified*** if bunchy top is found on a property, plants will be destroyed in a prescribed manner. Observe ***plant quarantine*** restrictions for movement of banana plants in some regions. Plant only ***virus-free plants***. Enzyme-linked immunosorbent assay ***(ELISA)*** tests are available for bunchy top and cucumber mosaic virus. Bunchy top has been listed as ***one of the world's most economically threatening plant viruses.***

Others: Cucumber mosaic virus, and overseas, banana bract mosaic, banana streak disease.

See Fruit F 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*) causes ***newly planted rhizomes*** to rot, and emerge poorly. See Vegetables M 5.

Moko disease, bacterial wilt (*Pseudomonas solanacearum* Race 2) affects bananas overseas. It can be confused with *Fusarium* wilt. Infected banana, plantain and *Heliconia* plants and banana fruit pose the greatest ***quarantine risk*** of introducing Moko disease into Australia. ***Quarantine precautions:*** Importation of *Heliconia* plants is prohibited, seed is allowed. Banana plants may be imported only under permit and strict precautions, eg growth in quarantine for at least 2 seasons. Importation of banana fruit is usually prohibited (Com. of Aust. 1988).

Others: ***Mokillo disease,*** gumming, bacterial finger tip rot (*Pseudomonas* sp.) is a minor disease causing distorted fruit (bulbous base and thin tip).

FUNGAL DISEASES

Bunch diseases

Anthracnose and black end (*Colletotrichum musae*) causes circular brown sunken spots on ***ripe fruit postharvest*** (see Fruit F 1, Fig. 96) which become covered with ***pink to rusty spores***. Cut ends of single fruits ***blacken*** and rot. As the fruit ripens the rot advances down the stalk into the flesh. Avoid bruising fruit. See Fruit F 5.

Black pit (*Pyricularia grisea*) is a minor disease. Small red spots, which become shallow black pits 3-6 mm wide, develop on upper hands of ***bunches*** and on ***fingers*** on exposed sides of bunches. Similar to damage by fruitspotting bug. Spores ***spread*** by wind from debris to fruit.

Black tip, black spot, fruit speckle (*Deightoniella torulosa*) is a minor disease of ***damaged fruit***. It is also present on ***flowers and leaves***. Sunken, dark brown spots 2-4 mm across surrounded by green halos, develop on fruit, especially towards the tip or blossom end. Chinese Cavendish appears to be ***more susceptible*** than other cultivars.

Ceratocystis fruit and corm rots (*Ceratocystis paradoxa*) causes a black rot of ***fruit crowns*** on which a grey fungus grows, in wet seasons. If stalks rot, bananas drop. ***Postharvest*** infection occurs through harvesting cuts. ***Corms*** are brown, watery, a grey mould grows in cavities. *Ceratocystis* is soilborne and infects corms through wounds. Do not plant infected material.

Cigar end (*Verticillium theobromae*) is a minor disease in wet seasons when it colonises dead flower parts and leaf debris. A firm dark decay develops at the blossom end of ***fruit*** and extends 20 mm back along the fruit. ***Ash grey spores*** develop on rotted areas.

Crown rots (*Colletotrichum musae, Fusarium pallidus*, *Verticillium* sp.) are ***serious postharvest diseases*** of banana. As ***fruit*** ripens, cut ends of hands rot. Rots advance down fruit stalks causing fruit to fall. The fungi inhabit dead flowers and enter fruit through wounds at harvest. Disease develops in ***storage***. Cut crown cleanly from bunch stalks and leave a large amount of crown tissue to reduce finger stalk infection.

Squirter (*Nigrospora sphaerica*) is a ***postharvest*** disease, the pulp decomposes to a dark semi-fluid state which can be squeezed from the fruit.
Others: Fruit spot (*Cercospora hayi*).

See Fruit F 5.

Fungal leaf spots

Black Sigatoka (*Mycosphaerella fijiensis* var. *difformis*) and ***black leaf streak*** (*M. fijiensis*) are ***serious diseases*** of bananas. They occur in Australia but not yet in commercial plantations. ***Quarantine risks:*** These diseases may be introduced to disease-free areas on planting material, leaves, or leaf trash associated with fruit (Com. of Aust. 1988). ***Resistant cultivars*** are planted in Australia. Movement of banana material from where it occurs is prohibited. ***Leaf speckle*** (*M. musae*) reduces fruit production. Watersoaked patches develop initially on ***5th and 6th youngest leaves*** and exude droplets of water under humid conditions. Later diseased areas dry out and severely affected leaves become dark yellow and droop. ***Yellow Sigatoka, leaf spot*** (*M. musicola*). Pale yellow streaks about ***10 mm*** long develop on upper surfaces of the ***3rd or 4th youngest leaves***. These streaks develop into grey spots with a thin blackish border and a yellow halo. Leaves may brown, with black and grey streaks, then die and fall. Fruit yield is reduced. Spores ***spread*** by wind or water.
Black-cross leaf spot (*Phyllochora musicola*) is ***serious*** on cooking bananas and Lady Finger in the Torres Strait; Cavendish is ***resistant***. ***Black 4-pointed stars*** develop on ***leaf undersurfaces*** of older leaves. No control required.
Cordana leaf spot, yellow leaf spot (*Cordana musae, Cordana* sp.) is a minor disease causing brown, zonate, elongated oval ***leaf spots*** up to ***100 mm*** long surrounded by a halo.
Freckle (*Guignardia musae*): Dark brown spots develop on ***older leaves, green fruit and fruit stalks***. Found on Torres Strait Islands and Cape York. Not yet found in commercial plantings in Australia. Cavendish is ***resistant***.

See Annuals A 5.

Panama wilt, Panama disease, fusarium wilt (*Fusarium oxysporum* f.sp. *cubense*) affects banana and some grass species and is ***potentially a serious disease*** of bananas. Young plants wilt when the fungus spreads in vascular tissue. In older plants foliage yellows and bases of pseudostems splits, plants die. ***Water-conducting tissues*** in the pseudostem are brown. There is no cure for infected plants. Uncommon in NSW ***Susceptible*** cultivars include Lady Finger. ***Resistant cultivars*** include Cavendish. Strains (Race 4) that attack Cavendish and other previously resistant cultivars have been found in Qld. Goldfinger is resistant to Race 4. ***Quarantine measures*** restrict spread of Race 4 to other areas. Disease must be confirmed by local departments of agriculture. ***Verticillium wilt*** (*V. dahliae*) may also attack banana. See Vegetables M 9.

Root and corm rots

Corm rot, dry rot (*Armillaria elegans*, *Armillaria* spp.). Fungal hyphae penetrate ***root and corm tissues*** at or below ground level and spread to the corm centre. ***Mushroom-like fruiting bodies*** may develop. Leaves may die from the base up. Plants may be pushed over. See Trees K 4.
Marasmiellus corm and pseudostem rot (*Marasmiellus inoderma*, Basidiomycetes) is a minor disease of banana, maize, turfgrasses, debris. Outer leaf sheaths of pseudostems die. White fungal threads and sunken brown lesions occur between the sheaths and slowly extend from leaf sheaths into the ***corms***, and plants are weakened. ***Spread*** from decaying leaf and grass debris to bananas. Pale yellowish-brown ***mushrooms*** may develop on the surface of diseased pseudostems during wet weather. Occurs on plants stressed by drought, nematode or banana weevil borer infestation.
Others: Ceratocystis rot (*Ceratocystis paradoxa* ***dry rot of corm*** (*Poria hyposclera*), ***corm and root rot*** (*Marasmius stenophyllus*), ***root and corm rots*** (*Elvingia mastospora, Fuscoporia contigua, Rhizoctonia solani*), ***sclerotinia rot*** (*Sclerotinia sclerotiorum*), ***sclerotium rot*** (*Sclerotium rolfsii*).

See Fruit 7, Vegetables M 7.

Others: ***Rust*** (*Uredo musae*), ***stalk and fruit rot*** (*Botryodiplodia theobromae*), ***northern speckle*** (*Ramichloridium musae*), *Chloridium musae, Glomerella cingulata*.

NEMATODE DISEASES

Burrowing nematode, *Radopholus* root rot (*Radopholus similis*) is a widespread introduced ***serious pest*** of banana plantations. It also attacks sugar cane, fruit and ornamental trees, vegetables, weeds. Nematodes invade ***roots*** and cause large cavities in the tissue, which are invaded by soil fungi, eg *Fusarium,* and extensive rotting may occur. Plants may fall over, particularly in wet windy weather. Bunches are small and fruit is undersized. Affected plants have fewer and often smaller bunches. After 4-5 years, cultivation may not be worthwhile. ***Overwinters*** in trimmed planting material, weed hosts Nematodes die quickly if plantations are destroyed. ***Favoured*** by new root growth. Practise ***crop rotations*** of at least 2 years. Appropriate fertiliser and irrigation regimes minimise effects of damage. All varieties are ***susceptible***, especially Cavendish. Plant nematode-free bananas from ***approved banana schemes***, from tissue cultured plants or sets disinfested in hot water, into ***Radopholus-free soil***. ***Soil may be treated*** with nematicide before planting and during the cropping cycle. ***Do not replant land*** where regrowth from former banana plantings is likely. ***Seek advice*** and contact the district horticulturist. See Vegetables M 10.

Others: ***Root knot nematode*** (*Meloidogyne incognita*) is widespread, but of minor importance. Galls on roots allow soil fungi to enter roots causing rotting. Also ***foliar nematode*** (*Aphelenchoides* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.) and ***spiral nematodes*** (*Helicotylenchus* spp., *Rotylenchus* spp.), *Criconema*, *Dipsaci*, *Filenchus* spp., *Hemicycliophora* spp., *Hoplaimus* spp., *Lelenchus*, *Paratrichodorus*, *Pseudohalenchus*, *Scutellonema* spp., *Tylenchus, Xiphinema.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Banana aphid (*Pentalonia nigronervosa,* Aphididae) affects banana (*Musa* spp.), especially Cavendish, Manila hemp, *Strelitzia*, *Ravenala*, *Alpinia, Arum maculatum*. ***Adult females*** are about 1 mm long, brown, winged or wingless. Fore and hind wings have dark borders; hindwings are very small. No male forms develop, no eggs are laid, live young are born. ***Nymphs*** are paler than adults. Banana aphid is more important as a vector of the ***bunchy top virus disease*** than for the feeding damage it causes. Aphids feed on ***leaf undersurfaces***, at the bases of ***pseudostems,*** and below soil level on emerging ***suckers***. Honeydew attracts ants and favours sooty mould (*Chaetothyrina musarum*). White slimy ***yeasts*** grow on honeydew on pseudostems. ***Spread*** by aphids flying and by movement of infested plant material. ***Favoured*** by warm moist weather in spring, aphids feed and breed throughout the year. ***Natural enemies*** and ***insecticides*** do not prevent transmission of bunchy top. See Roses J 4.

Banana weevil borer, banana root borer (*Cosmopolites sordidus,* Curculionidae, Coleoptera) is a pest of banana and sugar cane. ***Weevils*** are sluggish, about ***12 mm*** long, oval, with a snout, red-brown when young, later dark grey, wing covers and thorax have fine indentations (Fig. 113). They feign death if disturbed. During the day, they hide in leaf sheaths or at the plant base. ***Larvae*** are up to ***12 mm*** long, curved, fat and legless, cream with a brown head. ***Damage*** by adult weevils is minor. Larvae tunnel in ***corms and pseudostems*** which become riddled, and later rot (Fig. 113). Sucker growth is stunted, sucker production is reduced, bunches are small and fruit undersized. There are ***several generations*** each year. Weevils lay eggs in the bases of pseudostems or sheaths at night throughout the year. Larvae pupate near the outside of corms. Adults emerge in spring and autumn. ***Overwinters*** as adults in the ground. ***Spread*** by weevils crawling and introduction of infested planting material. ***Favoured*** by warm and moist weather, neglected plantations. ***Control*** is compulsory under plant diseases acts. Practise fallows of 3-6 months before planting. Maintain plantation vigour. ***Remove, chop up*** crop debris (corms and stems). and weeds to expose larvae and eggs. ***Natural enemies***, eg rats, cane toads, frogs, birds and ants, prey on adults and larvae but do not significantly reduce populations. A ***blue planarian worm*** (*Geoplana caerulea*) sucks body juices from weevils. ***Two predatory beetles*** (*Dactylostereum hydrophiloides*, *Plaesius javanus*) have been introduced. ***Quarantine legislation*** regulates movement of plant material belonging to the genus *Musa* spp. Plant ***weevil-free material***. ***Monitor*** weevil populations before applying an insecticide (Brough et al. 1994). ***Another weevil*** (*Enteles vigorsi*) breeds in banana crop debris. Do not confuse with banana weevil borer. See Fruit F 13, Vegetables M 17.

Caterpillars (Lepidoptera)

Banana fruit caterpillar (*Tiracola plagiata,* Noctuidae) feeds on banana plants and weeds in summer. ***Moths*** are about 50 mm across outspread forewings which are brown in females and red-brown in males. ***Caterpillars*** are khaki and about ***60 mm*** long with 2 pairs of black marks on the uppersurface. ***Young plantations*** may suffer ***serious foliage damage***. Small caterpillars chew ***fruit skin***, larger ones chew into ***flesh***. Caterpillars may migrate to bananas from weeds. ***Monitor*** caterpillar populations on bananas at regular intervals before applying an insecticide (Brough et al. 1994).

Banana scab moth (*Nacoleia octasema,* Pyralidae) lay eggs near or on the outside of newly emerging bunches in Qld north of Ingham. ***Caterpillars*** eat skin of ***young fruit*** wrapped in its bract, damaged areas scab over as fruit mature (on the outer curve) Caterpillars cease feeding soon after the fingers are exposed, about 2-3 weeks after the bunch has first emerged. They pupate in leaf bases or in debris on the ground. Natural enemies are ineffective.

Banana skipper, banana leafroller (*Erionota thrax,* Hesperiidae) caterpillars may cause up to ***70% defoliation*** of banana plants in areas of New Guinea and SE Asia. ***Quarantine risks:*** Butterflies are capable of island hopping from PNG to mainland Australia. Butterflies may be carried in cargo holds and eggs on banana plants. (Com. of Aust. 1991).

Others: ***Cluster caterpillar*** (*Spodoptera litura*), ***orange fruitborer*** (*Isotenes miserana*), ***sugarcane bud moth*** (*Opogona glycyphaga*, Tineidae).

See Annuals A 8, Fruit F 8.

Fruit flies (Tephritidae, Diptera) may infest bananas. ***Banana fruit fly*** (*Bactrocera musae*) infests cultivated and wild bananas in Qld north of Ingham (Brough et al. 1994). Although preferring ***ripening fruit***, it will also sting (lay eggs) in ***green fruit***, especially if fruit is damaged. Eggs laid in green fruit survive and hatch when the fruit ripens. Infestations are often mistakenly identified as Queensland fruit fly maggots, which are uncommon in banana. ***Queensland fruit fly*** (*B. tryoni*) may infest ***ripening bananas***. Stinging of green fruit in the field is unusual, but may occur if fruit ripens prematurely due to damage by weather or diseases. Bananas for certain markets may be required to be ***inspected or to be disinfested***. ***Papaya fruit fly*** (*B. papayae*) attacks fruit ***at a greener stage***. ***Strict quarantine measures*** and fruit treatments are in place to prevent the further spread of this fruit fly within Australia. See Fruit F 9.

Fruitspotting bugs (Coreidae, Hemiptera) may damage ***young shoots***. Feeding on fruit causes the skin to become sunken, dark, circular areas about 7 mm across which later crack, develop as fruit matures. ***Monitor*** populations prior to spraying. See Fruit F 10.

Mites (Acarina): ***Spider mites*** (Tetranychidae), eg ***banana spider mite*** (*Tetranychus lambi*), infests undersurfaces of older banana ***leaves*** causing bronzing which is only important on suckers and young plants. Webbing is insignificant. Skin of infested ***fruit*** becomes red-brown and cracks. ***Favoured*** by hot dry weather and mites moving in from weed hosts and the warm dry conditions under plastic bunch covers. **Twospotted mite** (*Tetranychus urticae*) infests **leaves** causing a sandy mottle, and tips of fingers may become silvery grey. See Beans (French) M 29. **Others:** **Banana rust mite** (*Phyllocoptruta musae,* Eriophyidae), **bunch mite** (*Brevipalus lewisi*).

Scales (Hemiptera): **Armoured scales** (Diaspididae), eg **cyanophyllum scale** (*Abgrallaspis cyanophylli*), is a minor pest but may be serious if plants have been heavily sprayed with fungicides. **Adult female scales** are light brown, roughly oval, 1-2 mm long, white and semi-transparent. **Males** are smaller and more elongate. **Latania scale** (*Hemiberlesia lataniae*) is a minor pest. **Adult female scales** are dirty white, circular, and about 1.5-2 mm across. Scales are found occasionally on the skin of banana fruits or on bunch stalks. See Avocado F 20. **Transparent scale** (*Aspidiotus destructor*) may infest some leaves heavily on some plants. See Citrus F 39.

Scarab beetles, canegrubs (Scarabaeidae, Coleoptera): **African black beetle** (*Heteronychus arator*), in land recently under paspalum pasture, chews the bases of newly-planted suckers ragged. Infested plants may wilt, be retarded or die. **Greyback cane beetle** (*Dermolepia albohirtum,* Scarabaeidae) feeds on older leaves, larvae feed on roots, plants may topple over. See Turfgrasses L 11.

Thrips (Thripidae, Thysanoptera)

Banana flower thrips (*Thrips hawaiiensis*) may be an **important pest** of Cavendish bananas in north NSW and occasionally in SE Qld. Thrips lay eggs on young fruit and cause unimportant minute raised spots. Adult thrips rasp and suck sap from **fruit** up to 2 weeks old, while it is wrapped closely in its bracts. A grey-brown corky scab and sometimes cracking, forms on the outer curve of the hand. Overhead irrigation is considered to nearly eliminate corky scab.

Banana rust thrips (*Chaetanaphothrips signipennis*) is a **serious pest** of bananas, may attack citrus, cunjevoi (*Alocasia macrorrhiza*) and some native plants. **Thrips** are about **1.3 mm** long. Eggs are laid in pseudostems under leaf sheaths or where 2 fruits touch. Nymphs and adults feed on **leaves,** causing reddish areas. Infested **young fruit** may split. **Older fruit** may be rusted but cracking is superficial. **Spread** on planting material. Adult thrips fly weakly. **Favoured** by warm weather October-March. **Destroy** old plantings and volunteer bananas. **Bunch covers**, applied soon after emergence, may give a measure of control. Only plant **thrips-free planting material. Insecticides** may be applied to bunches, stems, including throats, bases of parent plants, suckers and adjoining soil.

Banana-silvering thrips (*Hercinothrips bicinctus*) infests banana, choko, passion fruit, weeds. **Adult thrips** are about **1.5 mm** long (slightly larger than banana rust thrips). Banana **fruit** of all stages of maturity may be attacked. Fruit develops silvery speckling which turns brown with dark thrips excreta. Patchy infestation may cause damage similar to that of rust thrips. Deep longitudinal cracks in fruit may develop. **Favoured** in spring-early summer, by heavy weed growth or where choko or passion vines grow amongst bananas. Control as for banana rust thrips, may start in early spring.

See Greenhouses N 24, Roses J 6.

Whiteflies (Aleyrodidae, Hemiptera): **Spiralling whitefly** (*Aleurodicus dispersus*) occurs on Torres Strait Islands and Thursday Island and may infest tropical fruit and vegetables. It may be controlled biologically by a wasp (*Encarsia haitensis*). It has a spiral egg laying pattern and may be confused with **coconut whitefly** (*A. destructor*) which lays its eggs in a similar pattern. See Greenhouses N 24.

Others: **Banana stalk fly** (*Derocephalus angusticollis = Teleostylinus bivittatus*, Diptera), **black swarming leaf beetles** (*Rhyparida* spp.) and **redshouldered leaf beetle** (*Monolepta australis*).

SNAILS AND SLUGS

Snails and slugs may be occasional pests. See Seedlings N 70.

VERTEBRATE PESTS

Fruit bats (*Dobsonia* spp., *Pteropus* spp.) and **birds** damage bunches. **Feral pigs** and **possums** may damage plants and fruit. See Fruit F 13.

Non-parasitic

Environment: **Choke** (the fruit bunch fails to emerge or is abnormally twisted) is caused possibly by moisture stress just prior to when the bunch is due to emerge. Chlorine draining from swimming pools may also cause choke. Young bunches may be covered to protect them from **frost, sun, wind and birds**. **Temperature** and other environmental factors may cause many physiological bunch diseases. **Split corm** is uncommon, and is probably a physiological disorder, occurring in dry weather when soil moisture is low.

Nutrient deficiencies, toxicities: Nutrient tissue analyses are the basis of fertiliser regimes. **Leaf analysis standards** are available based on diagnostic and research analyses (Weir and Cresswell 1995).

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State/Territory Departments of Agriculture/Primary Industry eg

NSW Agfacts/Agric. Books

Banana Growing
Banana Rust Thrips and Banana Silvering Thrips
Bananas in the Garden
Bananas : Cultural and Financial Aspects
Bananas : NSW Grading, Packaging and Labelling Requirements
Bananas : Response to Temperature
Banana Varieties : Their Classification
Banana Varieties : Their Performance
Banana Weevil Borer
Bunch Covers for Bananas
Fertilising Bananas :
Calcium, Magnesium & Trace Elements
Leaf Analysis as a Guide
Nutrient Cycle and Fertiliser Strategy
Fertilising Bananas in NSW (NSW Agric. Book)
Leaf Speckle of Bananas
Leaf Spot of Bananas
Plantation and Market Diseases of Banana Fruit
The Banana Weevil Borer (NSW Agric. Book)
Upgrading Banana Quality

NT Agnotes

Banana Growing
Choko : A Disorder of Banana
Costs and Returns for Bananas

Qld video (Dept. of Primary Industries)

Banana Bunchy Top Disease
Banana Panama Disease
Panama Disease

Associations, Journals etc.

Australian Banana Growers Council
Australian Centre for International Agricultural Research (ACIAR) (Banana Project)
Banana Growers Federation Co-op.
Banana Industry Protection Board
Banana Replacement Program (Qld DPI)
Banana Sectional Group Committee
Good Fruit & Vegetables

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

The ***planting of bananas*** is usually controlled by state and territory authorities. An overview of the industry has been presented by Coombs (1995). Select varieties ***resistant*** to Panama wilt, eg Gold finger. Gene therapy may be used to develop varieties resistant to various problems. Plant ***disease and insect-free*** tissue-cultured material to exclude major diseases and pests. Queensland and NSW banana industries are developing accredited banana nursery industry scheme guidelines for the production of tissue-cultured disease-free planting material. Tests are available for bunchy top and cucumber mosaic virus. ***Propagated*** by suckers and by tissue culture. Preferably plant in ***areas*** not previously planted to bananas, if such areas are not available, allow a period of 2 years after removal of old plants before replanting. ***Weed control*** is important and in some areas legislation demands that no weeds be allowed to grow within 2 m of a banana plant. ***Sanitation*** includes the removal all banana debris. To minimise disease and pest spread, ***strict plant quarantine*** is applied. Under legislation, no person shall move any plant or any part of any plant, except the fruit, of the genus *Musa* into, or out of, or within, a quarantine area (which covers many of the commercial banana-growing districts in Australia), without a permit issued by state/territory departments of agriculture. ***Pesticides*** are registered for bananas including for bunch injections. ***Pest management programs*** are available (Pinese and Piper 1994). They are based on ***regular monitoring*** of pests and predators and strategic pesticide applications only when necessary. Trained pest scouts are available to conduct monitoring and provide advice on action when economic injury levels are reached. Three main associations, eg National Association for Sustainable Agriculture Australia (NASAA), Biological Farmers of Australia (BFA) and the 'Demeter' biodynamic trademark certify ***banana standards*** according to production standards which detail allowable practices and inputs. All bananas are subject to quality and size ***standards*** which can be obtained from state/territory departments of agriculture.

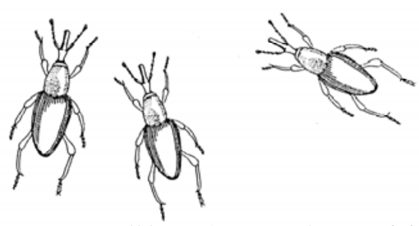

Fig. 113. Banana weevil borer (*Cosmopolites sordidus*). ***Left :*** Adult weevils (about 12 mm long). ***Right :*** Larvae (about 12 mm long) tunnelling in a banana corm.

Blueberry

Vaccinium spp.
Family Ericaceae (heath family)

Australia is free of some of the most serious problems affecting blueberry overseas, eg virus diseases and insect pests.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Blueberry stunt mycoplasma and other serious virus diseases are not known to occur in Australia.

BACTERIAL DISEASES

Bacterial blight (*Pseudomonas* sp.) affects blueberries. ***Blossoms, shoot tips***, and patches on ***previous season's growth*** are ***killed***. Disease is most obvious ***early in spring*** when dead shoot tips and laterals do not grow but undamaged buds do. Early frosts in autumn may predispose leaves, shoots and buds to infection. Blueberry in Tasmania is not normally subject to frost injury. ***P. andropogonis*** causes ***leaf spots*** on hardwood cuttings and field grown Highbush blueberry in New Jersey (Kobayashi et al. 1995). See Carnation A 16.

Crown gall (*Agrobacterium* sp.) may affect nursery stock. See Stone fruits F 125.

FUNGAL DISEASES

Anthracnose (*Colletotrichum* sp.) may be an important disease. See Fruit F 5.

Fungal leaf spots (*Alternaria* sp.) may be a problem ***during humid weather***. See Annuals A 5.

Grey mould (*Botrytis cinerea*) affect ***ripe berries*** in conditions of cool temperatures, prolonged rain and high humidity. See Fruit F 5, Greenhouses N 22.

Powdery mildew (*Microsphaera vaccinii*). See Annuals A 6, Fruit F 6.

Root and stem rots: ***Phytophthora root rot*** (*Phytophthora* spp.) may be a ***serious disease*** of blueberry. Also ***armillaria root rot*** (*Armillaria* spp.), ***sclerotinia rot*** (*Sclerotinia sclerotiorum*). See Fruit F 7, Vegetables M 7.

Stem cankers (*Botryosphaeria*, *Guignardia* sp., other fungi). ***Guignardia*** is associated with stem browning and tip dieback. See Trees K 5.

NEMATODE DISEASES

Dagger nematode (*Xiphinema americanum*)
Spiral nematode (*Helicotylenchus dihystera*)
Other species may attack blueberry overseas.
See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera), eg ***cotton aphid*** (*Aphis gossypii*). See Roses J 4.

Bugs (Hemiptera): ***Grey cluster bug*** (*Nysius clevelandensis*), ***Rutherglen bug*** (*N. vinitor*). See Vegetables M 12.

Caterpillars (Lepidoptera): ***Lightbrown apple*** moth (*Epiphyas postvittana*) caterpillars are an ***important pest*** of blueberry. ***Looper caterpillars*** (*Chrysodeixis* spp.) may damage foliage. ***Painted apple moth*** (*Teia anartoides*) caterpillars may chew dormant buds. See Annuals A 8, Fruit F 8, Pome fruits F 113.

Fruit flies (Tephritidae) may be ***important pests*** and require control in coastal areas of Australia. See Fruit F 9.

Redshouldered leaf beetle (*Monolepta australis*) may damage blueberry. See Trees K 15.

Scales (Hemiptera): ***Red scale*** (*Aonidiella aurantii,* Diaspididae), ***soft brown scale*** (*Coccus hesperidum,* Coccidae). See Citrus F 39.

Others: ***Crickets, grasshoppers and locusts*** (Orthoptera). ***European earwig*** (*Forficula auricularia*) may damage fruit. ***A leafminer*** may damage leaves. ***Thrips*** (Thripidae, Thysanoptera) may infest flowers. ***Weevils***, eg various root weevils; ***small lucerne weevil*** (*Atrichonotus taeniatulus*) adults feed on foliage and larvae chew roots (Woods et al. 1990).

VERTEBRATE PESTS

Birds are the ***most serious pest***, grow bushes in a bird-proof wire enclosure or in plastic netting. This is one of the ***main costs*** of commercial blueberry growing. There are other methods of controlling birds but anti-bird netting is probably the only sure way of achieving full control. See Fruit F 13.

Non-parasitic

Environment: Different types of blueberry require different climatic conditions. Late ***frosts*** can damage young growth and flowers. Blueberries have shallow roots and only thrive in soil which is ***well drained and kept moist*** by irrigation.

Nutrient deficiencies, toxicities: Symptoms of ***iron deficiency*** may develop on new leaves. See Azalea K 29. ***Leaf analysis standards*** are available based on diagnostic and research analyses. (Weir and Cresswell 1993).

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State/Territory Departments of Agriculture/Primary Industry eg

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Blueberries in the Garden (NSW Agfact)
Blueberries : Pest and Disease Control (Vic Agnote)
Blueberry Cultivars (NSW Agfact)
Blueberry Production (NSW Agfact, Vic Agnote)
Blueberry Varieties (Tas Farmnote)
Blueberry Varieties for the Fresh Market (Vic Agnote)
Growing Blueberries (Vic Agnote, WA Farmnote)
Insect Pests of Berry Fruit (NSW Agfact)
Nuts, Berries and Speciality Fruits Kit (Vic Agnote)

Associations, Journals etc.

Australian Berry Growers Federation
Australian Blueberry Growers Assoc.
Good Fruit & Vegetables

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

An overview of the industry has been presented by Coombs (1995). Blueberries prefer moist cool situations, shelter from hot afternoon sun and hot dry winds, well drained and acid soils. Selection of ***climate*** is important as successful fruit bud formation requires plants to receive chilling. Low-chill blueberries are available for warmer areas. Planting material should be ***free of bacterial and fungal diseases, and scales*** and planted in ***disease-free soil***. Blueberries are planted in rows and often with mounding (Coombs 1995). Spacing depends on the cultivar and the size of the harvesting machinery. Control perennial weeds ***before planting***. If possible use a ***mulch*** to protect the blueberry's fine shallow root system and to control weeds. Sawdust, pine bark, old manure and black weed mat are all suitable mulches. ***Areas between the rows*** can be sown to annual pasture plants and mown, or clean cultivated. ***Herbicides*** can be also used to control weeds. Do not cultivate deeper than 60-80 mm as roots may be damaged. Fruit is produced on 1-year-old wood so, after plants have established, ***prune*** during winter. ***Harvest*** when fully ripe as flavour will not develop if picked too early. Quickly cool to between 0-5^{o}C for maximum quality and shelf life. Fruit is marketed in punnets covered with plastic wrap to prevent moisture loss. Berries may also be frozen.

Bush Fruits
and Nuts

There are abundant native plant food sources in Australia, nearly all of which (except for the macadamia nut) are unimproved (unchanged by the process of human selection). There are many indigenous nuts of comparable value, but this cannot be said of the native fruits which are often sour, astringent, salty, bitter and which do not appeal to the general community (Glowinski 1991). ***Some fruits and nuts require special treatment to remove toxic substances prior to eating*. *Always check.***

SOME AUSTRALIAN NATIVE PLANTS WITH EDIBLE FRUITS OR NUTS

Asclepiadaceae
Native pear (*Leichhardtia australis*)

Aizoaceae
Pigfaces (*Carpobrotus* spp., *C. glaucescens*, *C. virescens*)

Caprifoliaceae
Yellow elderberry (*Sambucus australasica*, *S. gaudichaudiana*)

Conifers
Brown pine (*Podocarpus elatus*)
Bunya nut (*Araucaria bidwillii*)

Davidsoniaceae
Davidson's plum (*Davidsonia pruriens* var. *jerseyana*)

Elaeocarpaceae
Johnstone River almond, Ebony heart (*Elaeocarpus bancroftii*)
Quandong (*E. grandis*)

Epacridaceae
Shrubs (*Acrotriche aggregata*, *A. depressa*)
Shrub (*Cyathodes parvifolia)*
Shrubs (*Styphelia* spp., *S. strigosa*, *S. adscendens, S. triflora*)
Shrub (*Leucopogon parviflorus*)

Ericaceae (heath family)
Shrubs (*Gaultheria appressa*, *G. hispida)*

Euphorbiaceae
Candle nut (*Aleurites moluccana*)

Moraceae (mulberry family)
Native figs (*Ficus* spp.), banana fig (*F. pleurocarpa*), cluster fig (*F. racemosa*), Moreton Bay fig (*F. macrophylla*), *F. coronata, F. hispida.*
Shrub (*Cudrania cochinchinensis*).

Myrtaceae (eucalypt family, myrtle family)
Lilly pilly (*Acmena smithii*, *Syzygium* spp.)
Ground cover (*Austromyrtus dulcis*)
Ground cover (*Kunzea pomifera*)

Passifloraceae (passionflower family)
Native passionfruit (*Passiflora* spp.)

Pittosporaceae
Apple dumpling, apple berry (*Billardiera scandens*)

Proteaceae (waratah family)
Macadamia (*Macadamia* spp.)
Trees and shrubs (*Helicia* spp., *H. diversifolia*, *Hicksbeachia pinnatifolia, Turrillia bleasdalei*)

Rosaceae (rose family)
Native raspberry (*Rubus parvifolius*, *R. gunnianus*, *R. mollucanus*)

Rutaceae
Native citrus (*Microcitrus australica*)
Native guava (*Eupomatia bennettii*, *E. laurina*)

Santalaceae
Most are parasitic on roots of nearby host plants.
Ballarts (*Exocarpos* spp., *E. cupressiformis*)
Quandong (*Santalum acuminatum*)
Plum bush, northern sandalwood (*S. lanceolatum*)
Sandalwood tree (*S. spicatum*)
Shrub (*Anthrobolus foeveolatus*)

Sapotaceae
Black apple (*Planchonella australis*)

Vitaceae (vine family)
Climber (*Tetrastigma nitens*)

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State/Territory Departments of Agriculture/Primary Industry eg
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Associations, Journals etc.
Australian Native Produce Industries (ANPI), Adelaide
Australian Native Sustainable Agriculture System (ANSAS)
Bushfood Growers Service (BGS)
Australian Native Food Resource Developments (ANRFD) 6/63 Ballina St., Lennox Head, NSW.
Australian Quandong Industry Association
South Australian Nut & Tree Crop Assoc.
West Australian Nut & Tree Crops Assoc. (WANATCA) : Australasian Tree Crops Sourcebook, Quandong, Yearbooks

See Fruit and nuts F 15, Citrus F 44, Fig F 57, Grapevine F 64, Lilly-pilly K 95, Passionfruit F 94, Pittosporum K 113, Macadamia F 79, Trailing berries F 147

Remember, always check for recent references

Cape gooseberry

Physalis peruviana
Family Solanaceae (nightshade family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Alfalfa mosaic virus, broad bean wilt virus, cucumber mosaic virus, potato Y virus, tobacco mosaic virus, tomato big bud mycoplasma, tomato spotted wilt virus. See Fruit F 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria*) attacks *Physalis* spp. See Vegetables M 5, Tomato M 98.

FUNGAL DISEASES

Entyloma leaf spot, leaf smut (*Entyloma australe*) may cause ***slight to severe leaf spotting.*** See Annuals A 5, Dahlia C 24.

Rhizoctonia stem rot (*Rhizoctonia solani*) may rot ***stems*** at ground level. See Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) have been recorded on cape gooseberry. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae) may infest ***new growth*** and ***transmit virus diseases***. See Roses J 4.

Bugs (Hemiptera)
Green vegetable bug (*Nezara viridula*)
Rutherglen bug (*Nysius vinitor*)
A mirid bug (*Trilaccus* sp, Miridae)
See Vegetables M 12.

Caterpillars (Lepidoptera)

Cape gooseberry budworm (*Helicoverpa assulta*) is a ***serious pest*** in spring and early summer in Qld. ***Monitor*** eggs on flowers and young husks, apply insecticides that do not kill twospotted mite predators. See Sweetcorn M 89.

Others:
- Banana fruit caterpillar (*Tiracola plagiata*)
- Corn earworm (*Helicoverpa armigera*)
- Cutworms (*Agrotis* spp.)
- Eggfruit caterpillar (*Scelliodes cordalis*)
- Looper caterpillars (*Chrysodeixis* spp.)
- Native budworm (*Helicoverpa punctigera*)

See Annuals A 8, Fruit F 8.

Mites (Acarina)
Tomato russet mite (*Aculops lycopersi*)
Twospotted mite (*Tetranychus urticae*)
See Beans (French) M 29.

Others: ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***leafhoppers*** (Cicadellidae, Hemiptera), ***threelined potato beetle*** (*Lema trilineata*), ***thrips*** (Thripidae, Thysanoptera).

Non-parasitic

Environment: Cape gooseberry is damaged by ***frost***.

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State/Territory Departments of Agriculture/Primary Industry eg
Cape Gooseberries in the Garden (NSW Agfact)
The Cape Gooseberry (WA Farmnote)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Fruit may be used fresh, or for jams or jellies. Cape gooseberry is a warm season plant. In frost-free, warm and tropical climates, bushes are perennial and reach heights of 1 m or more. In cooler temperate climates it is grown as an annual during summer in a warm, sheltered position. In suitable areas it may be grown as an ornamental shrub. Generally, cultivation is similar to that for capsicum. ***Propagated*** by seed. Plants take 5-6 months before fruit is ready for picking. In warm frost-free areas ***prune*** plants hard after fruiting to induce new growth for next year's crop. Plants may bear well for 3-4 years. ***Harvest*** when fruits are yellow.

Cashew

Anarcardium occidentale
Family Anarcardiaceae (cashew family)

Many pests and diseases affect cashew overseas but few have been studied in detail in Australia.

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Flower and nut rots: Fungal rots during flower and nut development and harvesting cause ***serious losses*** in wet weather. Nuts on the ground sprout after about 4 days of wet weather.

Anthracnose (*Colletotrichum gloeosporioides*) may develop during rainy or humid weather on ***flowers***, causing flower drop. See Fruit F 5.
Aspergillus fruit rot (*Aspergillus niger*) causes soft watery spots on the ***stem end of fruits*** before harvest. Dark spores develop on the spots, fruit may fall prematurely or mummify on the tree. *Apergillus* can multiply in spent flowers caught in foliage or in caterpillar webbing. Fruit infection occurs through ***wounds*** or by ***direct penetration*** when dead flowers or tissue from flowers are in contact with fruit. Occasional cashew losses may occur prior to harvest. Control is difficult. See Fruit F 5.

See Fruit F 5.

Others: ***Blossom rots*** (various species), ***fusarium root rot*** (*Fusarium* spp.), ***leaf spots*** (various species), ***pink limb blight*** (*Corticium salmonicolor*).

INSECTS AND ALLIED PESTS

Bugs (Hemiptera)

Fruitspotting bugs (Coreidae)
Fruitspotting bug (*Amblypelta nitida*)
Banana-spotting bug (*A. lutescens lutescens*)

Mirid bugs (Miridae): ***Helopeltis bug*** (*Helopeltis* sp.) damage cashew nuts in Qld. ***Tea bugs*** (*Helopeltis* spp.) occur as ***serious pests*** in Asia and may cause up to 50% losses in cashew (Com. of Aust. 1996).

See Vegetables M 12.

Caterpillars (Lepidoptera)

A cup moth (*Scopelodes nitens*) caterpillar defoliates cashew trees in Cape York Peninsula. See Eucalypt K 60.
Mango shoot caterpillar, large mango tipborer (*Penicillaria jocosatrix*) bores into ***tips of shoots***, which may die back. See Mango F 80.

Redbanded thrips (*Selenothrips rubrocinctus*) may cause ***serious leaf fall*** in drier climates; trees are retarded and it may take up to 2 years for full leaf colour to re-establish. Leaf loss should be prevented if possible. See Mango F 81.

Termites (Isoptera) may be a ***serious problem*** in some areas, although cashew wood is reputed to be resistant to their attack. See Trees K 17.

Non-parasitic

Environment: ***Strong wind*** may cause leaf fall and retard tree development. Lack of adequate ***irrigation*** may cause premature nut drop. Young trees especially are very susceptible to ***frost***.

Poisonous shell: The shell contains ***cashew nut shell liquid*** which will cause peeling of the skin and of the hands. People who touch the shell may develop skin blisters. Gloves should be worn during handling.

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State/Territory Departments of Agriculture/Primary Industry eg
Cashew Culture (Qld Farmnote)
Grafting of Cashew Seedlings (NT Technote)
Home Processing of Cashews (NT Agnote)
Processing and Analysis of Cashews (NT Technote)
The Cashew (Qld Farmnote)
Associations, Journals etc.
The West Australian Nut & Tree Crop Assoc. (WANATCA)
See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Cashew is a tall tropical evergreen tree which prefers deep, well drained sands or loams. An overview of the industry has been presented by Coombs (1995). In addition to the nut, people eat the fleshy red or yellow base of the fruit, called the cashew apple, which may be eaten raw or made into a preserve. Cashew trees also yield gum which may be used in varnishes. ***Propagated*** by seed from selected trees (seed with a high specific gravity ensures a high rate of germination), also by air layering, cuttings, budding, grafting. ***Prune*** after 2 years of age to remove lower branches to allow machinery access. ***Fruit*** fall to ground when ripe and must be collected (cease irrigation, if it rains, nuts must be collected every day). Grass must be kept cut so that nuts can be collected.

Chestnut

European or Spanish chestnut

Castanea sativa
Family Fagaceae (beech family)

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Chestnut blight (*Endothia parasitica*, Ascomycetes) is a ***serious disease*** of American chestnut (*Castanea dentata*) and European chestnut (*C. sativa*); it is not known to occur in Australia. ***It has also been recorded on*** Japanese chestnut (*C. crenata*); Chinese chestnut (*C. mollissima*); seguin chestnut (*C. seguinii*); all chinquapins native to the south eastern USA including *C. pumila, C. ozarkensis*, *C. henryii, C. alabamensis*, *C. alnifolia*, *C. ashei, C. floribunda*, Golden chinquapin (*Castanopsis chrysophylla*); several other chinquapins native to Asia; ***important oak hosts*** include post oak (*Quercus stellata*) in the USA, holly oak (*Q. ilex*), dumast oak (*Q. petraea*) and pubescent oak (*Q. pubescens*) in Europe; dead chestnut oak (*Q. prinus*); also red maple (*Acer rubrum*); shagbark hickory (*Carya ovata*); and staghorn sumac (*Rhus typhina*). ***Eucalypts*** are also susceptible. ***Highly resistant*** (but not immune) species and hybrids include Chinese chestnut (*C. mollissima*), Japanese chestnut (*C. crenata*), *C. dentata* x *C. mollis*. ***Quarantine risks:*** Entry of vegetative material or viable nuts of *Castanea* spp. into Australia poses the greatest risk. Vegetative material of oak also poses a risk. Introduction of chestnut material is prohibited under quarantine legislation, except under special circumstances and only following strict quarantine supervision (Com. of Aust. 1990).

Nut rots: *Alternaria*, *Fusarium, Phoma* and *Rhizopus* may attack nuts stored incorrectly after harvest (Allen 1987). ***Phomopsis castanea*** is probably the most common nut rot. See Fruit F 5.

Root and trunk rots: ***Armillaria root rot*** (*Armillaria* spp.) and ***phytophthora trunk rot*** (*Phytophthora* spp.) are ***major diseases*** of chestnut. See Fruit F 7.

INSECTS AND ALLIED PESTS

Scale (Hemiptera) may infest twigs. See Citrus F 39.
Scarab beetles (Scarabaeidae) larvae may feed on ***roots*** of young trees after planting in the field. See Turfgrasses L 11.
Weevils (Curculionidae): Overseas *Curculio* spp. and *Cyrtepistomus* in the USA may damage the ***nuts*** of Asiatic chestnut species. See Fruit F 13, Trees K 17.
Others: Aphids (Aphididae) may infest new growth; ***grasshoppers*** (Orthoptera); ***oak leafminer*** (*Phyllonorycter messaniella*) may mine in leaves.

VERTEBRATE PESTS

Birds, ***possums***, ***rabbits*** and ***wallabies*** damage nuts and/or trees. See Fruit F 13.

Non-parasitic

Young trees are very susceptible to ***frost***. Cool spring conditions tend to ***delay flowering***. ***Leaf analysis standards*** are available (Weir and Cresswell 1993).

Remember, always check for recent references

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State/Territory Departments of Agriculture/Primary Industry eg
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Growing Chestnuts (Vic Agnote)
Sites, Layout & Irrigation for Nut Orchards (WA Farmnote)
Association, Journals etc.
Aust. Hort. Corporation (AHC)
Chestnut Growers of Australia
The West Australian Nut & Tree Crop Assoc. (WANATCA)
See Fruit and nuts F 15

MANAGEMENT

Chestnuts are large deciduous trees and will grow almost anywhere in southern Australia with well drained soils and summer irrigation. An overview of the industry has been presented by Coombs (1995). Trees bear both male and female flowers on current season's growth in 2 separate groupings. ***Propagated*** by suckers, seed, budding and grafting. ***Harvest*** when nuts turn brown and burr splits open, husk and clean then ***store*** at appropriate relative humidity so that nuts do not dry out.

Citrus

Grapefruit (*Citrus paradisi*)
Kumquat (*Fortunella* spp.)
Lemon (*C. limon*)
Mandarin (*C. reticulata*)
Orange (*C. sinensis*)
Family Rutaceae

PESTS AND DISEASES

Parasitic

- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial canker, citrus blast
  - Citrus canker
- **Fungal diseases**
  - Fruit rots and leaf spots
  - Mal secco
  - Phytophthora diseases
  - Root and collar rots
  - Wood rots
- **Nematode diseases**
  - Citrus nematode
- **Insects and allied pests**
  - Black citrus aphids
  - Borers
  - Bugs
  - Caterpillars
  - Citrus gall wasp
  - Citrus leafminer
  - Fruit flies
  - Fruitpiercing moths
  - Katydids, grasshoppers, locusts
  - Leafhoppers, planthoppers, treehoppers
  - Mealybugs
  - Mites
  - Redshouldered leaf beetle
  - Scales (armoured - Diaspididae)
  - Scales (Eriococcidae)
  - Scales (Margarodidae)
  - Scales (soft - Coccidae)
  - Thrips
  - Weevils
  - Whiteflies
- **Snails and slugs**

Non-parasitic

- Ants
- Environment
- Mutations
- Nutrient deficiencies, toxicities
- Pesticide injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus and virus-like diseases of citrus produce various symptoms including flecks, outgrowths and tattering of leaves, and pitting and scaling of stems on sensitive species of citrus. They are all ***spread*** by vegetative propagation, budding and grafting, some also on tools and by insects.

Citrus exocortis viroid, scaly butt: Grapefruit, mandarin, sour orange, sweet orange (uncommon). Causes cracking and scaling of ***bark*** below the bud union, with the bark often peeling off in vertical strips. Symptoms only appear in trees ***> 4 years*** old, and are apparent only on trees grafted on to ***trifoliate orange and citrange rootstocks***, other rootstocks may carry the viroid without showing symptoms. ***Spread*** by grafting and mechanically on pruning tools.

Citrus psorosis viruses cause brief flecking and patterns on ***new leaves*** in spring but more commonly, flaking of ***bark*** of ***grapefruit and sweet orange***. Symptoms are rarely seen in trees < 10 years old.

Citrus tristeza virus (several strains) is the ***most economically important*** viral disease of citrus in some areas overseas (Rocha-Pena et al. 1995). ***Quick decline strain*** has been prevented from causing damage by the use of tolerant stock/scion combinations. ***Stem pitting strain*** which can be serious on grapefruit has been controlled by pre-immunisation with selected mild strains. ***Orange Stem Pitting (OSP) strain*** occurs in Qld and is a ***serious disease*** of sweet oranges. There are restrictions on the entry of citrus propagating material to other states. ***Spread*** also by aphids, especially citrus aphid (*Toxoptera citricidus*). ***Quarantine*** regulates importation of citrus propagation material. New cultivars can only be imported under permit and are subject to extensive testing for diseases during growth in post-entry quarantine (Com. of Aust. 1992).

Others: Citrus concave gum, citrus crinkly leaf virus, citrus seedlings yellow, citrus tatter leaf virus, citrus vein enation-woody gall virus, citrus xyloporosis. ***Citrus dieback and greening*** are spread by insects overseas (Com. of Aust. 1982). ***Graft transmissible dwarfing viroid (GTD)*** is being researched for dwarfing orange trees in Australia.

Disinfect cutting tools to prevent mechanical transmission. ***Plant disease-free budwood*** from citrus budwood schemes guaranteed ***free from specified virus diseases***. See Fruit F 4.

BACTERIAL DISEASES

Bacterial canker, citrus blast, citrus pit, (*Pseudomonas syringae* pv. *syringae*) may occur on grapefruit, lemon, mandarin, sour and sweet orange. Rapidly spreading dark brown blotches develop on ***young growth,*** usually starting at the base of leaf blades or at axillary buds. Lesions spread to adjacent stems and leaves. ***Shoots*** may be girdled, leaves die, but remain attached to the stem. ***Nursery stock*** may be blighted and ring barked, symptoms are similar to those caused by *Phytophthora*. Lesions heal up with the onset of warm or dry weather. ***Fruit*** infection occurs occasionally in lemons and mandarins but rarely in oranges. If conditions favour disease, ***copper fungicides*** may be applied, particularly if disease has occurred on the site in previous years. See Stone fruits F 124.

Citrus canker (*Xanthomonas campestris* pv. *citri*) is a ***serious citrus disease*** in moist areas but is not known to occur in Australia. Outbreaks in Australia have been eradicated. Most varieties of citrus are susceptible but not all to the same extent. Canker affects all above-ground parts of the tree, particularly the young tender leaves, twigs, young branches and twigs. ***Quarantine risks and precautions:*** The most likely means of introduction is through the illegal importation of nursery stock or fresh fruit (Com. of Aust. 1996).

Others: ***Crown gall*** (*Agrobacterium* sp.) has been recorded on sweet orange.

FUNGAL DISEASES

Fruit rots and leaf spots

Anthracnose (*Colletotrichum* spp.) spots may develop on bruised, injured or stressed tissue. ***Pinkish spore masses*** develop on spots in humid conditions, *C. gloeosporioides* may cause ***postbloom fruit drop (PFD)*** overseas (Timmer et al. 1994). See Fruit F 5.

Black spot, citrus black spot (*Guignardia citricarpa*) affects ***woody plants***, eg camellia, citrus, especially lemons. Infection occurs from blossoming to 3-5 months later, small, rusty depressed spots, 1-2 mm across, develop on ***rind*** in late spring or summer after hot weather. Spots are up to 12 mm across, become brown, sunken, and may cover more than half the fruit surface. ***Fruit*** fall readily. Round brown spots 1-2 mm across develop on mature lemon ***leaves***. ***Harvest fruit promptly***, picking first from the north side of trees, where disease is likely to develop first. ***Irrigate*** after first harvest in dry weather. ***Remove*** diseased, late-hanging fruit.

Brown spot (*Alternaria* spp., *A. alternata*). ***Some strains*** attack lime and rough lemon, ***others***, navel oranges, etc. Some only attack leaves, others only fruit. ***Fruit*** develop numerous small black spots after fruit set. Badly affected fruit drop, spots on remaining fruit increase in size, becoming light brown as fruit ripens. On some hosts fruit may rot internally. ***Leaves*** may develop small spots at an early stage, defoliation may occur. ***Stem infections*** may cause shoot dieback. ***Overwinters*** on stem infections, leaves on trees. ***Favoured*** by cool, damp weather in early spring, late summer and early autumn, lush growth, and poor air circulation. Before planting yearling trees, ***prune and burn dead twigs*** as they can remain infective for > 6 months. In areas > 3 km from the nearest citrus plantation, prevent disease introduction. A spray program may be started when disease appears, after pruning off diseased twigs.

Melanose (*Diaporthe citri = Phomopsis citri*) may be a ***serious disease*** of citrus. Washington navel orange, Emperor mandarin and lemons are ***more susceptible*** than grapefruit and Valencia oranges. Small, dark brown/black raised rough spots develop on ***fruit, leaves and small twigs***. On ***fruit***, spots may occur in streaks, where drops of spore-laden water have fallen, or rind may be covered with brown gum. The fungus establishes in ***dead twigs***, and from these, penetrates into living wood of ***larger branches***, which ***die***. Rot may develop at forks between branches and main trunk ***(crotch rot).*** It can invade woody tissues through pruning cuts or bark injuries. It causes dieback. Spores are ***spread*** from infections on twigs and branches by splashing and dripping water. ***Favoured*** by young leaves and fruit, wet warm nights, mature trees with dead wood. ***Prune out dead wood*** prior to flowering. If necessary, spray with fungicide. ***Stem end rot*** (*Diaporthe citri, Diplodia,* other species of fungi) causes a firm, tan rot beginning at the ***stem end*** and slowly spreading through the ***fruit***. After infection the fungus remains dormant until ripening,

Penicillium moulds (*Penicillium* spp.) are ***major postharvest diseases.*** Rotted areas become covered with ***blue or green spore masses*** (Fig. 114). After packing the fungi may spread from fruit to fruit causing ***'nesting'.*** Spores produced on diseased fruit on the orchard floor and in packing sheds are spread by wind to infect healthy fruit through wounds. See Fruit 6.

Phytophthora brown rot (*Phytophthora* spp.) affects citrus fruit. See Citrus F 35.

Scab, citrus scab, lemon scab (*Sphaceloma fawcetti,* Ascomycetes) affects citrus, especially ***lemon and mandarin*** in damp weather. Only ***young fruit, leaves and twigs*** are attacked. Young fruit attacked at blossoming and petal fall, fall. Irregular ***wart-like scabby*** areas develop on infected ***fruit, leaves and twigs***, at first grey or pinkish, then becoming darker with age (Fig. 114). The internal fruit quality is not affected but market appearance is spoilt. Scabby lemons are sometimes offered for sale in shops.

Septoria spot, leaf scald and fruit spot (*Septoria citri, S. depressa*) affects commercial citrus varieties, especially ***Washington navels*** in high rainfall areas. Infection occurs early in autumn after cool, damp weather, then remains ***dormant in the fruit*** until cold weather, eg frost, allows dark-brown sunken spots up to 15 mm across to develop. These are scattered, or join together to form large, irregular dark sunken areas. Infection extends deep into the rind; diseased tissue is often bounded by a thin reddish line. Closely grouped ***black dots*** (fruiting bodies of the fungus) may develop in the brown spots. Spotting on the surface of the fruit may indicate late infection. Other symptoms include ***'tear-staining'*** when spore-laden water runs down the fruit causing sunken brown streaks. *Septoria* spot symptoms can easily be confused with frost injury. Small dark spots also develop on ***leaves***.

Sour rot (*Geotrichum candidum*) causes a pale soft watery ***postharvest*** rot of ***ripe fruit***. Fruit ***smell*** and maggots of the ferment fly may feed in rotted material. White fungal growth appears on surface. The fungus is a common soil inhabitant, and is splashed by wind and water on to fruit in the ***field***. Infection also occurs from contaminated tanks and drenches in ***packing sheds***, or in ***storage*** by contact causing nesting.

Others: Many other fungi cause minor fruit rots, eg ***aspergillus rot*** (*Aspergillus niger*), and leaf spots, eg *Botryodiplodia theobromae.*

Overwinters in lesions on dead twigs and branches on affected trees, some in debris in packing sheds. Spores are ***spread*** by wind-driven rain and irrigation to young fruit, leaves and shoots. ***Favoured*** by overhead irrigation, old trees with dead wood, by prolonged storage of mature fruit, and storing overmature fruit. ***Prune out*** dead wood, follow recommended ***fungicidal treatments*** in the ***field and postharvest***. See Fruit F 6, Annuals A 5.

Mal secco (*Deuterophoma tracheiphila*) is a ***serious disease*** of citrus, especially lemon in the Mediterranean region. It is not known to occur in Australia. ***Quarantine precautions:*** Approved vegetative imports are very carefully and extensively screened for fungal, bacterial and virus and virus-like diseases during post-entry quarantine. Fresh fruit is permitted from certain overseas areas under stringent conditions. The greatest risk of introduction is via illegal import of citrus propagating material or fruit from a country with mal secco disease (Com. of Aust. 1990).

Phytophthora diseases

Phytophthora brown rot of fruit (*P. citrophthora, P. hibernalis, P. nicotianae* var. *parasitica*) starts as a slight surface discolouration of ***citrus fruit***, eg Washington navel orange and lemon. Rind turns light brown, firm and leathery, with a ***distinctive smell***. In wet weather, a ***white fungal growth*** may develop on the surface and ***Penicillium moulds*** may follow. Fruit usually falls. ***Leaves*** develop dark brown, roughly circular, spreading blotches. Dark brown lesions, which often exude gum, develop on ***twigs***. Different *Phytophthora* spp. are active at different temperatures and some species may cause ***collar and root rots*** as well as ***fruit rots***. ***Fungicides*** give good protection against brown rot. It is usually sufficient to spray trees to a height of 1.5 m. Spraying the soil surface helps prevent fungal development. Skirt trees.

Phytophthora root and collar rots (*Phytophthora citrophthora*). ***Root rot:*** Trees fail to form vigorous new growth, and may die quickly or make periodic attempts at regrowth. Rough lemon and sweet orange rootstocks are ***susceptible***. Because rootstocks are usually more resistant, ***collar rot*** is usually confined to just above the bud union. Secondary infection by ***melanose*** may cause rotting of weak and dying trees. Lemons, particularly Lisbon and Eureka are ***very susceptible***. Plant ***resistant rootstocks***, particularly when replacing trees that have died from *Phytophthora*. Some rootstocks are ***resistant*** to *Phytophthora* collar rot, *Armillaria* root rot and frost.

See Trees K 6.

Root and collar rots: ***Phytophthora root and collar rot*** (*Phytophthora* spp.) is the most serious (see above). ***Others*** include ***armillaria root rot*** (*Armillaria* spp.), ***damping off*** (*Rhizoctonia* sp.), ***root rot*** (*Ganoderma*), ***sclerotinia rot*** (*Sclerotinia sclerotiorum*), ***sclerotium collar rot*** (*Sclerotium rolfsii).* See Fruit F 7, Trees K 7, Vegetables M 7..

Wood rots: ***Felty fungus***, twig girdle (*Septobasidium* spp.), ***pink limb blight*** (*Corticium salmonicolor*), ***yellow heart rot*** (*Schizophyllum commune*). ***Others:*** *Custulina duesta, Poria ambigua, Xylaria polymorpha*. See Trees K 8.

Others: ***Sudden death of citrus*** (cause unknown) causes vigorous trees, 7-15 years old to suddenly ***wilt and die***. Affected trees have 1-2 black rotted roots, discolouration may extend into the butt. Ink cap fungus (*Coprinus micaceus*) may fruit around butts of affected trees, but its association with the disease is not clear. ***Sooty blotch,*** smoky blotch (*Gloeodes pomigena*) causes a superficial light brown fungal growth on ***fruit*** in warm, wet weather. It overwinters on ***twigs***. Also ***pink mould*** (*Gliocladium roseum*), ***black scurf*** (*Coniothecium scabrum*), ***lemon scurf*** (*Cladosporium furfuraceum*), *Ascochyta, Phyllosticta.*

NEMATODE DISEASES

Citrus nematode (*Tylenchulus semipenetrans*) is a ***major pest*** in most citrus growing areas of the world. Almost every citrus tree in SA is infested and populations of 40,000 nematodes/kg soil are common (Stirling 1983). It affects other Rutaceae, grapevines, olives, other plants. ***Above-ground symptoms*** are similar to those caused by drought, salinity or deficiencies, eg yellowing of leaves, defoliation, reduced vigour and poor yields. There is a gradual decline in tree health. ***Female nematodes*** feed with their heads embedded in the root tissue and body protruding. Soil sticks to their jelly-like egg masses on the roots. The life cycle, overwintering, spread and conditions favouring citrus nematodes, are generally similar to that of root knot nematode. Delay ***replanting*** infested orchards for 1-2 years after old trees are removed and soil structure is improved. Plant ***rootstocks with some resistance*** (most commonly used citrus rootstocks are susceptible). Plant ***nematode-free nursery stock*** in ***nematode-free soil*** and keep it ***nematode-free***. If planting cannot be delayed and resistant rootstock is not available, soil may be treated ***prior to planting***, ***Nematicides*** may be applied to ***established trees***. See Vegetables M 10.

Others: More than 40 species of nematodes may be associated with citrus including ***burrowing nematode*** (*Radopholus* sp.), ***dagger nematodes*** (*Xiphinema* spp.), ***root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* spp., *Rotylenchus* spp.), ***stubby root nematodes*** (*Paratrichodorus* spp.), ***stunt nematode*** (*Tylenchorhynchus martini*).

INSECTS AND ALLIED PESTS

Black citrus aphids (*Toxoptera aurantii*, *T. citricidus,* Aphididae) are minor pests of citrus, other Rutaceae, camellia, macadamia and other plants. ***Adults*** are black, winged or wingless and about 1.5 mm long. ***Nymphs*** are dull red-brown. Aphids suck sap from ***young leaves, shoots and flowers***, causing leaf distortion and slowing growth of nursery stock, young trees and recently rejuvenated mature trees. Blossom infestation may ***reduce fruit setting***. Sooty mould growing on ***honeydew*** secreted by the aphids, dirties fruit and foliage. *T. citricidus* is an efficient vector of ***tristeza virus***. Winged and wingless adults produce active young, (not eggs) with many generations each season. Small colonies ***overwinter*** on young shoot growth inside trees, and move to new shoots in late winter. ***Spread*** by winged aphids and wind. ***Favoured*** by mild moist conditions during spring and autumn, and new growth. ***Effective predators*** include common spotted ladybird (*Harmonia conformis*), transverse ladybird (*Coccinella repanda*), variable ladybird (*Coelophora inaequalis*, hover fly and lacewing larvae and birds. ***Parasitic wasps***, eg *Aphelinus mali,* may depress aphid populations. ***Monitor*** aphids and damage during growth flushes before making a decision to apply an insecticide (Brough et al. 1994). ***Cowpea aphid*** (*Aphis craccivora*) and ***spiraea aphid*** (*A. spiraecola*) may also infest citrus. See Roses J 4.

Borers (Coleoptera)

Longicorns (Cerambycidae) are minor pests of citrus trees stressed by age, melanose, white louse scale, root rots or pruning. Larvae feed in ***oval tunnels*** packed with flour-like frass ***under the bark***. ***Citrus branch borer*** (*Uracanthus cryptophagus*) larvae tunnel in finger lime, ringbarking limbs. ***Also citrus longicorn*** (*Skeletodes tetrops*), ***speckled longicorn*** (*Paradisterna plumifera*), ***citrus trunkborer*** (*Platyomopsis pulverulens*), ***fig longicorn*** (*Dihammus vastator*), ***pittosporum longicorn*** (*Strongylurus thoracicus*). See Trees K 11.

Weevils (Curculionidae): ***Citrus root-bark channeller*** (*Pseudomydaus citriperda*), ***elephant weevil*** (*Orthorhinus cylindrirostris*) larvae feed in roots, ***tunnels are round*** and packed tightly with frass.

Monitor borer damage regularly. Only rejuvenate trees which are disease and pest-free and with sound roots and butts. See Trees K 11.

Bugs (Hemiptera)

Bronze orange bug (*Musgraveia sulciventris,* Tassaratomidae) is a minor native pest of citrus, eg rough lemon and native lime. ***Adults*** are about ***25 mm*** long, stout, bronze or nearly black (Fig. 115). Legs and the upper surface of the body beneath the wings are ***red***. During summer adults cluster on trees. If disturbed, they fly around noisily. ***Nymphs*** are green, turning orange to pink later. When disturbed, bugs discharge a ***smelly liquid*** which can stain and burn human skin and eyes and excrete a corrosive liquid from the anus which causes brown spots on leaves or fruit. Bugs suck sap from ***young shoots and stalks of flowers and young fruits*** in spring and early summer, shoots wilt and die, flowers and fruits fall, trees look unthrifty with a sparse or out-of-season crop. There is only ***1 generation per year***. Adult females lay green eggs on leaf undersurfaces from mid-summer to early April. ***Overwinters*** as 2nd-stage nymphs on leaf undersurfaces of hosts. ***Spread*** by adults flying. ***Favoured*** by summer rainfall, spring and early summer in subtropical to warm temperate climates. Small numbers may be dislodged and killed. High temperatures with low humidities cause bugs to crawl down to the butts where they may be sprayed. At higher temperature bugs die. ***Predators*** include birds and assassin bug (*Pristhesancus pupuensis*). There is also an ***egg parasite*** (*Anastatus* sp.). Bugs are detected by their ***odour in winter***, so infested trees can be ***spot sprayed*** early in spring, or in winter, before they cause damage. Remove infested lemons.

Rutherglen bug (*Nysius vinitor*) may swarm on young citrus trees in spring causing wilting, leaf fall, twig dieback and cracking of bark on stems. ***Young trees may die***. In summer, bugs swarm on trees infested with black scale but may cause little harm. See Vegetables M 12, Stone fruits F 130.

Spined citrus bug (*Biprorulus bibax,* Pentatomidae) may be a ***serious native pest*** of lemon, mandarin, lime, kumquat, trifoliata orange, desert lime, finger lime. ***Adults*** are active, green shield bugs about ***20 mm*** long with a stout sharp spine on each side of the prothorax (Fig. 115). ***Nymphs*** are initially black, green and orange, becoming green with black marks. Feeding on ***shoot growth*** is unimportant. Nymphs and adults suck sap from ***half-grown fruits***, causing premature colouring and fruit fall, more advanced fruits fall less readily, but may have internal damage (drying, browning). Rind punctures may gum. Seeds in damaged segments may brown. ***Secondary fungi*** may invade punctures in ripe oranges. There are ***many overlapping generations*** each year. ***Overwinters*** as females sheltering within trees. ***Spread*** by bugs flying, by migration from inland native hosts to coastal cultivated citrus. ***Favoured*** by moderate humidity in summer. If only a few bugs, ***collect by hand***. ***Wasp parasites*** (*Acroclisoides tectacorisi*, *Trissolcus biproruli basalis*, others) may parasitise 90% of eggs so that spraying is unnecessary. ***Assassin bug*** (*Pristhesancus papuensis*) preys on bugs during summer. ***Predatory species*** can be manipulated with pheromones, eg using ***husbandry of pest enemies (HOPE)*** so that pheromones could be used to attract predators to orchards, or to draw them away prior to spraying (Dick 1993).

Others: ***Citrus blossom bug*** (*Austropeplus* sp.) is about ***5 mm*** long, green underneath and dark above, yellow on the thorax, with red and black wing markings. Nymphs and adults feed on ***new shoots*** and ***smaller flower shoots*** which wilt and die. Even light infestations in spring in coastal areas can destroy blossom and reduce fruit set. ***Crusader bug*** (*Mictis profana*) is ***20-25 mm*** long, brown with a yellow St Andrew's cross on its back. It sucks sap from ***new spring growth*** and ***flowering shoots*** which wilt, blacken and die. Damage may be important on young trees. ***Green vegetable bug*** (*Nezara viridula*) may attack ***young shoots and fruit***. Fruit may fall.

Monitor bugs, eg crusader and spined citrus bugs, and fruit damage at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Vegetables M 12.

Caterpillars (Lepidoptera)

Budworms (Noctuidae): ***Banana fruit caterpillar*** (*Tiracola plagiata*) chews holes in young fruit. ***Flies*** (*Palexoristus solennis*, *Sturmia* sp.) parasitise caterpillars. ***Corn earworm*** (*Helicoverpa armigera*) and native budworm (*H. punctigera*) feed on ***flower buds, blossoms, seed and young fruit,*** causing fruit drop. Caterpillars grow to about ***40 mm*** and are yellow, green, red-brown with black or brown markings. They bore deep holes into young green fruits but damage unimportant. See Sweetcorn M 89.

Citrus butterflies (Papilionidae) caterpillars feed on ***Rutaceae***, eg cultivated citrus, *Choisya ternata*, and on native species, eg *Eriostemon, Geijera*, *Flindersia*, *Microcitrus*, *Zieria.* ***Large citrus butterfly*** (*Princeps aegeus*): ***Females*** have a wingspan of about 130 mm, brown to black forewings with the outer parts white or grey, and hindwings marked with white, orange-red and blue. Males have wings which are mainly black with white markings. ***Caterpillars*** are up to ***65 mm*** long, brown to olive green (Fig. 116). When disturbed they protrude a red fleshy forked process from behind the head and emit a strong odour. The ***small citrus butterfly*** (*Eleppone anactus*) resembles the large citrus butterfly, but measures only about 70 mm across the outspread forewings. Colouring is similar in males and females. ***Caterpillars*** are up to ***40 mm*** long with 3 rows of orange-yellow spots along their body, and have 2 rows of dark spines along the back (Fig. 116). ***Caterpillars of both species*** feed on ***new foliage,*** reducing shoots to bare twigs. Damage can be ***serious*** on nursery trees, newly planted trees, and trees in tubs. There are 2-3 generations each year. In spring butterflies lay eggs singly on young shoots.

Caterpillars pupate on hosts. ***Overwinter*** as pupae on the host plant. ***Spread*** by butterflies flying. ***Favoured*** by summer and autumn weather. ***Other species*** occur in northern Australia. ***Control: Hand squashing*** may be sufficient on a few small trees. ***Wasps*** (*Pteromalus puparum, Pachyneuron kingsleyi*) parasitise larvae and pupae. ***Predatory bugs*** feed on caterpillars.

Ermine moths (Yponomeutidae): ***Citrus flower moth*** (*Prays nephelomima*) and ***lemon bud moth*** (*P. parilis,* Yponomeutidae) are minor native pests of cultivated citrus, especially Eureka lemon, also lime, citron, kumquat, wild hosts are unknown. ***Moths*** are < 12 mm long, grey with brown marks on wings and a brush of golden hair-like scales on the head. They are poor fliers. ***Caterpillars*** are yellow, later green and red-brown and bore into ***flower buds*** preventing fruit set. Over ***50%*** of lemon flowers during summer/ autumn are infested, but this is only important if blossoming is light. There are several generations each year. Eggs are laid on tiny red fruit buds, but only 1 caterpillar survives per bud. Caterpillars pupate in a lace-like cocoon, at the edge of a curled leaf or at a twig junction.

Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) is a minor pest of citrus ***foliage, blossoms, young and mature fruit***. Caterpillars ***web leaves*** together, and may injure new foliage of nursery stock or young trees. Infested fruits may fall but if damage is undetected at harvest or packing they may decay postharvest. See Pome fruits F 112. ***Orange fruitborer*** (*Isotenes miserana*) caterpillars are ***native pests*** of ***fruit***, eg apple, avocado, citrus, guava, macadamia, mulberry, peach, ***ornamentals***, eg camellia, *Cupressus*, oleander, red cedar, rose in coastal areas. ***Moths*** are grey, speckled, bell-shaped when at rest and have a wingspan of about 15 mm. ***Caterpillars*** are up to ***25 mm*** long, green, later cream, with 3 red-brown longitudinal bands and a dark brown head. They wriggle backwards if disturbed. Caterpillars on ornamentals feed from between ***joined leaves***. They form silken shelters around feeding sites at the stem end of ***fruit***, where they touch, or where they bore into, young, maturing and ripening fruit. Fruit may decay and fall prematurely. Infested fruit have a small hole in the rind and a shallow excavation beneath it. There is only 1 caterpillar per fruit. Very young caterpillars may penetrate fruit just before harvest and if undetected during packing, cause decay ***postharvest***. ***Several generations*** occur each year. All stages occur in winter. Eggs are laid on leaves and fruit. Caterpillars pupate in a dead rolled leaf, a mass of flower debris, or webbed foliage. ***Activity*** is least in summer. ***Spread*** by moths (only from tree to tree), movement of infested fruit. ***Favoured*** by clustered fruit, sheltered situations, abundant spider webbing, autumn, winter and early spring.

Pyralid moths (Pyralidae): ***Sorghum head caterpillar*** (*Crytoblabes adoceta*) bores into colouring Navels, Silletas and Joppas where ***fruits touch***, fruits may drop. ***Yellow peach moth*** (*Conogethes punctiferalis*) caterpillars tunnel into ***ripening fruit*** which fall. See Stone fruits F 133.

Navel orangeworm (*Paramyelois transitella*, Phycitidae) is not known to occur in Australia, but is a ***serious pest*** of fruit and nuts especially walnuts and almonds overseas. Caterpillars feed inside the ***fruit*** or nuts (Com. of Aust. 1984).

Others: Blastobasid fruitborers (*Blastobasis* spp., Blastobasidae) tunnel into colouring navels, Silletas and Joppas mainly where ***fruits*** touch, causing fruit drop. ***Leaf case moth*** (*Hyalarcta huebneri*) caterpillars chew round window-pane holes in ***leaves***. ***Citrus fruit borer*** (*Citripestis sagittiferella*) is a ***serious pest*** of *Citrus* spp. in the islands north of Australia (Com. of Aust 1995). See Trees K 13.

Most caterpillars and their damage should be ***monitored*** at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Annuals A 8, Fruit F 8.

Citrus gall wasp

Scientific name: Eurytomidae, Hymenoptera: Citrus gall wasp (*Bruchophagus fellis*). ***Gall wasp*** (*B. muli*) occurs in Papua New Guinea, if introduced it could become a pest (Com. of Aust. 1996).

Host range: Cultivated citrus especially lemon, rough lemon and grapefruit, also finger lime. A different strain is thought to attack desert lime.

Description and damage: ***Wasps*** are black, about 3 mm long. ***Larvae*** are white, legless, thick-set, about 3 mm long and feed within ***galls*** on ***stems, leaf midribs, petioles and fruit stems*** (Fig. 117). Twigs may die, main stems of nursery stock may be attacked, heavy galling weakens older trees and may reduce fruiting. Fungal diseases, eg melanose, may invade dead tissues.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with 1 generation each year. Wasps emerge from galls in spring, females lay > 100 eggs in green plant parts. Larvae feed on soft internal tissue during summer, autumn, winter and early spring, causing galls which are noticeable in December-January. Larvae reach their full size in autumn, and pupate in the galls. Wasps emerge leaving many small round holes.

Overwintering: As larvae feeding within galls on the host plant.

Spread: By movement of infested young trees, cuttings, by wasps flying, assisted by wind. They are weak fliers and tend to reinfest the same tree.

Conditions favouring: Mild winter conditions and proximity to an existing infestation. Coastal districts of NSW and Qld.

Control:

Sanitation: ***Cut off*** and burn galls by end of August, before wasps emerge to lay eggs in new shoots. If pruning later, prunings must be burnt.

Biological control: ***Native wasps*** (*Megastigmus* spp.) ***parasitise gall wasp larvae*** and may be trapped in galls, unable to emerge. At emergence, wasps may be killed by heat or ants. Galled twigs may be collected in spring, and held for 2-4 weeks in ventilated jars until wasps emerge. Parasitic wasps may be purchased.

Plant quarantine: In areas where citrus gall wasp is a ***proclaimed pest*** under plant disease acts, owners or occupiers on land where infested trees are growing may be required to treat them in a prescribed manner. ***Advice should be obtained from the local department of agriculture***.

Resistant varieties: Varieties vary in ***resistance***.

Pesticides: At present there is no satisfactory method of disinfesting nursery trees.

Citrus leafminer (*Phyllocnistis citrella*, Gracillariidae, Lepidoptera) infests all cultivated citrus and finger lime. ***Moths*** are nocturnal, silver, about 2 mm long with a wingspan of 4.5 mm. ***Caterpillars*** are up to 3 mm long. They mine in ***leaves*** (Fig. 118) and are a major pest of trees < 4 years old (nursery trees, newly planted orchards). Young leaves may be severely distorted. Continual infestation of new leaves limits growth. Females lay eggs singly on leaves. Caterpillars pupate in rolled leaf edges. ***Favoured*** by successive bursts of new growth in summer to late autumn. In some states ***sale of infested nursery trees is illegal*** and all citrus consigned to areas where citrus leafminer does not occur, must be treated with a prescribed insecticide and be from a nursery ***certified*** to be free from infestation by an authorised inspector. ***Parasitic wasps*** (*Citrostichus phyllocnistoides*, *Quadristriatus* sp., *Ageniaspis citricola*) have been introduced. Wasps already here (*Semielachner petiolatus*, *Cirrospilus* sp.) give up to 10% parasitism. ***Petroleum oils*** applied during growth flushes (leaves are < 20 mm long) and discontinued when moth ceases to infest, forms a coating on leaves which female moths avoid, reducing egg laying (Beattie 1994, Moody 1995). ***Monitor*** leaf mines in new growth flushes at regular intervals before applying an insecticide (Brough et al. 1994). See Azalea K 28.

Fruit flies (Tephritidae, Diptera). eg ***Mediterranean fruit fly*** (*Ceratitis capitata*), ***Queensland fruit fly*** (*Bactrocera tryoni*) and ***island fruit fly*** (*Dirioxa pornia*) may be ***major and frequent pests*** of citrus. Mature and especially over-mature citrus of many varieties may be attacked when fruit fly is abundant (Hely et al. 1982). Maggots may fail to develop in fruit, ***stung fruit*** are unmarketable and eventually fall. See Fruit F 9.

Fruitpiercing moths (*Othreis* spp.) pierce rind, and suck sap from ***ripe fruit*** causing considerable fruit loss in some areas. The feeding hole is obvious but may be mistaken for damage by the ***orange fruit borer larva***. ***Decay*** develops around the hole and fruit ripen prematurely and fall. Hand swatting with racquets after dusk is practised by some growers during crucial periods of attack usually 1-2 weeks long. See Fruit F 9.

Katydids, grasshoppers and locusts (Orthoptera): ***Katydids*** (Tettigoniidae), eg ***citrus katydid*** (*Caedicia strenua*) and ***inland katydid*** (*C. simplex*), damage young fruit of Washington navels and Valencia but not lemons. Nymphs skeletonise ***young leaves*** and adults chew holes in ***older leaves***, but damage is unimportant. Nymphs gnaw rind of ***young fruit*** causing disfigurement and fruit drop. Damaged older fruits remain on trees, as they grow, scars grey and flatten out. ***Monitor*** damage to fruit prior to applying an insecticide (Brough et al. 1994). ***Others: Australian plague locust*** (*Chortoicetes terminifera*), ***giant grasshopper*** (*Valanga irregularis*), ***spur-throated locust*** (*Austracris guttulosa*) and ***wingless grasshopper*** (*Phaulacridium vittatum*). See Vegetables M 13.

Leafhoppers, planthoppers and treehoppers (Hemiptera)

Leafhoppers (Cicadellidae) are grey-brown, about ***5 mm*** long, and are numerous on summer grass around the skirts of coastal citrus trees in autumn. Their presence has been associated with ***oleocellosis*** type skin injury in oranges starting to colour in autumn. Prevent excessive grass growth around trees. ***Citrus jassid*** (*Empoasca smithi*) mainly feeds on Imperial mandarin and grapefruit. See Vegetables M 15.

Flatid planthoppers (Flatidae): ***Citrus planthopper*** (*Colgar peracutum*) and ***green planthopper*** (*Siphanta acuta*) infest ***fruit stalks***. An egg parasite (*Achalcerinys*) is an effective natural enemy of these planthoppers. See Trees K 15.

Others: Green treehopper (*Sextius virescens*). ***Passionvine hopper*** (*Scolypopa autralis*) sucks sap from fruit stalks but this is unimportant.

Some of these insects secrete ***honeydew*** which attracts ants and on which sooty mould grows. ***Monitor*** their presence and damage, prior to applying an insecticide (Brough et al. 1994). See Vegetables M 15.

Mealybugs (Pseudococcidae, Hemiptera) are ***major pests*** of thickly foliaged citrus trees. They are up to 6 mm long. Mealybugs suck sap from ***foliage, young twigs and fruits*** in protected sites, eg between touching fruits, under calyx lobes. Honeydew attracts ants and results in ***sooty mould*** which dirties fruit, causing end rots and fruit drop.

Citrus mealybug (*Planococcus citri*) are mealy white, oval and 3 mm long. Anal filaments are < 1/4 of body length. Glandular exudate is ***yellow-orange***.

Citrophilous mealybug (*Pseudococcus calceolariae*) Anal filaments are about 1/3 of body length. Glandular exudate is ***claret***; eggs are deposited in an irregular cottony sac.

Longtailed mealybug (*Pseudococcus longispinus*): Anal filaments are nearly as long as body and glandular exudate is ***colourless-yellow***.

Other species, eg *Rastrococcus*.

Natural enemies include wasp, ladybirds and lacewings, some of which can be purchased. Sooty mould in the navels of mature oranges is difficult to remove by ***cleaning***. ***Control ants*** and ***monitor*** mealybugs, at regular intervals before making a decision to release parasites or predators or apply an insecticide (Brough et al. 1994). ***Petroleum oil*** causes minimum harm to natural enemies, and loosens sooty mould. See Greenhouses N 25.

Mites (Acarina) may infest citrus (Fig. 119).

Broad mite (*Polyphagotarsonemus latus*) is a ***major, sporadic pest*** of lemon, mandarin and Valencia orange. Mites are about 0.25 mm long (Fig. 119). ***Leaf edges*** curl under, undersurfaces may bronze. ***Nursery trees*** may be lose vigour. Mites feed on sheltered inner faces of very ***small fruit*** causing silvery-green blemishes with sharkskin textures, low fruits are affected first. See Greenhouses N 26.

Citrus flat mite (*Brevipalpus lewisi,* Tenuipalpidae) is red, flat, false spider mite, about 0.25 mm long with 2 pairs of short legs flanking the narrow abdomen. They are rarely seen moving. Eggs are red, oval and usually laid singly. Their sap sucking causes grey, sand papery ***rind*** blemishes. See Grapevine F 62.

Spider mites (Tetranychidae): ***Citrus red mite*** (*Panonychus citri*) is one of the ***world's worst pests*** of orange and lemon. ***Adult females*** resemble ***bean spider mite*** (*Tetranychus ludeni*) but are dark red and have long bristles on their backs and sides (Fig. 119). Mites are about 0.5 mm long and prefer light green maturing leaves. Their scratchy feeding marks give ***leaves, green bark*** and ***immature fruit*** a pale appearance. Leaf fall starts at the tops of trees. Mature orange and lemon fruit turn a pale yellow. Mites develop all year, but more slowly in cooler conditions. Very hot dry windy weather or prolonged periods of high humidity, kills many. ***Natural controls*** include ***predatory mites*** (*Amblyseius elinae*, *A. deleoni*, *A. lentiginosus*) and ***ladybirds*** (*Halmus chaltbeus*, *Serangium bicolor*, *Stethorus nigripes*). Treatment of minor infestations is unnecessary. Spot spray infested trees. ***Oriental mite*** (*Eotetranychus orientalis*) is a minor pest in drier inland areas. Damage is similar to that caused by twospotted mite. *Stethorus* ladybirds are predators. ***Twospotted mite*** (*Tetranychus urticae*) is a minor and sporadic pest of coastal Meyer lemons infesting ***leaves*** and ***fruit***, causing mottled yellowing. See Beans (French) M 29.

Eriophyid mites (Eriophyidae) vary in colour, are microscopic (0.18 mm long), worm-like, with 2 pairs of legs (Fig. 119). ***Citrus bud mite*** (*Eriophyes sheldoni*) is a minor pest of lemon. ***Foliage, shoots, flowers and fruit*** may be seriously ***distorted*** (Fig. 119), nursery trees severely damaged. Mites are found in leaf axil buds on new shoots. On older wood, buds are small and may die. Secondary buds may develop and in turn become infested. Mites also occur in ***flower buds***, and beneath the ***calyx lobes*** of fruit. Female deposits eggs singly where mites feed. ***Favoured*** by humid weather in coastal areas at any time of the year. Very high temperatures may kill them Frosty weather does not seem to harm them. ***Citrus rust mites*** (various species) damage ***green immature fruits*** in summer/autumn. On heavily infested young fruit, mites and cast skins look like ***dust***. Blemished fruit look smaller, are sub- standard and deteriorate rapidly. Rust mites may also bronze ***leaves and green twigs***, and severely damage ***young trees***. ***Predatory ladybirds*** (*Serangium bicolor*, *Stethorus nigripes*, *Halmus chalybeus*), and a ***predatory mite*** (*Amblyseius victoriensis*) provide some control. ***Brown citrus rust mite*** (*Tegolophus australis*) is a ***major, frequent native pest*** of citrus, eg orange and mandarins. ***Adults*** are brown, broad and wedge-shaped. Mites prefer warm dry conditions, feeding mainly on ***leaf uppersurfaces*** and ***outer faces of fruit*** in the upper half of the tree. Fruit look shiny and brown. Females lay eggs in depressions on fruit and leaf uppersurfaces. ***Citrus rust mite*** (*Phyllocoptruta oleivora*) is a minor pest of grapefruit and lemon. Young ***green fruit*** inside and on lower sheltered parts of trees, inner surfaces of fruit, develop slightly rough, grey-brown blemishes with the outside edges deeper brown. It prefers humid conditions and temperatures < 35^{o}C. See Grapevine F 62.

There is a ***gradual metamorphosis*** (egg, nymph, adult) with many generations during summer/ autumn. ***Spread*** on nursery trees and introduced to young stock on buds. Also by wind, rain, visiting birds, insects, people and machinery. Some mites can crawl within and between trees. ***Favoured*** by excessive spraying or spray drift. ***Monitor*** mites, mite damage, and predatory mites and ladybirds at regular intervals, before deciding to release predators or apply a miticide (Brough et al. 1994).

Redshouldered leaf beetle

(*Monolepta australis*) quickly ruins ***blossoms, buds and new citrus foliage*** in spring, or leaves in summer. Small numbers are unimportant. An attack, if detected quickly, may be treated by lightly spraying buds, blossoms and young growth. ***Monitor*** beetles at regular intervals, if swarms are in the vicinity, before applying an insecticide (Brough et al. 1994). See Fruit F 11, Trees K 15.

Scales (armoured)

Scientific name: Diaspididae, Hemiptera

Host range: Most armoured scales suck sap from a range of woody plants; there are exceptions, eg white louse scale, which only infests citrus.

Circular black scale (*Chrysomphalus aonidium*) is a minor pest of ***fruit***, eg citrus, ***ornamentals***, eg bottlebrush, holly, palm. ***Adult female scales*** are circular, up to 2 mm across, and purple-black. Their central point is slightly raised and surrounded by a red-brown band and grey margin. ***Male scales*** are oval, and mature winged adult males are orange with pale lilac wings. Scales suck sap from both ***leaf surfaces***, and yellowish patches mark feeding sites. Leaves may fall. Scales may infest ***green twigs***. ***Fruit*** are blemished by the presence of scales and lack of uniform colour. ***Favoured*** by coastal tropical and subtropical climates. An introduced small yellow wasp (*Aphytis holoxanthus*) effectively ***parasitises*** the scale.

Purple scale, mussel scale (*Lepidosaphes beckii*) is a pest of ***fruit***, eg thickly foliaged orange and grapefruit, ***ornamentals***, eg camellia, holly. ***Adult female scales*** are 2-3 mm long, mussel-shaped, and moderately convex. They are tough, leathery, and purple-brown. ***Males*** are smaller and narrower. ***Branches*** from 3-25 mm in diameter are severely damaged and ***may die*** (large limbs weakened by purple scale may be invaded by white louse scale). Young trees are rarely damaged. ***Leaves*** show bright yellow blotches and may fall. ***Fruit infestation*** (Fig. 120) favours melanose. ***Favoured*** by warm, moist protected situations, through spring until late autumn. Hot dry conditions can kill purple scale. A ***parasitic wasp*** (*A. lepidosaphes*) usually keeps scale at a low level. ***Glover's scale*** (*Insulaspis gloverii*) infests thorns, leaf margins or petiole edges. ***Female scales*** are 2.5-3 mm long, narrow, straight or curved. They resemble purple scale and are often found with purple scale.

Red scale, California red scale (*Aonidiella aurantii*) is the ***principal pest of citrus*** in Australia. It is introduced and infests ***fruit***, eg citrus, fig, grape, olive, pear, ***ornamentals***, eg bottlebrush, ivy, rose, ***weeds***, eg Bathurst burr. ***Adult female scales*** are circular, slightly conical, about 2.5 mm across and orange-red. ***Males*** are oval, smaller and paler. Adult winged males are light orange-yellow. Scales blemish ***fruit*** (Fig. 120), restrict fruit growth followed by splitting and fruit-fall, cause ***leaves*** to yellow and fall, ***bark*** to harden, followed by splitting and dieback of ***twigs and branches***. ***Young trees may die.*** There are no eggs. As many as 45 six-legged nymphs are produced per female. They move out from under the female scale and crawl about for a few hours then settle permanently. ***Favoured*** by abundant light, dust on plants (from dusty roads), warm dry conditions, good rain in autumn after a dry summer and large numbers of mature citrus fruits on trees. ***Very hot conditions***

kill red scale. Low temperatures in winter in citrus areas have little effect. As many as 40-50% of crawlers may die in summer and many more in winter. ***Parasitic wasps*** (*Aphytis* spp.) and ***scale-eating ladybirds*** (*Rhyzobius lophanthae*) may be purchased. ***Yellow scale*** (*A. citrina*) is paler and flatter, infesting leaves and fruit, occasionally green twigs. It causes less damage to trees and mature fruit.

San Jose scale (*Quadraspidiotus perniciosus*) does ***not usually infest citrus***. It may affect ***other fruit***, eg apple, pear, quince, ***ornamentals***, eg hawthorn, *Prunus* spp., tree lucerne. ***Adult scales*** are 1-2 mm across, roughly circular, and white to brownish. Adults and nymphs suck sap from ***leaves, limbs and fruit***. ***Bark*** is rough, pink or ashy. Infested trees may ***die***. On ***pome fruits***, scales are surrounded by about 1 mm wide and surrounded by a white halo. See Pome fruits F 121 (Fig. 156). Presence of scales on fruit will result in its rejection for export to Europe. Scale should be eradicated from every tree in an orchard. Label trees with infested fruit; inspect bark of trees during pruning, spray them, and check 3 months later. ***Oystershell scale*** (*Q. ostreaeformis*) and ***pear scale*** (*Q. pyri*) also occur but are not nearly so harmful. See Pome fruits F 116.

White louse scale, snow scale (*Unaspis citri*) infests older citrus trees. ***Adult female scales*** are 1.5-2 mm long, brown-grey with grey margins, mussel-shaped with a lengthwise median ridge. Scales usually infest ***trunks and main branches*** but may spread to mature ***twigs, fruit and leaves*** causing yellow spotting and leaf fall. Trunks may look like whitewash. Twigs and branches may die. ***Bark*** of heavily infested trunks (Fig. 120) and limbs look dull and may crack as the tree grows. If untreated, infestations usually develop to a climax and then ***rapidly decline***. Weakened limbs and twigs may be attacked by melanose and borers. There are ***several overlapping generations*** each year. ***Favoured*** by dry seasons. Seedling trees appear to be more susceptible than commercial varieties. The introduced ***predatory orange ladybird*** (*Chilocorus circumdatus*) may be purchased. Ladybird pupae lie parallel to each other, often at branch forks. ***Lichen and moss*** reduce scale in wet areas and where there are few parasites.

Pest cycle: Gradual metamorphosis (egg, nymphs, adult) with usually one to several overlapping generations per year. Some scales have no egg stage, eg red scale. Eggs are laid under the female scale cover.

Overwintering: On infested hosts.

Spread: By introduction of infested nursery stock, buds or grafts, cuttings, container plants, some exceptions, eg white louse scale, because it is so obvious. Spread within plantings by nymphs crawling from plant to plant if plants touch, birds, clothes, hands during harvest and handling, and by wind. ***Soft scales*** may also be spread by ***ants***. See Citrus F 41.

Conditions favouring: Indiscriminate use of insecticides which kill natural enemies. Ants repel natural enemies.. Neglected plants. Depends on the scale, eg black scale dislikes hot dry weather.

Control may be compulsory, eg control of red scale is ***compulsory*** under plant diseases acts. ***Monitor*** to see if scale infestations are present.

Cultural methods: Heavily infested plants should be fertilised to restore vigour.

Sanitation: If only a few plants are affected, ***prune*** infested parts off; lightly infested areas can be washed with soap using a soft brush. Some scales, eg nigra scale, are easily be removed by hand. Harvest fruit at the correct time. Fruit are greenish where scales were attached, and if covered with scales or sooty mould, are ***difficult to clean*** before packaging, especially if skin is rough, eg mandarins.

Biological control: Most scales are controlled to varying degrees by weather, parasites, predators and diseases. ***Ants*** repel parasites and predators and very hot weather can kill many black scale crawlers. ***Parasites*** include ***introduced wasps*** (*Aphytis lepidosaphes*, *A. columbi, A. chrysomphali*, *A. lingnanensis*, *A. melinus*, *Aspidiotiphagus* sp., *Comperiella bifasciata*, *Encarsia perniciosi*) and ***native wasps*** (*Aenasoidea varia*, *Rhopalencyrtoidea dubia*). Some may be purchased. Wasps deposit eggs on or under scales, and larvae feed on scale. Parasitised scales are dark and there is an obvious exit hole. ***Wasps also kill scales*** by sucking their juice. ***Predators*** include ***ladybirds*** and their larvae which kill the scales and scatter the eggs, eg scale-eating ladybird (*Rhizobius lophanthae*), ladybirds (*Orcus australasiae, O. chalybeus*), steelblue ladybird (*Halmus chalybeus*), black ladybird (*Rhizobius ventralis*), mealybug ladybird (*Cryptolaemus montrouzieri*); ***green lacewing larvae*** (*Chrysopa* spp.) and ***scale-eating caterpillars*** (*Batrachedra* sp., *Catablemma dunia*). ***Fungal diseases*** in wet seasons, eg *Nectria,* a red-headed fungus (*Fusarium coccophilum*) and a felt fungus (*Septobasidium* sp.), attack scales. *Verticillium lecanii* can cause up to 90% mortality of some scales.

Resistant varieties: Not all citrus varieties are ***susceptible*** to a particular scale, eg red scale may attack all citrus, but lemons are preferred.

Plant quarantine: Some scales on fruit, eg San Jose scale, are subject to ***quarantine regulations***.

Disease-free planting material: Plant scale-free nursery stock.

Pesticides: ***Monitor*** scales, and their predators and parasites on fruit, trunks, branches or leaves, at regular intervals before making a decision to purchase parasites or predators or apply an insecticide (Brough et al. 1994). ***Evergreen trees***, eg citrus, may be sprayed with ***petroleum oil*** in summer when ***crawlers are active***, before the protective scale covering has developed, later stages become ***very resistant***. For some species of scales, ***insecticides*** do not kill the ***eggs*** and a repeat spray may be needed several weeks later after eggs have hatched. Some scales have only ***one generation of crawlers*** each year, while others have several. ***Exact timing of sprays*** usually depends on ***observation of crawler stages***. ***Increased ant activity*** will often serve as a good guide to presence of crawlers of soft scales. ***Scale covers*** or ovisacs may remain on twigs long after scales have died. ***Live pink wax scales*** have a pink fluid when squashed, dead scales are hard and dry. ***Deciduous trees*** (< 3 m high), eg persimmon, ash, may be sprayed with ***petroleum oil*** when trees are bare in ***winter***. ***Controlling the ants*** attracted to the honeydew produced by soft scales, may provide control. Thick grease/sticky material or insecticides/baits, applied around the base of trunks, traps or kill ants respectively. See Trees K 24.

Scales (Eriococcidae, Hemiptera) are ***not usually pests of citrus***. Most are host specific, eg ***gumtree scale*** (*Eriococcus coriaceus*) only attacks eucalypts. Australian species include some of the most bizarre insects, many forming spectacular galls on native trees, eg *Apiomorpha* on eucalypts. See Eucalypt K 63.

Scales (Margarodidae, Hemiptera): *Cottonycushion scale* (*Icerya purchasi*) infests ***fruit***, eg citrus, ***ornamentals***, eg eucalypt, grevillea, hakea, pittosporum, wattle, ***weeds***, also the ***parasitic native cherry*** (*Exocarpos cupressiformis*). ***Female scales*** are red-brown about 5 mm long and may be covered with a white mealy secretion. About 1,000 red oval eggs are laid beneath the female body into an ***ovisac*** which develops into a ***soft cottony white fluted mass*** up to 10 mm long (Fig. 121). ***Males*** are winged. ***Nymphs*** are bright red initially. ***Honeydew*** attracts ants and on which sooty mould grows, blackens the tree and fruit. Scales infest ***leaf undersurfaces, bark, small branches and trunks***. Gradual metamorphosis (egg, nymph and adult) with at least 2 main generations per year. Crawlers occur in spring and autumn. ***Favoured*** by temperate and subtropical climates, inland and coastal. ***Parasites and predators***, especially ***vedalia ladybird*** (*Rodolia cardinalis*), ***mealybug ladybird*** (*Cryptolaemus montrouzieri*) may be purchased. ***Control:*** See Citrus F 40.

Scales (soft)

Scientific name: Coccidae, Hemiptera

Host range: Most attack many woody plants, eg black scale, pink wax scale, white wax scale, others only attack citrus, eg citricola scale.

Description and damage: Direct injury to trees and shrubs by soft scales often seems to be minor. The ***most serious damage*** occurs because of the ***vast quantities of honeydew*** produced. Sap is high in sugar but low in protein. To obtain a balanced diet soft scales suck in large amounts of sap often many times their own body weight. Surplus sugary water is excreted as ***sticky honeydew*** and drips onto lower stems, leaves and fruit. ***Sooty mould*** grows on it. Extensive or persistent sooty mould reduces photosynthesis and inhibits ***normal colouring*** of leaves and fruit. ***Fruit*** is unsightly at harvest and cleaning before marketing can be difficult. Infested leaves may fall prematurely. Plants look black. Sooty mould will disappear only if the insects producing the honeydew are controlled. Sooty mould will then dry and flake off, hosing may assist removal. ***Honeydew attracts ants***, especially when nymphs hatch in spring,. The ants protect the scales from natural enemies and move them from plant to plant.

Black scale, brown olive scale (*Saissetia oleae*) is widespread and common. ***Adult female scales*** are dark brown, bun-shaped, and about 3 mm long and 2 mm wide (Fig. 122). The surface is smooth but raised ridges form a 'H' on its back. ***Nymphs*** are initially light brown. Females may lay up to 2,000 eggs, which look like little heaps of sand. Main hatches are usually in spring and autumn but there is some overlapping of generations. After hatching, nymphs crawl about and settle on ***twigs, leaves and fruit***. Autumn hatched eggs may mature on the leaves. ***Favoured*** by temperate climates with moderate temperatures and high humidities. ***Very hot weather***, eg 44^{o}C, kills scales. Parasites, predators and diseases may control black scale in plantings, eg on oleander, if ants are controlled. ***Nigra scale*** (*Parasaissetia nigra*) ***does not infest citrus*** but is a similar scale to black scale, infesting many plants, eg bottlebrush, casuarina, fig, hibiscus, lilly-pilly and indoor plants, eg ferns, orchids and palms. It is leathery, oval, black and 5 mm long. Nymphs are pale brown, and settle on young shoots, along leaf midribs or on adult covers.

Chinese wax scale (*Ceroplastes sinensis*) infests ***Myrtaceae***, eg lilly-pilly, melaleuca, tea-tree, and ***Rutaceae***, eg citrus, pittosporum. ***Adult scales*** are grey, domed, waxy, and about 7 mm long with 1 apical and 6 marginal dark spots when fully mature (in summer) and infest ***twigs***. Mature females lay thousands of eggs beneath their bodies in summer, then die. Eggs hatch over several weeks in autumn, ***nymphs*** settle ***along veins***, on ***leaf upper surfaces,*** and develop white marginal rays of wax ***(rosette stage)***. In early winter, scales move to stems and body wax changes to white, and for a time in spring ***half the wax is white and half is pink***. Males are seldom seen. In Sydney there is 1 generation a year (Hely 1982).

Pink wax scale (*Ceroplastes rubens*) infests ***fruit***, eg avocado, citrus especially Mandarin, custard apple, mango, ***ornamentals***, eg fern, holly, ivy, lilly-pilly, pittosporum. ***Adult females*** have a hard, pink cover, are 3-4 mm long, almost globular, and have a smooth slight depression on the top and two lobes on each side. Males are not known in NSW. ***Nymphs*** are purple-red. are present in spring and autumn and settle on ***leaves or young twigs***. There are 2 generations each year. Only 700 eggs are laid by each female. High populations cause premature leaf fall reducing fruit size and tree vigour. ***Favoured*** by humid climates, and sheltered low-lying situations. ***Native wasps*** exert considerable control. An introduced wasp (*Anicetus beneficus*) can be purchased. Insecticides are rarely needed. ***Florida wax scale*** (*Ceroplastes floridensis*) is a sporadic pest infesting leaves and twigs and is similar to pink wax scale. A ***wasp parasite*** (*Scutellista cyanaea*) is the main natural control.

Soft brown scale (*Coccus hesperidum*) is a minor and ***common pest*** of citrus, ferns and orchids. Adults are 4 mm long, flat, pale brown and cluster in small colonies on isolated ***branches, twigs, leaf midribs and stalks and stems*** (Fig. 122). ***Parasitic wasps*** (*Diversinervus elegans, Microterys flavus*) are important in restricting its population. Isolated colonies can be cut off.

White wax scale (*Ceroplastes destructor*) is a minor pest of citrus especially grapefruit, and persimmon. ***Adult scales*** are irregularly shaped and up to 10 mm long, 8 mm wide and 7 mm high. They are enveloped in soft white wax and infest ***twigs and fruit*** (Fig. 122). There are 1-2 generations each year. In late spring the mature female deposits up to 3,000 eggs in a mass beneath her body then dies. Nymphs settle on ***foliage*** and develop white marginal rays of wax ***(rosette stage).*** After 4-5 weeks, they crawl back to ***twigs*** where they settle permanently and secrete the wax cover. ***Favoured*** by vigorous trees, and subtropical and temperate climates with a relatively high humidity in summer. Scales are killed by high summer temperatures. ***Wasp parasites*** (*Anicetus communis*, *Paraceraptrocerus nyasicus*, *Tetrastichus* *ceroplastae*) lay eggs in scales 4-5 weeks old. ***Parasitism*** may reach 90% and the scale is now unimportant. Scales are attended by the green tree ant (*Oecophylla smaragdins*) which protects scales from natural controls. ***Indian white wax scale*** (*Ceroplastes ceriferus*) is similar to white wax scale and infests *Dodonaea*, some ferns and some garden perennials, but not citrus.

Others: ***Green coffee scale*** (*Coccus viridis*) may infest leaves and twigs. There are several parasites and predators. ***A fungus*** (*Verticillium lecanii*) can cause up to 90% mortality of the scale during wet weather. ***Hemispherical scale*** (*Saissetia coffeae*) is a minor pest infesting leaves twigs and fruit stalks. ***Long soft scale*** (*Coccus longulus*) infests leaves, twigs and fruit stalks, especially of Imperial and Ellendale mandarins. ***Pulvinaria scale*** (*Pulvinaria cellulosa*) is a minor pest infesting leaves, twigs and fruit. ***Citricola scale*** (*Coccus pseudomagnoliarum*) is a minor pest of citrus in some areas, infesting ***young foliage and twigs***. Scale covers are similar to soft brown scale but mature adults are grey, larger and more convex. ***Nymphs*** are oval, very flat, yellow-green and transparent. After egg-laying females die, they become brown and detach from the twig leaving a white oval mark.

Control: See Citrus F 40.

Thrips (Thripidae, Thysanoptera)

Citrus rust thrips, orchid thrips (*Chaetonaphothrips orchidii*) infest citrus fruit mainly in low lying isolated orchards. Overseas it also occurs on greenhouse plants. ***Adult thrips*** are similar to banana rust thrips (*C. signipennis*) and are active, yellow with black markings on the narrow fringed wings. If disturbed, they move rapidly into sheltered positions or exposed to light. Their rasping and sucking causes brown raised rust marks on the ***rind*** between touching fruit. ***Predatory thrips*** may exert some control. Where rust thrips is known to occur, ***monitor*** fruit for their presence prior to applying an insecticide (Brough et al. 1994). See Banana F 25.

Others: ***Greenhouse thrips*** (*Heliothrips haemorrhoidalis*) feed on ***ripe fruit*** or ***mature leaves*** where 2 surfaces (leaf or fruit) touch. Grey patches and ***black dots of thrips excreta*** disfigure rind, which becomes flaccid after harvest. See Greenhouses N 24. ***Onion thrips*** (*Thrips tabaci*) may cause an oval silvery skin blemish at the ***pistil end of ripe oranges*** after fruit set. ***Favoured*** by proximity to old infested crops, eg peas, as citrus fruit setting. See Onion M 68. ***Plague thrips*** (*Thrips imaginis*) feeds on petals, pistils and ***developing ovaries of citrus blossoms*** in spring. ***Petals brown***, small blisters develop on pistils due to egg-laying but do not seem to affect fruit setting. See Roses J 6.

Weevils (Curculionidae, Coleoptera) of several species emerge from pupae in the soil in spring and feed on ***shoots, leaves, rind and bark*** of citrus. Leaves have serrated edges. Larvae feed on ***roots*** but cause little damage. Larvae and pupae are found in soil under infested trees.

Apple weevil (*Otiorhynchus cribricollis*) is about ***9 mm*** long, shiny and dark brown. They climb trees at night to feed on ***foliage*** and shelter in the soil by day. Young trees may be stripped almost completely. Insecticides may be applied to butts and lower limbs when damage is seen. See Pome fruits F 116.

Citrus fruit weevil (*Neomerimnetes sobrinus*) damages ***rind*** of young fruit, mainly oranges.

Citrus leafeating weevil (*Eutinophaea bicristata*) is grey-brown and similar to dicky rice weevil but can fly. Males lack foreleg spines. ***Leaves*** on lower parts of infested trees may be grey from weevils chewing small irregular patches from both surfaces, leaves fall. ***Young fruits*** may be attacked.

Dicky rice weevil (*Maleuterpes spinipes*) is a native pest of native and cultivated ***Rutaceae***, especially orange, grapefruit. ***Weevils*** are brown, up to ***3 mm*** long, with grey-white marks on the back and legs. Males have long curved spines at the middle of each front femur. When shaken from a tree they feign death. They cannot fly. ***Leaf margins***, are saw-toothed, and ***rind of young fruits*** causing a network of irregular white furrows which grey as fruit matures. Probably 2 generations each year. During dry weather they feed on ***fallen ripe fruits, bark*** at the trunk base, or exposed surface ***roots***. After rain they swarm up into trees. Eggs are laid in the soil. ***Spread*** by crawling and on nursery trees, or in bins or boxes used for harvesting. ***Favoured*** by good rains in spring/summer. Larvae prefer heavy loam to sandy soils. Banding is not successful, weevils may be sprayed when they emerge from soil.

Fuller's rose weevil (*Asynonychus cervinus*) is a minor pest of citrus. Weevils chew ***leaf edges***, preferring replant trees in old orchards. Eggs laid underneath fruit calyces are a ***quarantine pest*** for exports to Japan. An ***egg parasite*** (*Fidobia citri*) is important. ***Monitor*** trees from which fruit will be exported. Skirt these trees in spring, control weeds and spray trunks or apply sticky bands to prevent weevils from accessing trees. See Roses J 6.

Whitestriped weevil (*Perperus lateralis*) is about ***6 mm*** long, smooth and light grey with a white stripe running along each wing cover. In spring they chew ***buds and young shoots*** slowing growth of young trees. Weevils feed at night, but may be found during the day in sheltered situations, eg curled leaves, under bark. ***Favoured*** by plants growing on sandy soils, and dry weather. Rain seems to disperse the weevils. ***Insecticides*** provide adequate control.

Others: ***Elephant weevil*** (*Orthorhinus cylindrirostris*) chew squarish pieces of ***green bark*** from branches and ***young buds*** and its larvae bore in ***trunks***. See Trees K 11, K 17. ***Fruit-tree root weevil*** (*Leptopius squalidus*) is a minor pest of citrus and feeds on ***foliage***. Female weevils are about 20 mm long, grey-buff, with a typical weevil snout. Larvae bore in deep ***roots***. See Fruit F 11.

See Trees K 17.

Whiteflies (Aleyrodidae, Hemiptera)

Australian citrus whitefly (*Orchamoplatus citri*) infests most citrus. ***Adults*** are about ***2.5 mm*** long, with powdery wings. Females lay oval yellowish eggs in ***circular patterns*** on ***undersides of young leaves***. ***Nymphs*** at first are flat and scale-like. Nymphs and adults suck sap mainly from leaf undersurfaces but cause no direct injury. They produce ***honeydew*** resulting in sooty mould which dirties fruit and foliage. ***Favoured*** by warm, moist weather during spring and autumn, new foliage.

Others: ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*). ***Citrus yellow fly*** (*Asterobemesia helyi*) is a pest of citrus trees in Sydney.

See Greenhouses N 24.

Others: ***Giant termite*** (*Mastotermes darwiniensis*) is a minor pest in north Qld. Young trees may be killed. See Trees K 17.

SNAILS AND SLUGS

The ***common garden snail*** (*Helix aspersa*) when young, skeletonises young ***leaves*** and grazes on rind of green citrus ***fruit***. Older snails eat holes in leaves reducing them to veins, and gouge circular holes in green and ripening fruits. ***Green bark*** is not attacked but dry bark of twigs is eaten, leaving the wood white. Other species may also attack citrus. See Seedlings N 70.

Non-parasitic

Ants (Formicidae) are attracted to some ***sap sucking insects***, eg soft scales. They also nibble ***edges of young citrus leaves*** which become cupped as they grow. Damage is minor. See Trees K 19, Turfgrasses L 8.

Environment: ***Freezing*** of mature lemons, Washington navel oranges and grapefruit causes ***rind break-down***, often followed by ***secondary fungal growth***. ***Heavy sudden frost*** may kill foliage and young twigs and cause bark to split longitudinally and gape. Secondary melanose may cause dieback. ***Continued cold conditions***, cause the juice sacs in immature fruit to dry out, but no injury to rind. Trees stressed due to poor root systems or drought, are susceptible. ***Lemon*** is the most ***frost susceptible*** citrus fruit commonly grown. Meyer lemon and most mandarin cultivars are more ***resistant*** to cold injury than orange. Do not prune until all danger of frost has passed. ***A succession of moderate frosts and cold winds*** cause foliage curling. Foliage immature at the onset of cold weather, may become yellow, but re-greens during warm spring weather. ***Alternation of warm day and cool night temperatures*** during spring is thought to cause the first flush of spring growth of Wheeny grapefruit to crinkle (the mid-vein or the leaf margins or both fail to expand fully). Leaf undersurfaces, exposed to the ***sun***, become bleached and covered with rust coloured spots and blotches. ***Rind splitting*** occurs in ***lemons*** in ***autumn*** when there has been a very rapid buildup of sugar in the fruit, so rapid that the skin has been unable to grow quickly enough to contain it. A combination of ***warm days***, when the fruit expands, and ***cold nights***, when it contracts, adds to the problem by putting further strain on the skin. Splitting in citrus may also be associated with fungal diseases and severe copper deficiency. ***Hail*** may damage fruit. ***Winds*** lash young and old leaves against thorns, dead twigs, branches. As young leaves mature, bruised tissue fails to grow causing puckering. Affected shoots fail to reach their full size. Wind may cause ***50-60% of rind damage.*** Damaged young fruits develop scaly patterns as they mature. Injured lemons often show some thickening and ridging of the rind. Plant ***windbreaks***, which ***reduce*** water loss and ***modify*** the micro-climate, eg by smoothing out fluctuations of temperature. Overhead irrigation efficiency, shading and tree drying time may be ***increased*** which may increase likelihood of diseases and pests. ***Prolonged wet weather*** in autumn, causes the rind of maturing navel oranges and some mandarin cultivars to absorb excess water. Minute cracks develop on rind. Affected tissue becomes watersoaked, brown and may be invaded by ***secondary fungi***. Fruit develop an off-flavour and fall. ***Favoured*** by the application of ***white oil*** earlier in the season and ***quick-acting fertilisers*** especially in autumn. ***Drying out of lemons*** can also be caused by water stress during winter.

Mutations or sports are caused by ***genetic alterations*** which occur in meristem cells. They include changes in ***leaf*** size, shape and form, leaf crinkling in Eureka lemon, leaf variegation, elongated, corrugated, pebbled or coloured sections of ***fruit***, abnormal ***shoot growth***, twisted, flattened or galled ***stems***, and thickened rough ***bark***. A ***chimera*** is the display of genetically different tissues in the same plant or part of a plant, eg patches of tissue with colour, texture or structure different from the normal.

Nutrient deficiencies, toxicities

Citrus are ***gross feeders*** and subject to many deficiencies and toxicities. Some are difficult to identify visually. ***Soil analysis*** should be done before planting and ***tissue analyses*** regularly after planting. Tissue analysis standards are available for citrus (Weir and Cresswell 1993). ***Copper deficiency*** (exanthema) is not common and is ***hard to recognise***. Symptoms include occasional giant leaves, dark gum pockets on leaves, bark and fruit, and multiple buds. Small pale fruit with a hard skin may split and gum. ***Iron deficiency*** causes yellowing between the veins of ***new leaves*** (Fig. 123). Severely affected plants may have leaves that are entirely yellow or even white, smaller than usual, and develop tip burn. ***Nitrogen deficiency*** causes pale yellow leaves which fall prematurely, poor fruit set, small-sized fruit, and poor growth. ***Phosphorus deficiency*** causes fruit to become rough and puffy. ***Potassium deficiency*** causes yellowing and scorching of mature leaves which fall prematurely and dieback of twigs in the growth flush. ***Excess*** can reduce the quality of Valencia oranges and grapefruit. ***Magnesium deficiency*** occurs on ***older leaves*** as yellow blotches which appear on either side of the main vein and then enlarge until the ***only green remaining*** is at the tip of the leaf or a V-shape near the base (Fig. 123). The entire leaf may yellow. ***Manganese deficiency*** occurs mostly on alkaline soils. and causes pale green mottling between dark green veins on spring growth flush. ***Zinc deficiency*** (mottle leaf or ***little leaf***) causes yellow mottling of new growth, eventually only the midrib and main veins remain green, new leaves are small and narrow (Fig. 123). ***Fruit*** becomes rounded and small. ***Nutrient toxicity: Excess soluble salts***, eg of manganese and boron, in soil reduces growth, yield and increase leaf drop. Leaves may develop brown spots and tip burn. ***Prevent*** by irrigating frequently and use sufficient water to wet the whole soil profile. Water ***nursery plants*** routinely to cause run-off from the base of the container. ***In the field***, use flood irrigation or under-tree sprinklers to minimise salt deposits on leaves. ***Select*** rootstock and/or scion varieties of citrus, grape and avocado with ***resistance to salt***.

Pesticide injury: ***Copper sprays*** if applied too frequently, or at too high a rate when trees are stressed from drought, may cause delayed and reduced ***flowering*** in spring, and ***loss of some leaves*** the next winter. ***Twigs*** may die, ***fruit*** is paler, coarser and smaller than normal. ***Bordeaux mixture*** may cause small star-shaped slightly raised spots on leaf uppersurfaces, and pale-brown superficial stains on rind. ***Mineral oils*** added to sprays may cause more severe injury with ***tear staining*** on fruit. Too high a rate or too frequent applications of ***petroleum oils sprays*** may reduce fruit quality and blossom. ***Insecticide emulsion sprays*** may blemish fruit. ***Dimethoate*** (Rogor®) may injure Seville orange, kumquat, Meyer lemon.

Others: ***Creasing or puffing*** causes irregular groves on rind and the collapse and sinking of tissue beneath. Occurs in Washington navel oranges and late Valencia oranges. It may be associated with ***over-maturity***, but its precise cause is unknown. Affected fruit are more liable to *Pencillium* moulds. ***Dry fruit, or granulation*** is the hardening of the walls of the juice sacs and the presence of air between them. Occurs on Valencia orange and Ellendale mandarins. ***Favoured*** by ***over-mature fruit*** on young vigorous trees. Earlier picking avoids losses. ***Oleocellosis*** is caused by ***slight rind damage*** which causes oil to stain tissue. In green fruit, areas around the oil glands, are round and slightly sunken. As ***fruit*** ripens, spotted areas remain ***green***. Injury on ripe fruit is irregular in shape and brown. ***Fruit*** on trees lightly injured by wind may also develop oleocellosis. Do not pick fruit when it is wet with rain or dew as oil cells may rupture. ***Paper nest wasps*** (*Polites* spp.) and ***webbing spiders*** (*Ixeuticus longinquus*) may annoy pickers.

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NSW Agfacts

Abnormalities in Citrus
Annual Citrus Management Program Sunraysia
Brown Spot of Mandarin
Chemical Control of Weeds in Citrus
Citrus Black Spot
Citrus Blast
Citrus Budwood Scheme
Citrus Establishment
Citrus Gall Wasp
Citrus Industry in NSW
Citrus in the Garden
Citrus Leaf Miner
Citrus Mould Control with Benzimidazole Fungicides
Citrus Mould Control with SOPP and Diphenyl
Citrus Nutrition
Citrus Petroleum Spray Oils
Citrus Rootstocks
Citrus Scale Insects
Citrus Soil Management
Citrus Spray Guide : Coastal Districts
Keeping Limes Green in Storage
Inland Citrus Irrigation Techniques & Developments
Iron and Zinc Deficiencies in Citrus
Lemon Growing
Lemon Scab
Lime Growing
Magnesium and Manganese Deficiencies in Citrus
Mandarin Growing
Mechanical Rind Damage in Citrus Fruit
Melanose of Citrus
Mite Pests of Citrus
Orchard & Vineyard Plant Protection Guide for Inland NSW
Phytophthora Diseases of Citrus
Septoria Spot of Citrus
Spined Citrus Bug
Sudden Death of Citrus

SA Fact Sheets

Citrus Leaf Analysis
Citrus Nematode on Citrus
Comparing Citrus Rootstocks
General Pests of Citrus
Oils for Red Scale Control
Pests of Citrus : Brown Garden Snail
Practical Control of Citrus Rind Disorders

Vic Agnotes

Alternate Bearing of Valencia Orange
Aphid Pests of Peaches, Cherries and Citrus
Biological Control of Red Scale on Citrus
Citrus and Avocado Kit
Citrus Blast
Citrus Butterfly
Citrus Collar Rot
Citrus Diseases : Anthracnose, Pit & Septoria Spot
Citrus Gall wasp
Citrus in the Home Garden
Citrus Leaf Analysis
Citrus Nematode on Citrus
Citrus : Non-Parasitic Disorders
Citrus : Pests, Diseases and their Control
Citrus Pests : Whitefly and Small Citrus Butterfly
Citrus Pit
Collar Rot
Controlling Snails in Citrus & Vines
Hedging and Skirting of Citrus
How to Collect Samples : Nematode Analysis Groves & Vines
Lightbrown Apple Moth in Orchards
Long-tailed Mealybug on Vines and Citrus
Magnesium Deficiency in Citrus
Maturity of Citrus
Nematodes in Horticultural crops in the N. Mallee
Non-Parasitic Disorders of Citrus
Postharvest Mould Control in Citrus Fruit
Propagation of Citrus
Red and Yellow Scale of Citrus
Sources of Propagating Material for Citrus
The Control of Fruit Drop and Rind Ageing in Navel Oranges, Grapefruit and Mandarins

WA Farmnotes

Brown Rot of Citrus
Citrus Fruit Splitting in Autumn
Citrus Leaf Miner

Associations, Journals etc.

Australian Citrus News
Australian Citrus Exporters Assoc.
Australian Citrus Growers Federation (ACGF)
Australian Citrus Improvement Assoc.
Australian Citrus Industry Council (ACIC)
Australian Citrus Processors Assoc. (ACPA)
Australian Citrus Propagation Assoc.
Australian Fruit Juice Assoc. (AFJA)
Central Coast Citrus Growers Assoc.
Citrus Board of SA
Citrus Industry Council
National Citrus Packers Assoc (NCPA)
National Citrus Research Liaison Committee
Queensland Citrus Bulletin (Qld DPI)
Riverina Quality Management Program (RQM)
Various Regional Citrus Growers Assoc.

See Fruit and nuts F 15, Preface xii

Remember, always check for recent references

MANAGEMENT

Citrus fruits, especially oranges, are ***one of the world's major fruit crops***. There are so many different types of citrus it is not possible to generalise. An overview of the industry has been presented by Coombs (1995).

Selection

Citrus are grown for fresh fruit, dried fruit, fruit juice, essential oils and for ornamental purposes, eg in containers. ***Horticultural requirements:*** Citrus are ***generally self-fertile***; an exception is some mandarins which will set more and produce larger fruit if cross-pollinated by other mandarin varieties (Baxter and Tankard 1990). ***Rootstocks and scion*** must be ***compatible***. Choose varieties which produce the ***required product quality*** for the ***proposed market***. ***Resistant varieties:*** ***Select rootstocks*** with some ***tolerance*** to relevant problems, eg tristeza, exocortis and xyloporis viruses, citrus nematode, salt, cold, available pHs and *Phytophthora;* also suitability to chosen soils, mycorrhiza dependency (*Glomus* spp.). ***Plant quarantine:*** It is an offence under various plant diseases acts to move citrus trees and propagation material to prevent the spread of viruses diseases, citrus gall wasp and other diseases and pests. ***Disease-free planting material:*** Selected budwood is obtainable from various Citrus Budwood Schemes. These buds are horticulturally sound and stable and have been indexed and are free from viruses.

Establishment/Maintenance

Pest monitoring is essential. Growers should monitor pests, parasites and predators and the damage caused, or employ a trained person to do so. New techniques of monitoring various aspects of citrus growth are being developed all the time, eg aerial colour infrared photography has been used to detect stress and growth (Blaasquez 1993). ***Scale insects are the most important pests*** of citrus, blemishing fruit and seriously harming trees. ***For home gardeners***, lemons are top of the list of problem plants, eg dying trees or fruit drop. ***Propagation*** is by budding on to seedling rootstock. ***Cultural methods:*** Match ***sites*** with the ***citrus varieties*** to be grown. Generally citrus prefer light sandy loam soils high in organic matter with a pH between 6.0-7.5. ***Heat*** is one of the prerequisites for ripening. Citrus trees ***do not tolerate frosts*** but some are more sensitive than others; the type of rootstock used also influences frost tolerance. Trees need good of ***air circulation*** but must be protected from strong winds; they require ***moisture*** throughout the year but must have good drainage. Trees need plenty of ***light***. As tree size varies depending on species and rootstock, adequate ***space*** must be provided. ***Sanitation:*** Recommended sanitation practices, eg skirting trees, controlling dust, must be carried out. ***Biological control:*** There are many parasites and predators available for the control of citrus pests (Broadley and Thomas 1995, Brough et al. 1994, Swaine et al. 1991). ***Pesticides/Pest management:*** Management guides containing recommendations for disease, pest and weed control and growth regulators are available for commercial growers and home gardeners for the various citrus growing regions of Australia.

Postharvest

Harvest: Colour does not indicate maturity. Key factors for ***processors*** include soluble solids content of the fruit, juice yields and sugar:acid ratios. ***Plant quarantine:*** Postharvest disinfestation of citrus for export may be required, eg for Fuller's rose weevil. ***Storage:*** Generally citrus fruit are stored in a cool, dry place or refrigerated. The Australian Horticultural Corporation ***(AHC)*** encourages citrus packing houses and growers to obtain ***accreditation*** in the Australian Horticultural Quality Certification Schemes ***(AHQCS)***. Companies can be certified by the National Association of Testing Authorities ***(NATA)*** as operating a management system which complies with requirements of the ***Australian Standard*** (AS/NZ ISO 9002:1994) (Coombs 1995).

Fig. 114. Scab, lemon scab (*Sphaceloma fawcetti*). Dept. of Agric., NSW.

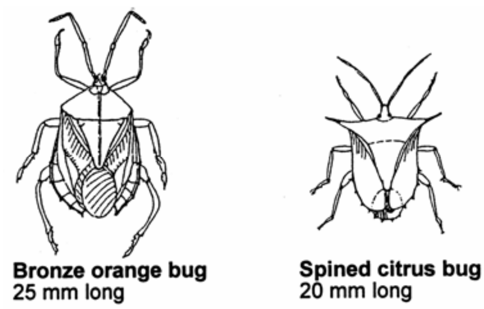

Fig. 115. ***Left*** *:* Bronze orange bug (*Musgraveia sulciventris*). ***Right*** *:* Spined citrus bug (*Biprorulus bibax*).

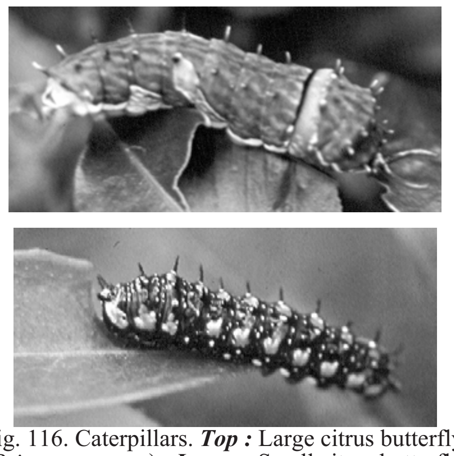

Fig. 116. Caterpillars. ***Top :*** Large citrus butterfly (*Princeps aegeus*). ***Lower :*** Small citrus butterfly (*Eleppone anactus*). Dept. of Agric., NSW.

Fig. 117. Galls caused by the citrus gall wasp (*Bruchophagus fellis*).

Fig. 118. Leaf mines caused by the citrus leafminer (*Phyllocnistis citrella*). Ampol Rural, Australia.

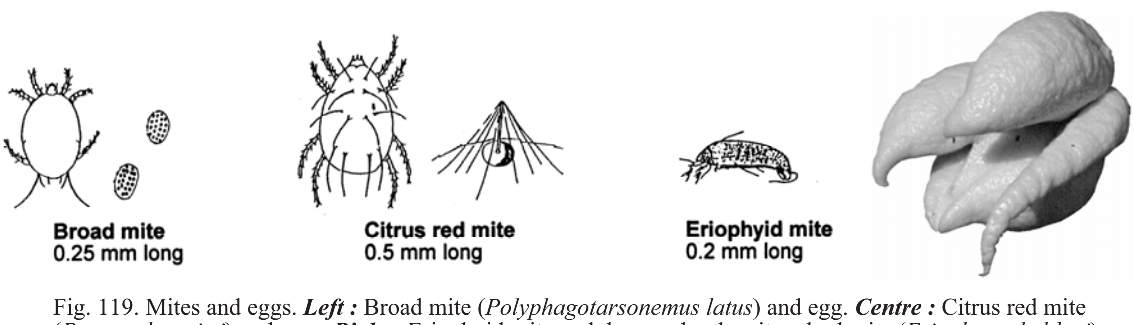

Fig. 119. Mites and eggs. ***Left :*** Broad mite (*Polyphagotarsonemus latus*) and egg. ***Centre :*** Citrus red mite (*Panonychus citri*) and egg. ***Right :*** Eriophyid mite and damage by the citrus bud mite (*Eriophyes sheldoni*).

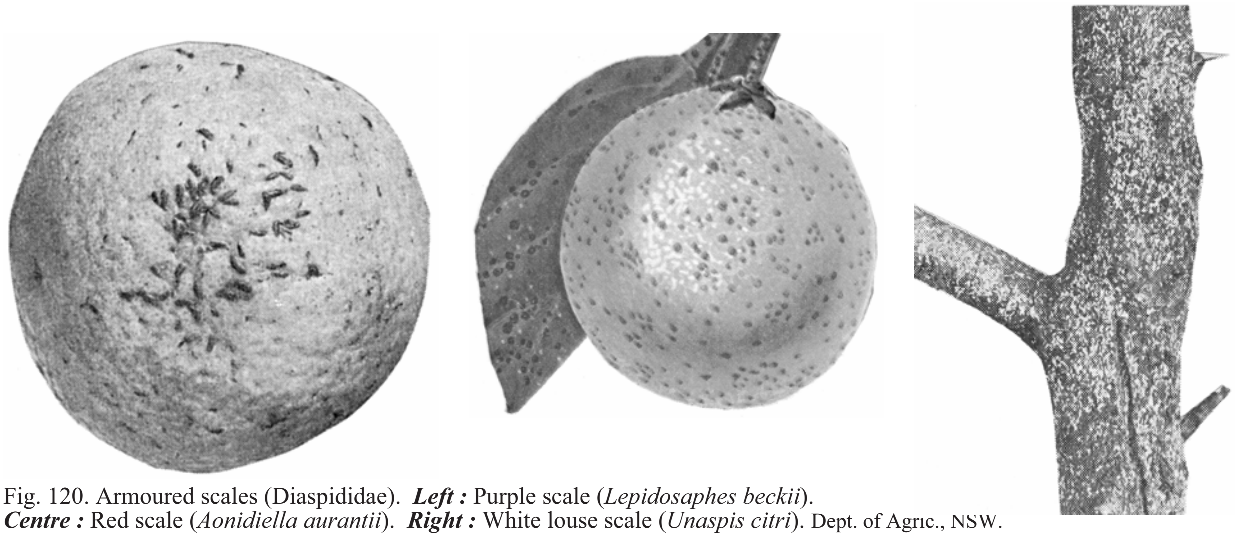

Fig. 120. Armoured scales (Diaspididae). ***Left :*** Purple scale (*Lepidosaphes beckii*).
Centre : Red scale (*Aonidiella aurantii*). ***Right :*** White louse scale (*Unaspis citri*). Dept. of Agric., NSW.

Fig. 121. Scales (Margarodidae). Cottony cushion scale (*Icerya purchasi*). Dept. of Agric., NSW.

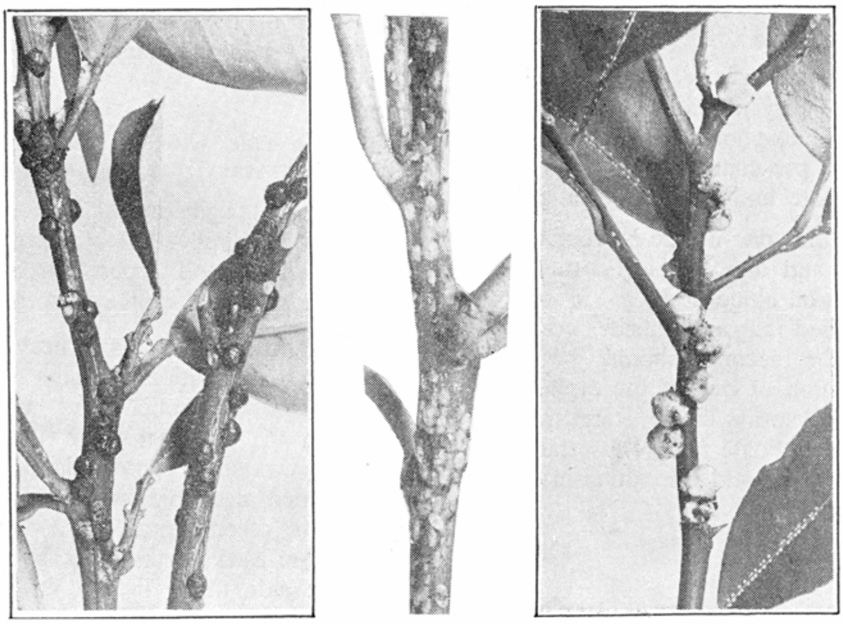

Fig. 122. Soft scales (Coccidae). ***Left :*** Black scale (*Saissetia oleae*). ***Centre :*** Soft brown scale (*Coccus hesperidum*). ***Right :*** White wax scale (*Ceroplastes destructor*). Dept. of Agric., NSW.

Fig. 123. Nutrient deficiencies. ***Left :*** Iron deficiency. ***Centre :*** Magnesium deficiency.
Right : Zinc deficiency. Dept. of Agric., NSW.

Currants

Ribes spp.
English gooseberry (*R. grossularia*)
Black currant (*R. nigrum*)
Red currant (*R. sativum*)
White currant (*R. rubrum*)
Family Saxifragaceae

Often known as bush fruits to distinguish them from trailing berries (*Rubus* spp.)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas ***cucumber mosaic virus*** (transmitted by at least 6 species of aphids) and ***gooseberry vein banding virus*** (transmitted specifically by currant and gooseberry aphids) may affect currants and gooseberry respectively. ***Black currant reversion*** (now not thought to be a virus or virus-like disease) is not known to occur in Australia. See Fruit F 4, Currants F 49.

BACTERIAL DISEASES

Crown gall (*Agrobacterium tumefaciens*) may develop on ***cuttings***. See Stone fruits F 125.

FUNGAL DISEASES

Fungal leaf and cane spots: ***Septoria leaf spot*** (*Septoria ribis*) is the most ***important disease*** of currants in Australia during wet weather in spring and summer. Grey angular spots with purple margins develop on ***leaves***, which may brown and fall early. Spots develop on ***canes***. ***Fruit*** may be infected and fall, reducing yields for the current and next season. Spray at budburst, preventative sprays may be essential in wet weather. ***Mycosphaerella grossulariae*** affects English gooseberry. See Annuals A 5.

Grey mould (*Botrytis cinerea*) affects flowers, fruit, leaves, shoots and limbs of English goose berry and currants during wet weather. ***Leaves*** wilt, turn brown and fall, leaving limbs bare. ***Twigs and limbs*** in turn are attacked and the plant dies. ***Flowers and fruit stalks*** affected during flowering die rapidly. ***Green and ripe fruit*** develop a brown rot that becomes covered with masses of dry greyish spores. Ripe fruit can be infected by touching a dead petal, the ground or dead leaves. Severely affected bushes may be completely removed, and all leaves and branches burnt. ***Fungicides*** during blossoming and fruiting are usually required. See Fruit F 5, Greenhouses N 22.

Powdery mildew, American gooseberry mildew (*Sphaerotheca mors-uvae*) infects gooseberry and black currants (overseas also red currants) during spring, winter and autumn. ***Leaves and shoots*** develop white powdery patches during spring, which turn brown with age, stunt the plant and reduce crop production. Leaves and shoot tips may become distorted. Tips of shoots may die, reducing fruiting wood for the following year and facilitating invasion by other fungi. After leaf fall, infected shoots, remain covered with a brown felt-like fungal growth. ***Infected fruit*** may be distorted and unmarketable. ***General:*** Lower parts of bushes are affected first. Shoots and berries of gooseberries can be severely infected. Infection on black currant in the field is less severe than that on gooseberry. Overseas losses on black currants are mainly due to restricted shoot growth which hinders flower and consequently fruit production in the following year. Direct berry infection is only a minor cause of crop loss on black currant. ***Control is difficult.*** Minimise nitrogenous fertiliser to prevent soft lush shoots which are ***very susceptible*** to disease. ***Prune bushes*** to improve air movement and reduce humidity, prune out and burn infected shoots in autumn to reduce overwintering lesions. ***Plant powdery mildew-free transplants,*** treat gooseberry transplants before planting to prevent the introduction of mildew into new areas. If there are no nearby sources of infection, plantings could remain free from mildew indefinitely. ***Fungicide*** sprays during the growing season protect developing fruit and limit carryover into next season. The need for later sprays depends on the weather. ***Growth regulators*** which retard shoot growth are being researched to provide partial control on gooseberry. Dormant sprays have been used overseas to reduce the amount of overwintering powdery mildew on black currant. See Annuals A 6.

Root rots, wilts

Armillaria root rot (*Armillaria* sp.) may occur on English gooseberry. See Trees K 4.

Ashy stem blight, charcoal rot (*Macrophomina phaseolina*) also occurs on English gooseberry. ***Branches*** are attacked one by one, leaves turn yellow, fruit stops growing, leaves fall, ***bushes die***. Roots do not seem to be affected. Rot is favoured by reduced vigour due to inadequate or ineffective irrigation or boron deficiency. See Vegetables M 7.

Verticillium wilt (*Verticillium dahliae*) may affect English gooseberry. See Vegetables M 9.

See Fruit F 7, Vegetables M 7.

Others: ***Dieback*** (*Botryosphaeria ribis*) on English gooseberry, ***wood rot*** (*Nectria cinnabarina*).

NEMATODE DISEASES

Foliar nematodes, leaf and bud nematodes (*Aphelenchoides* spp.) infest some varieties of black currants and can be ***spread*** on cuttings. They cause ***buds*** to blacken inside and shrivel. See Ferns E 2.

Others: ***Root knot nematode*** (*Meloidogyne hapla*), ***root lesion nematode*** (*Pratylenchus* spp.) and ***stunt nematode*** (*Tylenchorhynchus* sp.).

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Sowthistle aphid*** (*Hyperomyzus lactucae*), infests currants and gooseberry and spreads ***virus diseases***. Infested ***leaves*** are down-curled and ***shoots*** stunted. At least 6 other species may be ***serious pests*** of currants and gooseberries overseas. See Roses J 4.

Caterpillars (Lepidoptera)

Currant borer moth (*Synanthedon tipuliformis*) caterpillars tunnel in ***stems*** (see below).
Currant bud moth (*Stathmopoda chalcotypa,* Oecophoridae) caterpillars tunnel in ***buds***, also in rust galls on *Acacia decurrens*.
Lightbrown apple moth (*Epiphyas postvittana*) caterpillars may roll up and chew ***leaves and fruit clusters***. See Annuals A 8, Pome fruits F 112.

Currant borer moth (*Synanthedon tipuliformis,* Sesiidae, Lepidoptera) is the ***major pest of currants*** (*Ribes* spp.), especially blackcurrant, gooseberry, raspberry, also persimmon, hazel, elder, juniper, overseas also sumac and black elder. ***Moths*** look like small wasps about 12 mm long, with black bodies, yellow bands across the abdomen and clear wings. There is a fan-shaped mass of black hair-like scales at the tip of the abdomen. ***Caterpillars*** have a yellowish body and dark brown head and are up to ***20 mm*** long. Caterpillars tunnel in ***canes*** in spring (Fig. 124). Leaves yellow, and ***small young shoots die***. Infested canes usually die within 2-3 weeks. Severely attacked plants may have ***many dead canes***. Burrows may run nearly the entire length of the cane, partly in the pith and partly in the wood. Stems break easily in strong winds or when work is being carried out on the plants. Yield is lowered. ***Pest cycle:*** Complete metamorphosis (egg, caterpillar, pupa, adult) with 1 generation each year. Moths emerge from September onwards and each female lays about 60 eggs on new growth close to a bud or young shoot. ***Caterpillars bore into canes*** (either by chewing through new buds or by crawling through holes left by emerging moths). Inside stems they feed during spring and summer ***on the pith*** and may bore down into the ***main root***. In spring they chew a circular exit hole through the side of the cane. They cover the hole with a silken web and pupate inside the burrow a short distance from this exit hole. They emerge through the hole as moths. ***Overwinter*** as caterpillars inside canes a short distance above the ground. ***Spread*** by moths flying, and movement of infested canes. ***Control is difficult:*** Before moths emerge in spring ***prune out*** infested canes, which are weak and sickly, close to the ground and burn. Moths and caterpillars appear to have few ***natural enemies***. A ***nematode*** (*Steinernama bibionis*) has been found to enter the bodies of caterpillars and make its way into the bloodstream where it releases bacteria which cause septocaemia. The caterpillars die and nematodes reproduce in the corpses. Borer-infested currant cuttings may be disinfested by spraying with these nematodes and storing for 2 days. New plantations can be established that are relatively ***borer-free***. If new plantings are not near infested plantations they may stay free from borer infestation for many years. Difficulties include weather and developing suitable spray equipment. Mating disruption techniques using ***pheromones*** is being trialed (Coombs 1995). As caterpillars feed internally, control with ***insecticides*** is difficult.

Mites (Acarina)

Currant bud mite, currant gall mite (*Cecidophyopsis ribis*, Eriophyidae) infests blackcurrants and hazel. ***Adult mites*** are microscopic, cigar-shaped and feed on buds during winter. ***Buds*** swell (Fig. 125) to about twice the size of normal buds (big bud), dry out and may produce small distorted leaves. ***Canes*** may die or develop abnormally. Mites ***overwinter*** inside buds; early in spring they move out to feed on new leaves and flowers. Mites are ***spread*** by wind, and by the movement of infested nursery stock and plant material. Prune off swollen buds when observed in spring. Varieties with hairiest leaves are least affected. ***Resistant varieties*** are being developed. Miticides may be applied just before bud burst and after flowering. Overseas this mite transmits ***reversion disease*** (cause undetermined) which causes black currant bushes to become ***sterile*** (Traijkovski and Anderson 1993). See Grapevine F 62.
Twospotted mite (*Tetranychus urticae*) may infest ***leaves***, which mottle, bronze, wither and fall. Dense webbing may be produced on ***leaf undersurfaces***. Bushes lose vigour. See Beans (French) M 29.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***San Jose scale*** (*Quadraspidiotus perniciosus*) may infest all parts of English gooseberry and when numerous, form silvery-grey discoloured areas. Bushes lose their vitality and may ***die***.
Soft scales (Coccidae)
Brown gooseberry scale (*Eulecanium tiliae*)
Frosted scale (*E. pruinosum*)
Soft brown scale (*Coccus hesperidum*)

See Citrus F 39, F 41.

Plague thrips (*Thrips imaginis*) feed in ***flowers*** and cause distorted ***fruit***. See Fruit F 12, Roses J 6.

Weevils (Curculionidae, Coleoptera)***:*** ***Black vine weevil*** (*Otiorhynchus sulcatus*) may damage ***stems***. See Grapevine F 63. ***Gooseberry weevil*** (*Ecrizothis inaequalis*).

Others: ***Driedfruit beetles*** (*Caprophilus* spp.), ***leafhoppers*** (Cicadellidae, Hemiptera) and ***wingless grasshopper*** (*Phaulacridium vittatum*).

SNAILS AND SLUGS

Snails and slugs may damage currants and English gooseberry. See Seedlings N 70.

VERTEBRATE PESTS

Birds are a ***major pest*** of English gooseberries. They damage both buds and fruit. Birds also attack currants. See Fruit F 13.

Non-parasitic

Environment: ***Frost*** may damage flowers and young fruit. Provide adequate ***irrigation*** during summer. Bush fruits have shallow roots and readily suffer from water stress. ***Wind*** may damage new growth of currants and gooseberries in early summer. Avoid hot winds which dry berries out rapidly, but provide enough air circulation to prevent disease. Strong, hot ***sun*** will damage fruit.

Others: ***Premature shedding*** of black currant fruit causes ***severe losses***. The reason for the shedding is unknown.

Remember, always check for recent references

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State/Territory Departments of Agriculture/Primary Industry eg

American Gooseberry Mildew (Vic Agnote)
Black Currants (Vic Agnote)
Black Currants for the Home Garden (Vic Agnote)
Currant Borer Moth (Vic Agnote)
Currant and Gooseberry Aphids (Min. of Agric., Fish and Food, HMSO, UK)
English Gooseberries (NSW Agfact, Vic Agnote)
Gooseberries and Currants (NSW Agfact)
Insect Pests of Berry Fruits (NSW Agfact)
Nuts, Berries and Speciality Fruits Kit (Vic Agnote)
Orchard Spray Calendar, Agdex 203/604. Riverina/Young (Griffith)
Red Currants (Vic Agnote)
Reversion Disease and Gall Mite of Black Currant (Min. of Agric., Fish. and Food, HMSO, UK)
Southern Tablelands Calendar (NSW Agric)

See Fruit and nuts F 14

MANAGEMENT

Only black currants and English gooseberries are marketed commercially for the fresh fruit market. An overview of the industry has been presented by Coombs (1995). They are graded according to colour and size, and packed and marketed like strawberries, in punnets. The main market for black currants is for juice, jams and jellies. Black, red and white currants and English gooseberries produce a good crop only if temperatures are low for long periods in winter (chilling requirement). ***Propagation*** is by cuttings. Currants, if well cared for, will continue producing well for many years. English gooseberries may continue bearing for 50 years or more. To avoid *Verticillium* wilt do not plant gooseberries in soil previously planted with cherry, tomato, potato or infected raspberries or strawberries, otherwise ***pre-plant treat*** the soil. Control perennial ***weeds*** prior to planting and during the life of the plantation. Cultivation can damage shallow roots of currants and English gooseberry. Both require adequate ***irrigation*** during summer. ***Prune*** to encourage new growth each season and to remove canes killed by the currant borer moth, and diseased wood. Black currants ***fruit only*** on the previous year's growth, so that canes > 2 years old should be cut off. Red currants and English gooseberries fruit on canes produced in the previous year or on spurs of old wood. On red currants a mixture of 1-3 year old wood should be maintained. Keep plantation ***free of plant debris*** on which grey mould and other diseases can multiply. ***Growth regulators*** are used on currants for advancing maturity, improving fruit set and yield, and increasing size. The introduction of bees at flowering may improve pollination.

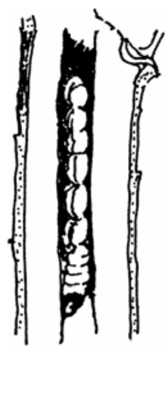

Fig. 124. Caterpillar (up to 20 mm long) of the currant borer moth (*Synanthedon tipuliformis*).

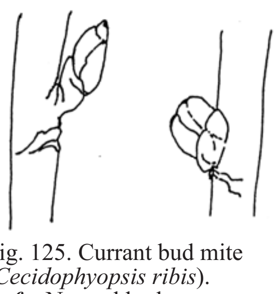

Fig. 125. Current bud mite (*Cecidophyopsis ribis*).
Left : Normal bud.
Right : Infested swollen bud

Custard apple

Annona spp.
Atemoya, Queensland custard apple (*A. atemoya*)
Cherimoya (*A. cherimola*)
Family Annonaceae

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial wilt (*Pseudomonas solanacearum*) is a ***common cause of death and decline*** of custard apple trees in late spring. Trees ***< 3 years*** old may wilt and die suddenly in summer. Examination of the trunk and root system just below ground level often reveals dark internal discolouration of the ***vascular tissue***. Older affected trees decline over 1-2 seasons and eventually die. ***Avoid*** inter cropping custard apple trees with susceptible annual crops during orchard establishment and control Solanaceous weeds and other weed hosts. ***Between rows*** maintain weed-free grass sod. ***Along rows*** between plants, control weeds with mulch or herbicides. Ensure adequate ***surface drainage*** and avoid waterlogging. Select rootstock with some ***resistance*** to bacterial wilt and plant ***disease-free grafted trees***, propagated in disease-free (treated) potting mix, in disease-free soil. See Tomato M 98, Vegetables M 5.

FUNGAL DISEASES

Damping off: ***Pythium root rot*** (*Pythium splendens*), ***rhizoctonia stem rot*** (*Rhizoctonia solani*), ***sclerotium stem rot,*** base rot (*Sclerotium rolfsii*). ***Rootstock seedlings and scion cuttings*** may suffer from root rots when grown in unpasteurised soil or if untreated water is used for irrigation. See Seedlings N 66.

Fruit rots: Some fungi which rot ***fruit***, may also cause ***leaf spots*** and ***stem cankers***, resulting in dieback:

Anthracnose (*Colletotrichum gloeosporioides*) and glomerella fruit spot (*Glomerella cingulata* var. *minor*) damage fruit ***postharvest***. See Fruit F 5.

Black canker (*Phomopsis annonacearum*) is a minor disease in Qld. ***Purple spots*** and later large blotches develop on ***fruit***. Cracks develop, but rotting does not penetrate deep into the flesh. ***Leaves*** may have marginal scorch. Damage may be confused with that caused by ***fruitspotting bugs***. Control is not usually required.

Cylindrocladium fruit rot (*Cylindrocladium colhounii*) causes ***leaf and fruit spots*** about 1 mm across, especially on African Pride. Spots on fruit often enlarge, causing cracking. Juice may run down the outside.

Diplodia fruit rot, dieback (*Lasiodiplodia theobromae*) causes dieback of ***young twigs*** as well as deeper rotting of the ***fruit***, especially on ***neglected trees***. Small black spots expand rapidly and become hard and cracked. External symptoms are similar to those of black canker. Internal discolouration and rotting extends into the fruit, making it look corky. Affected fruit usually ***mummify*** and remain on the tree.

Pseudocercospora fruit spot (*Pseudocercospora* sp.) causes small grey spots 1-5 mm across in the natural indentations on the ***fruit surface***. Spots join together, cracks may form. ***50%*** of fruit may be unsaleable.

Purple blotch (*Phytophthora palmivora*) affects custard apple and papaw, causing excessive fall of small immature ***fruit*** from lower branches. Many have ***small purple spots*** on the ***skin***. Affected fruit are usually brown internally prior to fall. Diseased sections of the fruit do not become hard as they do in black canker and diplodia fruit rot and the advancing edge of the affected area is indistinct. This fungus may also cause a ***leaf spot*** and ***twig dieback***. The disease is easily confused with damage caused by fruitspotting bugs. ***Overwinters*** in soil. ***Favoured*** trees growing in bare soil. Mulching bare soil under and between trees and raising tree skirts to keep fruit above the reach of soil splash will usually provide control. See Fruit F 7, Trees K 6.

Rhizopus soft rot (*Rhizopus stolonifer*) is a minor ***postharvest*** disease. See Fruit F 6.

Overwinters on infected crop debris, eg infected leaves, twigs, mummified fruit under trees, and sometimes in the soil. Spores are ***spread*** by wind and rain splash, lower fruit are more often affected. ***Favoured*** by humid conditions. ***Pruning*** the lower limbs and mulching will reduce the risk of fruit infection. ***Control weeds*** under trees, remove and destroy mummified fruit and dead twigs before fruiting commences. See Fruit F 5.

Root and collar rots, wilts

Armillaria root rot (*Armillaria luteobubalina*) can cause serious losses of ***trees*** in affected orchards. It affects trees of all ages, causing slow decline, then death. See Fruit F 7, Trees K 4.

Phytophthora root and collar rot (*Phytophthora* spp., *Phytophthora cinnamomi*) is a minor disease of custard apples. See Fruit F 7, Trees K 6.

Others: ***Fusarium root rot*** (*Fusarium solani*), ***pythium root rot*** (*Pythium* spp.), ***verticillium wilt*** (*Verticillium dahliae*).

See Vegetables M 7.

Wood rots: ***Pink limb blight***, pink disease (*Corticium salmonicolor*) causes patches of pale pink fungal growth along ***twigs and limbs***. Bark on infected limbs cracks and exudes gum. Where limbs are girdled, they wilt and die. See Trees K 8.

NEMATODE DISEASES

Nematodes on custard apple (*Annona squamosa*):
Burrowing nematode (*Radopholus similis*)
Dagger nematode (*Xiphinema americanum*)
Spiral nematode (*Helicotylenchus dihystera*)
Also *Criconema mutabile*
See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera) feed on foliage:

Orange fruitborer (*Isotenes miserana*) caterpillars ***roll leaves*** and may feed on the ***surface of fruit*** near stems. Caterpillars usually ***enter fruit*** near the stalk or where 2 fruits touch. See Citrus F 37.

Swallowtails (Papilionidae): ***Blue triangle butterfly*** (*Graphium sarpedon choredon*) may damage young trees. Caterpillars eat holes in ***leaves*** and occasionally damage ***fruit***. Fly parasites are common. ***Palegreen triangle butterfly*** (*Graphium eurypylus lycaon*) caterpillars are attractive, smooth velvety green, yellow or brown and feed on ***foliage*** of young trees, and occasionally ***fruit***. See Citrus F 36.

Yellow peach moth (*Conogethes punctiferalis*) is a ***sporadic problem*** particularly on Pink's Mammoth. Caterpillars damage ***fruit*** by eating and tunnelling in flesh. Webbed larval droppings occur around the entry hole in the skin. Damaged fruit are unmarketable. Infestation is usually noticed on maturing fruit in mid-late autumn. Picking up and destroying dropped infested fruit helps reduce moth populations. A ***fly*** (*Argyrophylax proclinata*) is an important ***parasite***. If ***insecticides*** are to be used they should be applied as soon as the pest is detected, ensure coverage of fruit. See Stone fruits F 133, F 137 (Fig. 166).

Caterpillars of the blue triangle butterfly and yellow peach moth and the damage they cause, can by ***monitored*** at regular intervals, before making a decision to apply an insecticide (Brough et al. 1994). See Annuals A 8, Fruit F 8.

Citrus mealybug (*Planococcus citri*) is a ***major pest*** of custard apples. Others, eg ***longtailed mealybug*** (*Pseudococcus longispinus*), may also infest custard apples. Mealybugs gather on ***fruit***, usually near the ***stalk***, also in ***skin depressions***. Mealybugs produce ***honeydew*** which encourages sooty mould and attracts ants, eg coastal brown ant (*Pheidole megacephala*), which tends the mealybugs for their honeydew, moves them around and fends off their natural enemies. Fruit touching the ground is often covered with dirt from ant activity. The mealybugs and sooty mould detract from the ***appearance of fruit***. Mealybugs are easily removed after harvest but sooty mould is not. ***Natural enemies*** include the predatory mealybug ladybird (*Cryptolaemus montrouzieri*) and lacewing (*Oligochrysa lutea*), and a parasitic wasp (*Leptomastix dactylopii*). Petroleum oil is only effective against young stages of mealybugs and does not disrupt natural enemies. ***Monitor*** mealybug populations and their predators and parasites. See Citrus F 38, Greenhouses N 25.

Elephant weevil (*Orthorhinus cylindrirostris*) is a minor and sporadic pest which chews pieces of bark from ***fruit stalks***, causing fruit drop. They also tunnel through the ***trunk and roots*** or chew around the base of ***leaf petioles*** causing leaf drop. If damage is obvious monitor weevil numbers prior to applying an insecticide (Brough et al. 1994). See Trees K 12, K 17.

Fruit flies (Tephritidae, Diptera) may damage ***fruit*** during March-May. African pride is ***more susceptible*** than Pink's Mammoth. Maggots feed in the flesh, making it inedible. One infested fruit can result in a whole consignment being rejected. When ***monitoring*** during March to May indicates that fruit fly numbers are high, control is advisable, especially in African pride. Use either baits or sprays. Insecticides may disrupt natural enemies. The Victorian Department of Agriculture requires that custard apples sent to Melbourne from September-April be dipped after harvest in an insecticide to ensure freedom from fruit fly. Special equipment is required. See Fruit F 9.

Fruitspotting bugs (*Amblypelta* spp., Coreidae, Hemiptera) are ***major pests*** causing dark spots on ***young fruit*** (often on the shoulders). On cutting open, deep internal damage is present. ***Do not confuse*** spotting bug damage with ***fungal diseases***, eg black canker, *Cylindrocladium* spot or *Diplodia*. ***Monitor*** bug damage. See Fruit F 10.

Soft scales (Coccidae, Hemiptera) produce honeydew which attracts ants, and encourages sooty mould. Trees look black.

Nigra scale (*Parasaissetia nigra*) is a leathery, oval, raised, black waxy scale about 5 mm long. Nymphs settle on ***young shoots***, along the midribs of ***leaves*** and on ***fruit*** Young scales frequently lodge on adult coverings. Common on young custard apple trees. ***Ants*** (mainly the coastal brown ant) feed on the honeydew and tend the scales closely. Scale is normally heavily ***parasitised*** by a small black wasp (*Scutellista cyanae*) but this is prevented by regular spraying for other pests or by ants. Heavily infested trees may be ***spot sprayed*** in early summer. Nymphs (crawlers) are more susceptible than adults, to ***oil sprays*** (do not apply if the temperature is > 30^{O}C). Control ants. Scales are easily dislodged so could be removed by hand.

Pink wax scale (*Ceroplastes rubens*) may settle along ***leaf midribs and twigs***, completely covering young growth. High populations cause premature leaf fall and reduce fruiting capacity. ***Natural enemies*** exert considerable control on mangoes, but insecticides may be required in late October/early March when crawlers are present. See Citrus F 41.

Others: ***Black scale*** (*Saissetia oleae*), ***long soft scale*** (*Coccus longulus*) and ***soft brown scale*** (*C. hesperidum*) A ***coccid scale*** (*Taachardina decorella*) resembles hard crusts on twigs. Control is often not warranted.

Fruit covered with sooty mould must be ***cleaned***. ***Monitor*** scale populations on twigs at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Citrus F 41.

Twospotted mite (*Tetranychus urticae*) may cause yellow stippling of ***leaves***. Predatory mites usually give adequate control so spraying is not necessary. See Beans (French) M 29).

Whiteflies (Aleyrodidae) may infest ***leaf undersurfaces***. See Greenhouses N 24.

Non-parasitic

Frost damages fruit. ***High temperatures*** and ***very low or very high humidities*** affect ***pollination*** of the flower either by breaking down pollen or drying out flowering parts (Passmore 1987). Partial pollination produces deformed or dropped-shoulder fruit. Hand pollination improves both the number of fruit and quality of individual fruit. Ripe fruit often show ***internal browning and grittiness*** or woodiness, the cause of which is not clear (Fitzell et al. 1994). ***Leaf analysis standards*** are available based on diagnostic and research analyses (Weir and Cresswell 1995).

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Weir, R. G. and Cresswell, G. C. 1995. *Plant Nutrient Disorders 2 : Tropical Fruit and Nut Crops.* Inkata Press, Melbourne.

State/Territory Departments of Agriculture/Primary Industry eg

Custard Apples : Cultural and Financial Aspects (NSW Agfact)

Custard Apples in the Garden (NSW Agfact)

Fertilising Custard Apples (NSW Agfact)

Associations, Journals etc.

Good Fruit and Vegetables

Sunshine Coast Subtropical Fruits Association

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Custard apple is a semi-deciduous, winter growing tropical and subtropical small tree, 5-7 m tall. It requires a warm climate with high humidity in summer. High humidity during the flowering period is necessary for a good fruit set. Hand pollination can be carried out if necessary. Trees are sensitive to cold and frost and are unsuited to hot, dry conditions. An overview of the industry has been presented by Coombs (1995). ***Resistant varieties:*** Select rootstocks resistant to bacterial wilt. African Pride is more tolerant of cold weather, bears fruit early and does not grow as tall as some other varieties. ***Disease-free planting material:*** Planting material must be free of bacterial wilt and other diseases and pests. Purchase from an accredited supplier.

Establishment and Maintenance

Propagation: By grafted plants, seeds are unreliable. ***Cultural methods:*** Plant in sheltered sites and protect from wind and frost. In early spring or summer plant in a well-drained site and do not overwater. Regularly fertilise to promote rapid growth in spring and summer. Prevent bacterial wilt and *Armillaria* root rot by careful site selection and land preparation. Initially ***prune*** back to 300-400 mm and develop a vase shape over the first 3-4 years. Custard apples bear fruit on new as well as old wood. They may take up to 7 years to produce the first fruit. ***Control weeds*** before planting by cultivation or herbicides. Young trees suffer most from grass and weed competition. Do not damage shallow or feeder roots near the tree by cultivation. Damage to the bark allows entry of diseases. Grass and weeds between tree rows are mown and areas under trees kept weed-free by hand weeding, mulching or by herbicides. Do not allow translocated herbicides to drift on to bark or foliage of trees < 2 years of age (protect trunk with strip of builder's foil or paint with white plastic paint). ***Biological control:*** Biological control agents are available for mealybugs and mites. ***Pesticides:*** ***Monitor*** caterpillars, fruit flies, fruit spotting bugs, scales and their damage, at regular intervals before making a decision to apply an insecticide (Brough et al. 1994, Sanewski 1991). Select the least disruptive sprays. The pest most likely to be a nuisance in a home garden is ***mealybugs*** but natural enemies will often keep them under control. Custard apples grown in home gardens usually do not need spraying.

Postharvest

Harvest fruit as soon as mature and before it starts to soften, otherwise fruit fly may be a problem. Clip from tree when edges of the segments change from greenish to cream, it may take a few days to soften for eating. ***Storage:*** Custard apples can only be stored for a short period.

Feijoa

Fruit salad tree, pineapple guava

Feijoa sellowiana
Family Myrtaceae (eucalypt family, myrtle family)

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Diseases are not a major problem in Australia. But ***damping off diseases*** (various fungi) occurs on cuttings, and ***root rots***, eg ***armillaria root rot*** (*Armillaria luteobubalina*) and ***phytophthora rot*** (*Phytophthora*), probably occur. ***Anthracnose*** (*Colletotrichum* sp.), ***blue mould*** (*Penicillium* spp.) and ***grey mould*** (*Botrytis cinerea*) cause ***fruit rots*** overseas.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Guava moth (*Coscinoptycha improbana*, Carposinidae) caterpillars bore into ***feijoa fruit***. See Guava F 67.

Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) feed on ***young leaves*** and developing ***shoots*** and join them together with silken threads. See Pome fruits F 112. ***Orange fruitborer*** (*Isotenes miserana*) caterpillars feed between ***leaves*** and bore into ripening ***fruit***. See Citrus F 37.

See Annuals A 8.

Fruit flies (Tephritidae, Diptera), eg ***Queensland fruit fly*** (*Bactrocera tryoni*), is the ***main problem*** in coastal areas, both in the ***field and postharvest***. Harvesting fruit before it is fully ripe, and ripening it indoors, helps to avoid infestation. See Fruit F 9.

Scales (Hemiptera)

Armoured scales (Diaspididae)
- Circular black scale (*Chrysomphalus aonidum*)
- Mussel scales (*Lepidosaphes* spp.)
- White palm scale (*Phenacaspis eugeniae*)

Soft scales (Coccidae)
- Chinese wax scale (*Ceroplastes sinensis*)
- Nigra scale (*Parasaissetia nigra*)
- Tessellated scale (*Eucalymnatus tessellatus*)

See Citrus F 39, C 41.

Non-parasitic

Environment: Feijoa are ***frost hardy*** and will tolerate temperatures as low as -7^{o}C. Although feijoas are ***drought resistant***, a good fruit crop will be produced only if summer irrigation is supplied. Feijoa do not like being waterlogged. Like citrus trees, feijoa have a comparatively ***shallow root system*** which should be mulched well with organic matter. Avoid cultivation under the plant to prevent surface root damage.

Nutrient deficiencies, toxicities: Feijoa seem to be sensitive to ***salt***. They are heavy feeders and for good yields need ***fertilising*** in spring and autumn. ***Excessive nitrogen*** will result in lush vigorous vegetative growth at the expense of fruit production.

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State/Territory Departments of Agriculture/Primary Industry eg
Feijoa (Adel. Bot. Garden Leaflet, Adelaide)
Feijoas (Vic Agnote)
Feijoas in the Garden (NSW Agfact)
The Feijoa or Pineapple Guava (Vic Agnote)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Feijoa may be grown as an ornamental plant or for fruit. Some varieties require ***cross pollination*** to obtain a good crop, eg Triumph, requires cross pollination with Mammoth. Mammoth is self-fertilising. Although Feijoia can be ***propagated*** by seed, seedlings are too variable for commercial planting. Plant ***scale-free*** grafted plants or cuttings from trees with good cropping records and high quality fruit, in well drained soil. ***Fertilise and irrigate*** appropriately to ensure a good crop. ***Prune*** young plants to remove suckers and low growth, and prune bearing trees to encourage new growth and reduce the number of minor branches and dead or diseased material. ***Harvest*** fruit from the tree when a few fruit start to fall. Pick the largest first, taking care not to bruise the tissue. Fruit are ready for eating in a few days. ***Store*** at 1^{o}C for about 6 weeks.

Fig

Ficus carica, Ficus spp.
Family Moraceae (mulberry family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Fig mosaic virus affects *Ficus carica, F. altissima, F. krishna* and *F. tsida* causing ***leaves*** to develop irregular yellowish-green blotches. Leaf tissue does not usually die and ***fruit*** may show spot-like markings and may drop prematurely. ***Spread*** by vegetative propagation, by fig blister mite (*Eriophyes ficus*), by grafting, not by mechanical transmission, not by seed. ***Do not propagate*** from infected trees. In California, White Ischia and Celeste are among the most susceptible (Smith 1972). In Australia, mosaic symptoms are commonly found on ***leaves*** of cultivated figs, it is possible that these are caused by fig mosaic virus. ***Tomato spotted wilt virus*** has been detected in *Ficus* sp. in Spain. See Fruit F 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Xanthomonas campestris* pv. *fici*) causes brown, angular ***leaf spots*** and leaf fall in the NT (Bodman et al. 1996). Also ***crown gall*** (*Agrobacterium* sp.). See Stone fruits F 125.

FUNGAL DISEASES

Fruit rots (various fungi and yeasts) attack ***fruit*** as they mature, during periods of wet weather, causing rotting and fermentation. ***Anthracnose*** (*Glomerella cingulata*) produces decayed spots on ripening fruits in storage. ***Aspergillus black mould*** (*Aspergillus niger*) causes a distinctive black mould, *Aspergillus* spp. are being researched for their association with ***mycotoxins*** in figs (Michailides and Morgan 1996). ***Phytophthora fruit rot*** (*Phytophthora palmivora*), prefers the white Adriatic variety, and may be controlled with fungicides. ***Pink rot, pink mould*** (*Trichothecium roseum*) causes a storage rot of fig, quince, pear, tomato. ***Other fruit rots:*** ***Brown rot*** (*Sclerotinia fructicola*), ***grey mould***, shoot blight (*Botrytis cinerea*), ***leaf and fruit spot*** (*Alternaria fici, Alternaria* sp.), ***rhizopus soft rot*** (*Rhizopus stolonifer*) and ***yeasts*** (*Saccharomyces* spp.). ***Various insects spread fruit rots***, eg ***driedfruit beetles*** (*Carpophilus* spp.) infest ripening figs and spread many rots, ***capri fig wasp*** (*Blastophaga psenes*) spreads ***fig endosepsis*** (*Fusarium* spp.) causing internal rot and other symptoms in California (Michailides et al. 1996). ***Fruit rots are difficult to control***. If wet weather persists it is unwise to harvest fruit. A return to sunny weather will permit harvest, provided trees have not been deprived of sunshine for too long. See Fruit F 5.

Fungal leaf spots other species).

Brown leaf spot (*Phyllosticta* sp.): Large brown spots up to 15 mm across develop on ***leaves***. Defoliation may result in poor quality fruit. More than 2-4 copper sprays may damage leaves and reduce fruit quality. Use fungicides which are ***not phytotoxic***.
Leaf spots (*Fusarium hypocreoiudeum* and *Phyllachora rhysatismoides*) may cause ***leaf blotches*** on native *Ficus* spp.
Others: ***Leaf and fruit spot*** (*Alternaria fici*), *Cercospora fici, Pseudocercospora* sp.

See Annuals A 5.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*), ***root rot*** (*Cylindrocladium scoparium*), ***phytophthora rot*** (*Phytophthora* spp., *P. palmivora, P. cinnamomi*) have been recorded on *Ficus* spp. (not necessarily *F. carica*). See Fruit F 7, Vegetables M 7.

Rust (*Cerotelium fici*): ***Leaf uppersurfaces*** have a brown speckled appearance. On the ***underside*** of the speckles, brown powdery spores are produced. Older foliage is attacked first. ***Affected leaves*** shrivel and fall. If defoliation occurs early in the season, fruit may be reduced in quality or may fall while immature. See Annuals A 7.

NEMATODE DISEASES

Dagger nematodes (*Xiphinema* spp.)
Foliar nematode (*Aphelenchoides fragariae*)
Citrus nematodes (*Tylenchus* spp.)
Spiral nematodes (*Helicotylenchus dihystera*)
Also *Coslenchus costatus, Filenchus exiguus, Heterodera fici, Ogma octangulare.*
See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Fig longicorn (*Acalolepta vastator,* Cerambycidae) infests native and cultivated figs (*Ficus* spp.), citrus, grapevine, passionfruit, wisteria, red cedar (*Toona australis*) and other plants. ***Beetles*** are yellow-grey, about ***30 mm*** long. The sides of the thorax are extended into spines, antennae in the male are 3 times the length of the body. ***Larvae*** are about ***40 mm*** long, whitish, glossy with a brown head and black jaws. Larva tunnel up or down for a metre or more in ***trunks, limbs and roots***. ***Tunnels are oval*** and tightly packed with frass. Branches may die. Sometimes larvae may be traced by the formation of hard lumps along infested branches (frass and gnawed wood mixed with gum). ***Oval exit holes*** of the adult are visible on trunks or limbs. There is a ***complete metamorphosis*** (egg, larva, pupa, adult) with 1 generation each year. In spring females lay eggs singly on rough bark and then gnaw a circular patch about 12 mm across around each egg. Young larvae eat their way into the ***wood***. Fully grown larvae pupate just under the bark in a small cavity at the end of their tunnel. ***Pupa*** are whitish and about 25 mm long. Adults emerge from September through ***oval exit holes***. ***Overwinters*** in trunks, limbs and roots of host plants as larvae. ***Great figtree borer*** (*Batocera boisduvali*) and *Rosenbergia megacephala* may also attack *Ficus* spp.

Large auger beetle (*Bostrychopsis jesuita*) ***larvae*** are thick, white, and have legs. They bore ***round tunnels*** in sap and heartwood of ***large branches and trunks***. Tunnels are filled with droppings and undigested wood particles. ***Round exit holes*** are seen on the ***trunk***. See Trees K 11.

Fruit-tree borer (*Maroga melanostigma*) caterpillars bore short tunnels in the ***forks of trees***. See Fruit F 10.

See Trees K 11.

Caterpillars (Lepidoptera)

Fig fruitborer (*Phycomorpha prasinochroa,* Copromorphidae) infests cultivated and wild fig. ***Moths*** are bell-shaped, about 18 mm across the outspread green wings which have brown flecks. ***Caterpillars*** are about ***12 mm*** long, cream and thickset. Caterpillars bore into ***green fruit*** to feed on pulp, into ***shoot terminals*** and sometimes into the midribs of ***leaves***. The entry point is visible as a mound of brown frass. ***Spread*** by moths flying. ***Favoured*** conditions in coastal districts in late summer and autumn. Spraying may be necessary.

Figleaf moth (*Talanga tolumnialis*, Pyralidae) caterpillars feed on native *Ficus* spp. but also damage ***foliage*** and ***flowers*** of cultivated figs in Qld and NSW.

Others: Caterpillars of > 10 species of moths and butterflies feed on native *Ficus* spp. (Common and Waterhouse 1981, Common 1990).

See Annuals A 8, Fruit F 8, Trees K 13.

Driedfruit beetles (*Carpophilus* spp., Nitidulidae, Coleoptera)

are ***serious pests*** of more mature ***fruit***, they also ***spread fruit rots***. See Fruit F 8.

Ferment flies, vinegar flies (Drosophilidae, Diptera)

may be ***important pests***. See Fruit F 8.

Fig bark beetle (*Aricerus eichhoffi,* Cucurlionidae, Coleoptera)

infests cultivated figs, Moreton Bay fig (*F. macrophylla*), Port Jackson fig (*F. rubiginosa*) and other native figs. ***Beetles*** are tiny, round, thick, red-brown and about ***1.5 mm*** long. They nibble ***bark and twigs***. ***Larvae*** are tiny, white and legless; they tunnel in ***terminal shoots,*** frass indicates entry points, twigs usually die. They pupate inside the tunnels. Beetles emerge through ***small circular exit holes*** near leaf axils. Control is difficult but repeated sprays in summer kills adults and prevents egg laying. See Trees K 10.

Figleaf beetles (*Poneridia australis, P semipullata,* Chrysomelidae, Coleoptera)

are pests of cultivated fruiting and ornamental figs (*Ficus* spp.) and native figs, eg Moreton Bay fig. ***Figleaf beetle*** (*P. semipullata*) has dull brown wing covers with reddish-brown thorax and head, and is about ***10 mm*** long (Fig. 126). *P. australis* is smaller. ***Larvae*** are about ***12 mm*** long, yellowish, becoming darker and look spiny. They feed in groups. Beetles and larvae skeletonise ***leaves***, which fall. ***Fruit*** attack exposes flesh. There is a ***complete metamorphosis*** (egg, larva, pupa, adult) with several generations each year. Female beetles lay eggs on leaves in groups of about 50. Fully grown larvae crawl down the trunk and pupate in the soil or in debris at the tree base. Beetles emerge about 2 weeks later and crawl up the tree to feed. Adults are strong fliers. ***Favoured*** mainly by summer rainfall climates in coastal areas, but they occur in north NSW. A ***shield bug*** (*Ceratulus nasalis*) may be an important predator. ***Inspect*** trees in spring before damage occurs and if adults or larvae or many egg masses are present, the foliage of cultivated figs will usually be severely damaged if a chemical control is not applied. On small trees egg masses may be squashed by hand. ***Others: Pumpkin beetle*** (*Aulacophora hilaris*) and ***redshouldered leaf beetle*** (*Monolepta australis*). See Trees K 15.

Fig leafhopper (*Dialecticopteryx australica,* Cicadellidae, Hemiptera)

infests cultivated figs. ***Adults*** are dark orange, about ***3-4 mm*** long with dark compound eyes. Three simple eyes (ocelli) appear as dots between the compound eyes. Wings are mainly clear. ***Nymphs*** are smaller, wingless, fragile and yellow with dark eyes. When disturbed they move sideways. Adults and nymphs suck sap mostly on the undersides of ***young leaves,*** from the midrib and larger veins. Rusty spots develop along the main veins. Leaves curl upwards and fall prematurely. Eggs are laid on leaves. Occurs in coastal districts during summer and autumn. ***Insecticides*** are used to control leafhoppers. See Vegetables M 15.

Flower chafers (Scarabaeidae), eg *Dilochrosis atripennis,*

are large strong flying ***scarab beetles*** which eat out pulp of ***ripening fruit*** during the day. Only the skin is left. See Fruit F 12.

Fruit flies (Tephritidae, Diptera)

may damage ***ripening figs*** in some seasons. See Fruit F 9.

Mites (Acarina)

Fig blister mite (*Eriophyes ficus,* Eriophyidae) is microscopic and infests ***leaves, buds, twigs*** and green and occasionally ripe ***fruit***. Mites occur in colonies, especially near the opening or 'eye' of figs. They cause rusty patches inside. See Grapevine F 62.

Fig rust mite (*Rhynchaphytoptus ficifoliae,* Rhyncha-phytoptidae) has a coating of white, waxy material. They feed in large numbers on ***leaf uppersurfaces***, giving them a rusty appearance, as well as on the ***bracts*** around the openings of the fruit receptacles. Control is not usually necessary.

Moreton Bay fig psyllid (*Mycopsylla fici,* Homotomidae, Hemiptera)

infests *Ficus* spp. especially Moreton Bay fig. They suck sap from ***leaf undersurfaces*** and become covered with the white sap oozing from puncture areas on the host and as this congeals, a blob (like old chewing gum) develops. Leaves may fall prematurely. Severe attacks may cause dieback. ***Spread*** on shoes, feet and picnic rugs. ***Control is difficult***. Small trees may be sprayed. Larger trees may be injected, but a special sleeve is needed because of the milky sap, and repeat treatments needed. See Eucalypt K 62, Trees K 16.

Scales (Hemiptera)

Armoured scales (Diaspididae)
Red scale (*Aonidiella aurantii*)
Ground pearls (Margodidae)
Cottonycushion scale (*Icerya purchasi*)
Soft scales (Coccidae)
Nigra scale (*Parasaissetia nigra*)
Soft brown scale (*Coccus hesperidum*)

See Citrus F 39, F 41.

Thrips (Thysanoptera): ***Cuban laurel thrips*** (*Gynaikothrips ficorum*) is a prominent ***black leafrolling thrips*** which infests *F. microcarpa* var. *hillii.* Eggs are laid in batches on ***leaf uppersurfaces***; the thrips pupate in the rolled leaves. Affected leaves can be pruned off and burnt, but follow up insecticide applications may be required. ***Thrips*** (Phaeothripidae) cause galls on *Ficus* spp. See Greenhouses N 24.

Others: ***Wasps*** are a general pest of figs. ***Capri fig wasp*** (*Blastophaga psenes, Agaonidae*) pollinates Capri fig to develop its special flavour and quality. ***Moreton Bay fig wasp*** (*Pleistodontes froggatti*). ***Metallic shield bug*** (*Scutiphora pedicellata*). Worldwide *Ficus* spp. is host to > 80 species of ***whiteflies*** (Aleyrodidae, Hemiptera).

VERTEBRATE PESTS

Birds are the ***worst pest of figs*** and can damage a large number of fruit. See Fruit F 13.

Non-parasitic

A sudden increase in water supply or humidity when fruit is near maturity may cause ***fruit splitting*** which favours fruit rots. Young trees are damaged by ***frost***, but when established they can withstand temperatures as low as -10^{o}C. Figs produce 2 crops/year (spring and autumn); autumn crops may not mature in cold areas. ***Sulphur and copper pesticides*** damage fig trees in hot weather. Fruit of white fig (*F. virens* var. *sublanceolata*) is ***poisonous*** to pigs (McBarron 1983).

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The Fig : Varieties and Culture (Vic Agnote)

See Fruit and nuts F 14

Remember, always check for recent references

MANAGEMENT

Figs have been prized for centuries for both medicinal and dietary value since ancient times. Today they are grown for fresh fruit and drying. Figs are adaptable to a wide range of climates but flourish on the more humid coast. Commonly grown figs in Australia do not need pollination; only the ***Smyrna fig*** requires pollination by the ***Caprifig*** to develop its species flavour and for this is requires the ***Capri fig wasp*** (*Blastophaga psenes*) as a pollinating insect (Baxter and Tankard 1990). ***Propagated*** by cuttings on their own roots. Seedling trees are more variable. ***Avoid acid soil***, provide good drainage and do not allow their shallow roots to dry out or be damaged by cultivation. Figs bear fruit on ***current season's growth***, so unless trees produce new growth each year, crops will be small. Cut back old trees or trees making poor growth in winter to encourage new growth. Trees usually form a well balanced framework so little pruning is needed. Fruit ripen over a long period and should be ***harvested*** every few days. Fruit may ferment on the tree in wet seasons. Fresh fruit for eating should be picked when mature, when the colour has changed and the skin gives slightly if pressed. Fresh fruit do not store well. ***Controlled atmosphere (CA) storage*** can extend shelf life of fresh figs by 2-3 weeks. For dried fruit, figs are left on the tree to develop fully before harvesting.

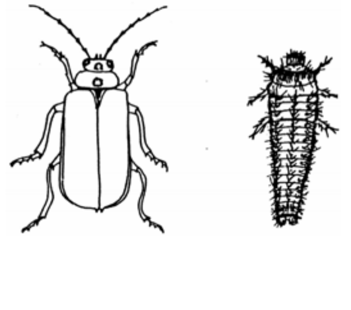

Fig. 126. Figleaf beetle (*Poneridia semipullata*). ***Left :*** Beetle (about 10 mm long). ***Right :*** Larva (about 12 mm long).

Grapevine

Vitis spp.
Family Vitaceae (vine family)

*Grapes are the world's most important fruit crop. In Australia, both the area planted and production is about 75% of all other fruit combined. Although there are many diseases and pests of grapes in Australia (Nicholas et al. 1994), the most destructive diseases affecting these plants, ie **black rot** (Guignardia bidwellii) and **Pierce's disease** (Xylella fastidiosa), do not occur in Australia.*

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Most virus diseases of grapevines only cause a gradual reduction in yield and fruit quality. Leaves and fruit are mainly affected. Symptoms are often only apparent during cool spring or autumn weather, later growth is symptomless.

Grapevine fanleaf virus (many strains) is widespread but not serious. ***Spread*** by vegetative propagation, by ***dagger nematode*** (*Xiphinema index*), which is known to occur only in north-east Victoria and south-east NSW, by mechanical inoculation, not by pollen, not by contact, rarely by seed. Leaves have yellow spots, and are distorted and fan-like. Vines of ***susceptible varieties*** may die. ***Yellow mosaic*** (a strain) causes a general yellowing of vines in late spring, many varieties show no symptoms.

Grapevine leafroll virus (several strains) ***is the most important virus disease of grapevines in Australia***, reducing yields of some varieties by up to ***50%***. ***Leaf margins*** roll downwards usually in late summer and most obviously in late autumn. Leaf blades thicken and foliage feels brittle. Main veins of leaves remain green, leaves of most red-fruiting varieties turn red between the veins, leaves of white-fruiting varieties yellow prematurely in autumn.

Grapevine yellows mycoplasma-like organism occurs mostly in Chardonnay & Reisling causing rubbery shoots with patchy yellow downward curled ***leaves and bunches*** that die at flowering.

Grapevine yellow speckle viroid is widespread and common on sultana and Waltham Cross and some other varieties. Small irregular yellow speckles occur along the main vein and veinlets. ***Leaves*** are speckled yellow.

Others: ***Grapevine enation virus*** causes ***leafy outgrowths*** from veins on leaf undersurfaces. ***Also*** grapevine veinclearing virus, stem pitting, vein necrosis, summer mottle, others occur overseas.

All viruses are spread by ***vegetative propagation material***, eg infected stocks (buds, grafts) or rootstocks. There are no known vectors of grapevine virus diseases in Australia. When establishing vineyards plant only recommended ***virus-tested planting material*** from vine improvement schemes. Because there are no known vectors in Australia (except for dagger nematode transmitting fanleaf virus in some areas), virus-tested vines will remain free from the viruses for which they have been tested for life unless they are reworked with infected material or there is root grafting, or if they are planted into soil infested with dagger nematodes. See Fruit F 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* spp.) is the only significant bacterial disease of grapevine. ***Galls*** as large as footballs develop on ***main stems*** at or below ***ground level***. See Stone fruits F 125.

Others: ***Bacterial leaf and stem spot*** (*Pseudomonas viridiflava*) is a minor disease unless wet weather occurs during flowering. Small yellow spots which later fall out form on ***young leaves*** which may become tattered and malformed. Berry stalks blacken and wither, berries drop. ***Bacterial blight*** (*Xanthomonas ampelina*) only affects grapevine and is not known to occur in Australia. It causes lower yields in, and a shorter life of, affected vineyards. ***Quarantine risks:*** The introduction of graftwood or cuttings from infected areas (Com. of Aust. 1992). ***Pierce's disease*** (*Xylella fastidiosa*) is not known to occur in Australia, but is one of the oldest known plant diseases. It can cause devastating losses in grape crops. ***Quarantine risk:*** The introduction of graftwood or cuttings of grapevines from infected areas, or in its symptomless alternative hosts, eg grasses, trees, whether it would spread to grapevines cannot be predicted. ***Leafhoppers*** which spread the disease overseas are not known to occur in Australia but leafhoppers already here may adapt. Not known to be seedborne (Com. of Aust. 1982).

FUNGAL DISEASES

Black rot (*Guignardia bidwelli*) which is not known to occur in Australia, is a ***destructive disease***, causing ***young fruit*** to rot, turn black, shrivel and become mummified. Mature fruit are blemished. ***Quarantine risks:*** The fungus may be imported on grapevine cuttings and on fruit (Com. of Aust. 1990).

Bunch rots, fruit rots

Often bunch rots follow other diseases and insect injuries and are aggravated by wet weather. Most have a wide host range and can grow on dead plant debris.

Bitter rot (*Melanconium fuligineum = Greeneria uvicola*) may infect ***leaves, twigs*** and especially ***overripe fruit***, during warm, humid weather. Pulp may have a bitter taste. ***Berries*** become darker than usual and covered with tiny black spots. It often follows downy mildew. ***Overwinters*** as shoot infections. Spores are ***spread*** by wind and water splash. Prune out infected canes in winter. Fungicides for other diseases will usually control bitter rot.

Grey mould, botrytis rot, noble rot (*Botrytis cinerea*) is ***important on bearing grapes***, reducing crop quantity and quality. Infected grapes are ideal for making natural sweet wines, eg Sauternes (Fig. 127). ***Flowers*** become brown and covered with masses of grey spores. ***Grape skins*** of white cultivars initially develop light-brown areas while black grapes develop dull areas. For identifying early stages of *Botrytis* the ***'slip-skin' test*** is used. When berries are rubbed, the skin over the spots cracks and slips off freely. Later, infected berries soften, turn brown and grey masses of spores are produced. *Botrytis* can spread rapidly from berry to berry and continue to grow in cold storage ***(nesting).*** Varieties with compact bunches, eg Shiraz are ***very susceptible***. See Greenhouses N 22.

Others: Aspergillus soft rot (*Aspergillus niger*), ***anthracnose*** (*Colletotrichum gloeosporioides*) and ***ripe rot*** (*Glomerella cingulata*). ***Penicillium moulds*** (*Penicillium* spp.), ***rhizopus soft rot*** (*Rhizopus* spp.), ***white rot*** (*Coniella diplodiella*), also *Alternaria*, *Aureobasidium*, *Cladosporium*, *Nectria radicola*.

See Fruit F 5.

Downy mildew (*Plasmopara viticola*). Infection first occurs on ***leaves***, late in spring after fruit set. Oily-looking patches appear on ***leaf uppersurfaces***. During wet weather, white downy spores develop on ***undersurfaces*** under the oily patches. The whole leaf may be affected. If weather is dry, downy mildew spots dry out and become brown. ***Severe defoliation*** exposes fruit to sunscald and reduces yield and quality. Infection at blossoming causes failure of fruit to set. A white fungus grows on ***young berries*** and ***fruit stalks***, ***young bunches wither and die.*** If attacked later when partly grown, berries harden, become grey and a fungal growth develops on the surface. Later, infected fruit withers, becomes brown or red, shrivels and mummifies. Heavily diseased ***shoots*** are swollen, distorted and stunted. If late in the season, vitality of ***canes*** needed for the following season may be reduced. Badly affected canes may die. Varieties of the European (*V. vinifera*) vary only slightly in ***susceptibility***, sultana and Pinot Noir are ***very susceptible*** while Cabernet Sauvignon and Semillon are ***less susceptible***. Hybrids of *V. vinifera* and other *Vitis* species, eg *V. riparia* or *V. rupestris,* are ***much less susceptible*** and some are relatively ***resistant***, eg Improved Golden Muscat and Isabella (Coombe and Dry 1992). Traditionally ***Bordeaux mixture*** has been applied. Other fungicides are available for use on prescribed schedules. Disease outbreaks can be ***forecast*** (temperature/rain) reducing the number of sprays, costs and possible environmental pollution. See Annuals A 5.

Eutypa dieback, dying arm

Scientific name: Ascomycetes:
Eutypa dieback (*Eutypa lata = E. armeniacae*)

Host range: Eutypa dieback is an ***important pruning wound disease*** of grapevine and apricot. It may attack other woody plants, eg almond, apple, peach, pear, plum, pittosporum, tamarisk.

Symptoms: Symptoms are rare on grapes < 10 years old. Grey-black elongated superficial lesions with pin-point black fruiting bodies develop on ***canes***. Lesions become rough and split with age. Infection can work back from pruning cuts, killing canes or spurs. Small black circular or elongated lesions occur on ***leaves*** causing them to tear and become distorted. Elongated black lesions appear on ***leaf and bunch stalks***, bunches may be destroyed. ***Mature fruit*** rot.

Overwintering: In the fruiting bodies on the lesions on the dead tissues on canes. In spring in wet weather these fruiting bodies produce spores which infect young canes, leaves and bunches.

Spread: Spores are produced on dead woody tissue and spread by wind to healthy vines. They are then splashed or washed on to new pruning cuts by rain or irrigation.

Conditions favouring: Cool, damp weather. Optimum conditions for infection of pruning wounds are warm (21-24^{o}C) and wet spring weather on the day of pruning.

Control: Although biological control agents have been used on apricot, they do not seem to work on grape. ***Control is aimed*** at reducing the chance of spores reaching unprotected fresh pruning wounds.

Cultural methods: ***Pruning*** early in winter when spore production is lowest, minimises infection.

Sanitation: ***Burn all infected branches*** as soon as pruning is completed. At an early stage, *Eutypa* infections can be removed by surgery, and eradication from vines is possible. Old infected vines should be removed to below ground level.

Resistant varieties: All *V. vinifera* varieties in Australia are ***susceptible***.

Pesticides: Paint or spray all fresh pruning cuts with ***fungicide*** to protect them from infection, immediately after pruning.

Fungal leaf spots

Black spot, anthracnose (*Elsinoe ampelina = Sphaceloma ampelina,* Ascomycetes) is more common in home gardens than commercial vineyards. ***Leaf spots*** are initially small and dark, centres become lighter and may fall out. Distortion occurs if there are many spots or if veins are involved. Dark elongated sunken cankers with raised margins develop on ***young canes***. Canes may be girdled and die. Girdling of ***flower stems*** causes withering and falling of flowers or young fruits. ***Berries*** develop dark brown areas which later develop into round spots with grey centres and dark margins, between which there may be a well-defined red band ***(bird's-eye spot)***. There may be reduced yield and fruit quality. ***Favoured*** by low temperatures and wet weather early in the season. Prune out and burn infected canes.Varieties vary in ***susceptibility***. ***Fungicides*** may be applied, if weather is damp and cool.

Phomopsis leaf and cane spot, dead arm (*Phomopsis viticola* = *Cryptosporella viticola*): Infection can work back from pruning cuts, killing canes or spurs. Lesions on ***canes*** are black, elongated and superficial, splitting and becoming rough with age. In winter, pin-point black fruiting bodies ***(pycnidia)*** develop in the ash-coloured lesions. Small black circular or elongated lesions occur on ***leaves*** causing them to tear and distort. Leaves may fall. Elongated black lesions also appear on the ***bunch stalks***. Bunches may be destroyed and a ripe rot of mature ***fruit*** may develop. ***Favoured*** by cool, damp weather. Remove and destroy diseased canes. Many table and wine grape varieties are ***susceptible***. Only plant ***Phomopsis-free*** cuttings. ***Fungicides*** are registered for use.

Others: *Ascochyta ampelina*, *Cercospora viticola*, *Mycosphaerella phaseolina*, *Pseudocercospora vitis.*

See Annuals A 5.

Powdery mildew

Powdery mildew (*Uncinula necator*): ***Young leaves*** may be distorted, shrivel and die. ***Flower*** infection causes poor fruit set. ***Berry*** infection causes stunting, hardened cracked skin and uneven colouring of dark coloured varieties. If possible, plant varieties with some ***resistance***, eg Grenache and Shiraz. Powdery mildews are difficult to control. ***Petroleum oils*** are as effective as myclobutanil for preventing powdery mildew (Northover and Schneider 1996). A ***mycoparasite*** (*Ampelomyces quisqualis*) is being researched overseas (Falk et al. 1995). See Annuals A 6

Root and stem rots

Damping off: ***Pythium crown rot*** (*Pythium* sp.) occurs on vines < 2 years old, ***rhizoctonia root rot*** (*Rhizoctonia solani*) may occur in nurseries. See Seedlings N 22.

Others: ***Armillaria root rot*** (*Armillaria* spp.), ***ashy stem blight***, charcoal rot (*Macrophomina phaseolina*), ***fusarium root rot*** (*Fusarium* sp.), ***phytophthora root rot*** (*Phytophthora cinnamomi*), ***thielaviopsis black root rot*** (*Thielaviopsis basicola*), ***white root rot*** (*Rosellinia necatrix* = *Dermatophora necatrix*).

See Fruit F 7, Vegetables M 7.

NEMATODE DISEASES

More than 70 species of nematodes are associated with *Vitis* spp. in Australia. ***Parasitic nematodes*** may reduce vigour and yield. Most agricultural land has a population of nematodes, numbers generally depend on the intensity of land use.

Dagger nematode (*Xiphinema index*) attacks grape, fig, pistachio, roses, stone fruit, and possibly citrus. It sucks sap from ***rootlet tips*** causing roots to bend, swell and perhaps die. To compensate, roots produce more roots, the root system becomes very ***branched*** with many dead rootlets. Young vines may die, older vines may be stunted, pale, weak and unproductive. *X. index* occurs only in some areas of Australia so ***quarantine regulations*** prohibit the removal of any grapevine part from affected areas. *X. index* also ***transmits*** fanleaf virus. Only 1 generation per year. Males are rare and not required for reproduction. Some rootstocks have some ***resistance*** .

Root knot (*Meloidogyne* spp.) is the ***most important*** nematode disease of grapevines. Grapevine tolerance depends much on soil texture, root knot is most serious in ***light and sandy soils***, with production being reduced to uneconomic levels. See Vegetables M 10.

Others: ***Citrus nematode*** (*Tylenchulus semipenetrans*), ***pin nematodes*** (*Paratylenchus* spp.), ***ring nematode*** (*Criconemella xeniplax*), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* spp.), ***stubby-root nematode*** (*Paratrichodorus minor*).

Control in established vineyards is difficult. To confirm diagnosis, collect soil and root samples for analysis (Nicholas et al. 1994). Improve ***management practices*** to reduce the damaging effects of nematodes, eg reduce stress due to inadequate water and fertiliser, increase soil organic content (parasites and predators increase in soils rich in humus). Plant infested areas with ***nematode-free resistant*** or ***tolerant rootstocks.*** ***Before replanting*** infested areas, remove infested roots and treat soil, even if resistant or tolerant rootstock are to be planted. Nematodes can be eradicated from bare-rooted grapevine rootlings by hot water treatments. Crop rotation and soil fumigation often give poor control because *X. index* and grapevine fanleaf virus can survive for many years at great depth in the soil in the absence of host plants (Coombe and Dry 1992). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Auger beetles (Bostrichidae): ***Common auger beetle*** (*Xylopsocus gibbicollis*, ***large auger beetle*** (*Bostrychopsis jesuita*). See Trees K 11.

Elephant weevil (*Orthorhinus cylindrirostris*) causes similar damage as the vine weevil . See Trees K 12.

Fig longicorn (*Acalolepta vastator*) larvae may tunnel upwards in grapevine ***stems*** for over 1 m or downwards into the main stem. See Fig F 55.

Oecophorid borers (Oecophoridae, Lepidoptera), eg fruit-tree borer (*Maroga melanostigma*) and *Echiomima* sp. are pests of grapevines in SA, boring into ***runners***. See Fruit F 10, Trees K 12.

Vine weevil (*Orthorhinus klugi*) is about **7 mm** long, reddish-brown and hard. ***Adults*** may feed on buds and bark of canes. They drill holes in the canes with their long snout and insert their eggs. ***Larvae*** are legless. They bore downwards in ***canes***, and pupate at the end of the tunnel. Adults bore their way out in early spring, leaving a round hole. Tunnels are packed with fine flour-like dust (Hely et al. 1982).

See Trees K 11.

Bugs (Hemiptera)

Metallic shield bug (*Scutiphora pedicellata*) sucks sap from ***grape berries*** which wilt and shrivel. See Vegetables M 12.

Rutherglen bug (*Nysius vinitor*) sucks sap from ***shoots, stems and berries***. Affected berries shrivel and gum from feeding punctures. Shoots may wilt and die. See Stone fruits F 130, Vegetables M 12.

Others: ***Coon bug*** (*Oxycarenus arctatus*), ***green vegetable bug*** (*Nezara viridula*), ***green stink bug*** (*Plautia affinis*), ***pale cotton stainer*** (*Dysdercus sidae*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Cutworms (*Agrotis* spp., Noctuidae) damage ***young vines*** in newly planted orchards. See Seedlings N 68.

Hawk moths (Sphingidae): ***Grapevine hawk moth*** (*Hippotion celerio*) is an introduced minor pest of grapevine, citrus, sweet potato, golden guinea vine, rhubarb, Virginia creeper and Boston ivy during spring, summer and autumn. ***Moths*** have a wingspan of 70-100 mm, are greenish-brown, with a pink area on each hind wing with dark markings. The body tapers to a point. ***Caterpillars*** are ***60-80 mm*** long, greenish or brownish-black with 2 large eye-spots behind the head and a row of spots along each side. See Sweet potato M 95 (Fig. 358). They mostly feed on leaves. ***Overwinters*** as pupae in soil. ***Other hawk moths*** may feed on grapevines and other Vitaceae, eg ***vine hawk moth*** (*Thereta oldenlandiae*) (Fig. 13, Annuals A 3) and *T. latreillei*, ***whitelined hawk moth*** (*Hyles lineata*), *Acosmeryx anceus, Gnathothlibus erotus* subsp. *eras* (Common 1990).

Lightbrown apple moth (*Epiphyas postvittana*) caterpillars can destroy up to 20% of a crop. They feed on ***flowers and fruit clusters***, weaving them together. Caterpillars feed on the ***fruit skin*** causing large irregular blemishes, which may callous over. Fruit remain on the tree, or in wet weather, it may rot and fall. A ***wasp*** (*Trichogramma carverae*) is an egg parasite. See Pome fruits F 112.

Noctuids (Noctuidae): ***Grapevine moth*** (*Phalaenoides glycinae*) is found in all grape growing areas of Australia in warm, humid weather during spring and summer. It also infests ornamental grapevines, fuchsia, Virginia creeper, glory vine, *Gnaphalium luteoalbum*, *Hibbertia linearis* and *Glycine* spp. ***Moths*** are black with yellow markings, about 50-60 mm across its outspread wings and day-flying. There is an ***orange tuft of hairs*** at the tip of the abdomen and orange markings beneath the body. ***Caterpillars*** are up to ***50 mm*** long, greenish-yellow with numerous short, transverse, irregular black lines and several reddish spots, the body is covered with long fine, white hairs (Fig. 128). They usually feed on ***leaf undersurfaces*** and can defoliate young vines. Young ***bunches*** may be damaged, berries being marked as they mature. Pellets of excreta may be found beneath the vines. There are 2-3 overlapping generations each year. Female moths lay eggs in spring on stems and leaves of hosts. ***Overwinters*** as pupae in soil, or between cemented leaves or rubbish. As they are readily controlled they are generally only pests of home garden vines. ***Cockatoos*** prey on moths and caterpillars, and a ***predatory shield bug*** (*Oechalia schellenbergii*) feeds on caterpillars. In home gardens where often no sprays are used these bugs may be seen with their stylet inserted in a caterpillar, sucking its contents. ***Parasitic wasps*** are commonly seen trying to oviposit in caterpillars. A ***wasp*** (*Euplectrus* sp.) parasitises eggs and caterpillars. ***Fungal diseases*** commonly attack these caterpillars during prolonged damp weather (Fig. 129). ***Native budworm*** (*Helicoverpa punctigera*) may damage vineyards. ***Painted vine moth*** (*Agarista agricola*) caterpillars feed on fruiting and ornamental grapevines, *Cissus* spp., Boston ivy and Virginia creeper. ***Moths*** have a wingspan of about 65 mm and are black, forewings are marked with a pattern of pale blue, deep yellow, cream and red. Hindwings are black with a white edge. ***Caterpillars*** have black, orange and cream stripes and slender black projections from the body. They are not usually found in large numbers and can be removed by hand. Caterpillars of ***Argyrolepidia subaspersa*** feed on Vitaceae eg grapevine (*V. vinifera*), *Cissus hypoglauca*, *Cayratia*,, Virginia creeper in Qld and NSW.

Raisin moth (*Cadra figulilella,* Pyralidae) caterpillars infests ripening and fallen grapes but is more importantly, ***a postharvest pest of drying grapes***. All fallen and waste fruit must be collected and destroyed. Process grapes as soon as possible.

Others: ***Small citrus butterfly*** (*Papilio anactus*), ***leaf case moth*** (*Hyalarcta huebneri*). Also *Acropolitis rudisana* on ornamental grapes and radiata pine; orange fruit borer (*Isotenes miserana*), tussock moth (*Porthesia paradoxa*).

Monitor caterpillars of lightbrown apple moth on bunches, and grapevine moth on foliage, at regular intervals before making a decision to apply an insecticide (Brough et al. 1994, Nicholas et al. 1994). ***Bacillus thuringiensis*** (Dipel®) may applied as a regular program to control leafeating caterpillars. See Annuals A 8, Fruit F 8.

Driedfruit beetles (*Carpophilus* spp.)

are attracted to and breed in ***overripe fermenting fruit*** and are pests of ***drying grapes***. They also spread bunch rots. See Fruit F 8

Ferment flies (Drosophilidae, Diptera)

are important pests of ***drying grapes***, around cellars and in some crops, eg coastal vineyards producing table grapes. ***Flies*** are brown and grey with reddish eyes, and are about ***3 mm*** long. If the berries split in late summer, flies will deposit eggs in the cracks the small white maggots cause fermentation and breakdown. ***Maggots*** grow to about ***4 mm*** long, and pupate in dried areas of the rotted fruit. ***Do not confuse*** with fruit flies. See Fruit F 8

Fruit flies (Tephritidae, Diptera),

eg ***Mediterranean fruit fly*** (*Ceratitis capitata*) may damage ***late table grapes*** in WA. Control is compulsory. Prune out stung berries from bunches before marketing. ***Queensland fruit fly*** (*Bactrocera tryoni*) rarely attacks grapes. See Fruit F 9.

Grape phylloxera (*Daktulosphaira vitifolii*, Phylloxeridae, Hemiptera)

is the ***most serious pest*** affecting grape. ***Adult aphids*** are greenish-yellow and live on roots as well as on the aboveground parts. Fleshy yellow galls develop on the fine ***roots***. Galls are about 10 mm across and may be curved into an S-shape. If they are cut open, 1-2 greenish-yellow aphids may be seen. Once a gall forms, the root stops growing. ***Leaves*** of *V. riparia* and *V. rupestris* may develop fleshy yellowish irregular galls on the lower surface (Fig. 129). Infected vines have weak growth and will never crop properly. There is a ***gradual metamorphosis*** (egg, nymphs, adult) with many generations each season. ***Overwinters*** on roots as nymphs on *V. vinifera* and as eggs and nymphs on *V. riparia* and *V. rupestris*. ***Spread*** on cuttings, winged forms flying, wind, on rootlings, soil. ***Favoured*** by heavy soils. Where it is known to exist, grapes are usually grown on ***resistant rootstocks.*** Very few galls are formed. ***Quarantine regulations*** restrict the movement of grape cuttings and other plant parts. There is no chemical control and no economic means of removing phylloxera from soil once it is established.

Grapevine scale

Grapevine scale (*Parthenolecanium persicae,* Coccidae, Hemiptera) is a common minor pest of grapevines, mainly in home gardens. ***Adult scales*** are shiny, hard, convex, dark brown, elongated oval and about 7 mm long by 4 mm wide. They are found on ***leaves and young canes.*** Old canes are often heavily infested. Scales produce ***honeydew*** on which sooty mould grows. Infested canes have a sooty appearance. If the honeydew falls on ***fruit***, then sooty mould makes bunches unmarketable. ***Overwinters*** as adults on old wood where they produce masses of eggs beneath old scale covers. Eggs on canes hatch in late spring and small, yellow crawlers move out on to leaves where they settle. In autumn they move back onto the canes and old wood where they mature. ***Examine canes*** during normal winter pruning. If any are found, remove infested canes and spot spray infested canes after pruning and before bud burst. See Citrus F 41.

Mealybugs

Mealybugs (Pseudococcidae, Hemiptera) are ***serious pests*** of bunches, leaves, canes and roots of vines. Damaged berries may be invaded by secondary fruit rots. Mealybugs extrude a white cottony material and secrete quantities of sticky honeydew which falls over ***bunches*** and lower parts of the ***vines***. The cottony material, together with dust and other debris becomes entangled in the honeydew, rendering bunches unsightly. Sooty mould grows on the honeydew.

Longtailed mealybug (*Pseudococcus longispinus*) and *Pseudococcus* spp. infest ***older canes*** and crowns in winter and are found under rough bark. ***Favoured*** by sandy soil and heavy foliage; sultanas, currants and some wine and table grapes with heavy foliage are ***susceptible***; sparse foliaged varieties, eg Gordo Blanco, are not.

Tuber mealybug (*P. affinis*) is found in cracks on ***bark***, in curled leaves within ***bunches***, on ***roots*** of vines and weeds. As few as 1 mealybug/bunch/carton at harvest may cause downgrading. Apply a preventative spray before bunches close. Mealybugs on roots are difficult to control with insecticides.

Others: Citrophilous mealybug (*P. calceolariae*).

See Greenhouses N 25.

Mites

Mites (Acarina)

Eriophyid mites (Eriophyidae) adults are 0.2 mm long (microscopic), cream and worm-like with 2 pairs of legs situated near the head end. ***Grapeleaf blister mite*** (*Colomerus vitis*) is a minor pest of *V. vinifera.* Mites are found in the felt-like areas on the ***undersurface*** of ***blisters*** on ***leaves*** during the growing season and in the buds during winter. There are two strains, one which infests leaves and another morphologically identical strain which infests growth buds. ***Blister mite forms*** suck sap from ***leaf undersurfaces*** in spring causing small yellow areas (up to 6mm or more across) to develop with a felt-like appearance due to the production of densely-packed hairs (erinose) by the host. This mat of hairs turns rusty brown as the leaf ages. The upper surfaces of these felty areas develop ***blisters*** (Fig. 130). In severe infestations leaves may be small and covered with blisters and shrivel in hot weather causing bunches to be sunburnt. ***Bud mite forms*** cause stunting of canes, short internodes at the base, zig-zagged shoots, dead overwintering buds and abnormal development of buds reducing yield. Waltham Cross is especially susceptible in spring. ***Gradual metamorphosis*** (egg, nymph, adult) with many generations each season. ***Overwinter*** as adults under bud scales, in spring they attack new leaves. Mites multiply in the felty areas, during spring, summer and autumn. In late autumn they move to the buds. ***Favoured*** by warm, moist weather (especially above average spring and summer rainfall). ***If only a few shoots*** or leaves are affected, these may be pruned out as they appear during the growing season. ***Predators*** include mites, hoverfly larvae, lacewings and thrips. Some varieties, eg Muscat Gordo Blanco, are ***very susceptible***. Where severe mite injury has occurred the previous season, ***lime sulphur*** may be applied after pruning and before budswell during the dormant season. Control during the growing season is more difficult. ***Grapeleaf rust mite*** (*Calepitrimerus vitis*) is usually a minor pest. Adults are similar in shape and size to the grapeleaf blister mite. Mites are present, sometimes in large numbers on ***both leaf surfaces,*** but mainly on uppersurfaces and the whole surface becomes ***reddish-brown*** with the area along the main veins being the deepest brown. Sometimes most leaves are discoloured and the whole vineyard affected. Leaves fall prematurely. ***Overwinters*** apparently in crevices in the bark and between the bud scales. ***Favoured*** by hot dry years. ***Control:*** If severe the previous year, spray after pruning before bud burst. Cover all parts of the vine especially crevices around the buds. ***Others: Citrus rust mite*** (*Phyllocoptruta oleivora*).

False spider mites (*Brevipalpus* spp., Tenuipalpidae). ***Bunch mite*** (*B. californicus*) is a ***major pest*** of grape, citrus, also camellia, docks, fuchsia, hydrangea, rhubarb, tomato and some other plants. ***Adults*** are deep red, flat and small, about ***0.25 mm*** long and practically invisible to the naked eye (adults of citrus flat mite, *B. lewisi,* are brown). They move very slowly and are found on ***leaf undersurfaces*** close to bunches or in the bunches themselves. Mites feed on the ***stalks of bunches and berries*** causing berries to drop or shrivel due to moisture loss. Mites may feed on the berry surfaces causing brown encrustations (thick skin) which may develop a network of cracks and become reticulated. ***Leaves*** are not usually damaged but may develop a browned, roughened appearance. Mites are also found at the bases of the ***canes*** which may be brown and scarred. ***Gradual metamorphosis*** (egg, nymph, adult) with many generations each season. Eggs are laid on leaves and under bark and nymphs suck sap from the surface tissues. They do not seem to move far from the place where the eggs were laid. ***Overwinter*** as non-feeding adults under outer bud scales, in cracks on canes and under rough bark at the bases of canes.

Favoured in hot inland growing regions. **Doreen's predator mite** (*Typhlodromus doreenae*) provides adequate control. Where mites are a problem spray at budswell the following season. Control may be required during summer.
Others: **Broad mite** (*Polyphagotarsonemus latus*). **Twospotted mite** (*Tetranychus urticae*) may be a serious pest if broad spectrum pesticides are used to control other pests. See Beans (French) M 29.

Spread by movement of infested cuttings and nursery stock, by wind or on insects and birds. Mites have a limited ability to crawl. Only **plant mite-free cuttings**. Varieties vary in **resistance**. **Monitor** grapeleaf blister mite and grapeleaf rust mite populations at regular intervals before making a decision to apply an **insecticide** (Brough et al. 1994, Nicholas et al. 1994).

Thrips (Thysanoptera)

Black plague thrips (*Haplothrips froggatti*, Phlaeothripidae) suck juice from **young berries**, scar tissue forms over the feeding area.
Greenhouse thrips (*Heliothrips haemorrhoidalis)* may cause **leaf silvering**. Leaves are speckled with black dots of excreta, brown and wither. Berries may be mottled, brown and scurf. **Favoured** by thickly foliaged household vines grown on trellises. Control is usually not necessary. See Greenhouses N 24.
Plague thrips (*Thrips imaginis*) and **tubular black thrips** (*Haplothrips victoriensis*) may invade **flowers** and attack **fruit** in large numbers in some seasons. Flower tissues and fleshy fruit stalks may look pimply due to egg laying. Thrips do not reduce yields and apart from slight brownish scarring of the berries, seem to do little damage. See Fruit F 12, Roses J 6.
Others: **Western flower thrips** (*Frankliniella occidentalis*). See Annuals A 9.

Weevils (Curculionidae, Coleoptera) are minor pests, but young vines and trees may be severely damaged in some areas.

Black vine weevil (*Otiorhynchus sulcatus*) may attack over 50 different plants species including grapevines and cyclamen (even in pots). **Weevils** are **10-12 mm** long, brown-black with faint yellow spots. Weevils are nocturnal, coming out at night to feed on **leaf margins** and leaving small notches. **Larvae** are white, legless and up to **10 mm** long and are found around the base of plants in spring (Fig. 131). Most damage is caused by larvae feeding on **fine root hairs** during summer and autumn. Plants may fail to grow in spring. There is probably only **1 generation** each year. Only female adults are known and they are flightless. They emerge in November and lay eggs on the soil surface. Soil may be cultivated thoroughly in early October to destroy pupae. *Heterorhabditis* sp. (Otinem®) is a **nematode** which controls the larvae.
Other weevils chew foliage and buds, eg **apple weevil** (*O. cribricollis*), **elephant weevil** (*O. cylindrirostris*), **vine weevil** (*O. klugi*). Also **apple root weevils** (*Persperus* spp.), **fruit-tree root weevil** (*Leptopius squalidus*), **Fuller's rose weevil** (*Pantomorus cervinus*), **garden weevil** (*Phlyctinus callosus*), **gooseberry weevil** (*Ecrizothis inaequalis*), **spine-tailed weevil** (*Desiantha* sp.), **white striped weevil** (*Perperus lateralis*).

See Grapevine F 60, Trees K 17.

Others: **African black beetle** (*Heteronychus arator*) infests young vines, **ants** (Formicidae) are attracted to sucking insects. **Flower chafer** (*Dilochrosis atripennis*) may damage ripening grapes and other fruit, eg figs and oranges. **Leaf beetles, flea beetles** (Chrysomelidae, Coleoptera), eg **metallic flea beetle** (*Altica* sp.), **redshouldered leaf beetle** (*Monolepta australis*) and **small monolepta beetle** (*M. divisa*). **Also aphids** (Aphididae), **black cicada** (*Melampsalta* sp.), **crickets, grasshoppers, katydids, locusts** (Orthoptera), **green scarab beetle** (*Dihucephala* sp.). **Also leafhoppers** (Cicacellidae), **passionvine hopper** (*Scolypopa australis*), **termites** (Isoptera).

SNAILS AND SLUGS

Several species, eg **common garden snail** (*Helix aspersa*), **reticulated slug** (*Deroceras reticulatum*), **sand dune snail**, white Italian snail (*Theba pisana*), **small pointed snail** (*Cochlicella barbara*) and **vineyard snail** (*Cernuella virgata*) may damage newly planted and older vines. See Seedlings N 70.

VERTEBRATE PESTS

Kangaroos, rabbits, and hares damage **newly planted vineyards.** **Birds**, eg blackbirds, silver eyes, wattle honeyeaters, starlings, cockatoos and parrots are major pests of **berries**. See Fruit F 13.

Non-parasitic

Environment: **Spring frosts** may kill new growth, immature canes, occasionally split trunks, and reduce fruit set. In frost-prone areas, manage plants to minimise frost injury (implement frost protection). Site vineyards on elevated sloping sites with free air drainage. Avoid hollows, troughs and saddles between hills, where air movement is restricted. **Sun** may burn berries. **Rain-split berries** and bunch rots increase near harvest. **Wind-suck** is the withdrawal of water during hot, dry, windy weather, from the fruit causing it to shrivel.

Nutrient deficiencies, toxicities occur on grapevines and are **complex**, and vary according to many factors including soil type, variety, rootstock used, irrigation systems, training methods and canopy exposure. Nutrition may affect **wine quality**. Some hybrids have good **salt tolerance**. Fertiliser requirements may be predicted by tissue, soil and juice analysis. **Tissue analyses**, eg petiole analysis, at flowering, is considered at present to be the best method of predicting fertilising requirements. **Soil analyses** is mainly used for determining pH and salinity prior to planting (Coombe and Dry 1992, Weir and Cresswell 1993). See Citrus F43, Trees K20.

Pesticide injury: **Copper sprays** may harden vines if applied frequently. In some districts and in some seasons they cause a marginal browning. **Sulphur** may cause injury if applied at temperatures >30 °C. **Hormone herbicides**, eg 2,4-D used for killing and sometimes for fruit setting and fruit thinning may injure grapes and other plants.

Very sensitive: Grapevine, bean, lettuce, potato, tomato, cotton, tobacco, hibiscus, zinnia.
Sensitive: ***Most fruit*** (banana, citrus), ***field crops***, eg lucerne, clover, cowpea, soybean, medics, ***vegetables***, eg crucifers, cucurbits, most ***trees, shrubs, roses***.
Intermediate: Cereals, linseed, passionfruit, strawberry, asparagus, potato, bent buffalo grasses.
Tolerant: Most pasture and turf grasses.

Growth subsequent to hormone exposure is usually reduced and thickened, ***leaves*** curled and twisted, with thickened veins which tend to have a parallel arrangement (Fig. 130). ***Stems*** may split and callus growth may develop. Aerial roots may be initiated on the stems. Vines may ***die*** rapidly. Slightly affected vines usually recover, but the season's crop may be lost or seriously reduced. Avoid spray drift onto nearby grape crops, and volatile ester forms of 2,4-D near sensitive crops as vapours may continue to rise from sprayed areas for some hours after spraying, particularly on warm windless days. The use of hormone herbicide near vineyards is often ***regulated***. Set aside spray equipment especially for use with herbicides and do not use this equipment for the application of insecticides or fungicides. Do not store herbicides near fertilisers, seeds, tubers, insecticides or fungicides. ***Others***, eg glyphosate.

Others: ***Guttation:*** Vines in mild humid weather may exude small droplets of sap from leaves or shoots. Drops dry and whiten but are not detrimental. ***Other problems*** include mutations, waterberry, high nitrogen, hen and chickens (Fig. 132) (unevenly-sized berries on some varieties caused by poor fruit set following cold or wet weather or other factors).

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Dead Arm of Grapes
Downy Mildew of Grapevine
Grape Growing : An Introduction
Grape Growing in Cool Areas
Grapevine Management Guide for Coastal, Tablelands and Hunter Valley Districts
Grapevines in the Garden
Grapevine Spray Calendar for the Coastal and Tablelands Districts (NSW Agric)
Maturity Testing of Grapes : A Guide for Commercial Growers
Orchard & Vineyard Plant Protection Guide
Pests of Grapes
Phylloxera : A Threat to Grapevines
Powdery Mildew (Oidium) of Grapevine
Production and Marketing of Table Grapes
Pruning Grapevines
Table Grape Varieties
Vineyard Soil Management. Herbicides & their Use
Wine, Women & Vineyard Mite Control (Video)

SA Fact Sheets

A Guide to the Control of Fruit, Vine and Vegetable Pests (SA Dept Agric.)
Chemical Weed Control in Mature Cool-Climate Vineyards
Control of Lightbrown Apple Moth in Vineyards
Eutypa Dieback in Apricots and Grapevines
Identification & Control of Grapevine Phomopsis (Video)
Mites Damaging Grapevines
Nematode Control in Grapevines
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Table Grape Varieties

Vic Agnotes

Available Grapevine Clones
A Vine Grafting Kit
A Water Jet for Planting Vines
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Chemical Control of Weeds in Irrigated Vineyards
Collection & Storage of Grafting Wood for Grapevines
Controlling Mould on Drying Grapes Damaged by Rain
Controlling Snails in Citrus and Vineyards
Control of Phylloxera and Fanleaf Nematode
Cool Storage of Table Grapes
Cover Crops in Vines
Dehydration of Grapes Using the Hudson Bin Drier Dehydrator
Dipping, Rack Spraying & Trellis Drying of Sultanas
Downy Mildew of Grapevine
Dried Vine Fruit : From Picking to the Drying Rack
Eutypa Dieback of Grapevines
Frost : Its Nature and Control
Furrow Irrigation of Vines
Grape Phylloxera
Grapes : Pests, Diseases & Chemicals for their Control
Grapevine Nurseries
Grapevines Kit`
Growing Grapes in the Home Garden
How Moisture Stress Affects Grapevines
How to Collect Samples : Nematode Analysis
How to Topwork Grapevines
Improving Furrow Irrigation in Sunraysia Vineyards
Improving Mineral Nutrition in Vineyards
Lightbrown Apple Moth on Grapevines
Lime-induced Chlorosis in Grapevines
Management of Sultana Grafted to Ramsey Rootstock
Nematode Pests of Grapevine
Nematodes in Horticultural Crops in the Northern Mallee
Obtaining Grapevine Rootstock Material within Victoria
Phomopsis Cane and Leaf Spot
Powdery Mildew (Oidium) of Grapevine
Preparing Land and Planting Grapevines
Principles of Pruning Grapevines
Producing Sultanas for the Table
Producing Sultanas (Thompson Seedless) as Table Grapes
Pruning Grapevines in the Home Garden
Rack Spraying and Dipping to Produce Dried Raisins
Rain Damage to Dried Vine Fruit
Selecting a Site for a Vineyard
Selection of Vineyard Sites by Comparison of Climate
Soil Preparation for Fruit Trees & Grapevines in Southern Victoria & the Goulburn Valley
Sprays for Setting Currants and Carina
Sulphur Dioxide Fumigation of Grapes
Supply of Grapevine Varieties in Victoria
Supply of Virus-tested Grapevine Cuttings
Testing Table Grapes for Maturity
The Dagger Nematode on Grapevines
Training Young Vines
Trellis Design for Vines
Trellis Drying of Sultanas
Trickle Irrigation Vineyards Leaves Less Salt Near Roots
Varieties of Fruit Trees, Vines and Berries
Varieties of Wine Grapes in Use in Australia
Virus Diseases of Grapevines
Weed Control Under Drying Racks
Wine Grafting in Field Nurseries
Zinc Sprays for Fruit Setting in Vines

WA Farmnotes

Control of Pests in Young Vines
Powdery Mildew of Grapes
The Grapeleaf Blister Mite
Viticulture in WA (Bull. 4152)

Associations, Journals etc.

ASVO Seminar Proceedings
Australian and New Zealand Wine Industry Council
Australian & New Zealand Wine Industry Directory
Australian Dried Fruits Association (ADFA)
Australian Dried Fruits Corporation
Australian Grapegrower & Winemaker
Australian Soc. of Viticulture and Oenology.
Australian Wine and Brandy Producers Assoc.
Australian Wine Research Institute
Co-operative Research Centre for Viticulture
Cropwatch Horticultural Hotline
Dried Fruits Processing Committee
Dried Fruit Research & Development Council
Grape and Wine Research Council Research and Development Plan (1990/91-1994/95)
Grape and Wine Research and Development Corporation
Mudgee Wine Grape Grower's Association
Rural & Allied Industries Council/Dept. of Agric, Caversham, WA (Seminar : Production, Promotion & Marketing of Western Australian Table Grapes)
The Australian Grapegrower & Winemaker
Vine Improvement Program
Wine Grapegrowers Council of Australia
Wine Industry Journal
Winemakers' Federation of Australia (WFA)
Winetitles, Adelaide

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Grapes are grown for fresh grapes, wine and grape products, eg dried grapes. An overview of the industry has been presented by Coombs (1995). ***Grape management guides*** are published for particular districts each year (Browne 1994, Nicholas et al. 1994). ***AusVit*** (Australian Viticulture) is one Expert System and is a cooperative project between some state departments of agriculture and universities. ***AusVit*** guides vineyard managers to maximise production through better pest control and irrigation, helping to solve problems before they occur. ***An Australian Standard*** for organic and biodynamic produce is to be incorporated in the Australian Food Standards Code for the domestic market and in orders under the Export Control Act for fresh grapes, grape products and wine. ***Organic certification*** may be achieved by ***maintaining the fertility and biological activity of the vineyard and soil by any one or any combination of:*** eliminating artificial fertilisers; handling pests and disease by biological means; permitting only certain pesticides; controlling weeds by non-chemical means, eg mulch.

Selection

Select varieties which are suited to the climate, site, product to be produced, and are high yielding, vigorous and crop evenly. ***DNA fingerprinting*** for grapevines will enable varieties to be accurately identified. The introduction of grapevine graftwood or cuttings into Australia requires prior approval from ***plant quarantine*** authorities. If approval is granted, it must be treated, then grown in post-entry quarantine and screened for disease, including indexing for virus and virus-like diseases. Within Australia, legislation regulates the movement of grapevines and vine material to control the spread of pests and diseases, eg phylloxera. Where there are particular problems, ***select varieties*** with some ***resistance*** to diseases and pests, eg to virus diseases, and ***select rootstocks*** with some ***resistance*** to nematodes, phylloxera, incompatibility, soils, potassium, salinity, chlorosis, uptake of ions other than potassium, sodium and chloride, soil acids and water supply (May 1994). ***Plant virus-tested grapes*** from vine improvement programs.

Establishment and maintenance

Australian grape growing is highly mechanised. Grapevines are ***propagated*** by cuttings and by meristem culture. Table grapes may be grown outdoors or in greenhouses. Wine grapes and dried fruit grapes are grown outdoors. All problems affecting grapevines must be ***monitored.*** Problems affecting ***young grapes*** include African black beetle, cutworms, rabbits and hares, snails, and damping off. ***Cultural methods*** include local site selection, layout, irrigation and drainage, pruning and training, fertilising. Vines should be grown in full sun and correctly pruned each year. Different varieties require different pruning methods. ***Sanitation:*** ***Ripe fruit*** should be removed from vines and processing sheds. ***Prunings*** should be removed from vineyards and destroyed. ***Biological control*** agents are available for various pests, eg crown gall. ***Pesticides:*** Growth regulators are applied to promote uniformity. Despite the pressure to reduce chemical use, ***routine spray schedules*** still dominate viticultural pest and disease management, rather than spraying in response to monitoring, the presence of symptoms, disease warnings or weather conditions. This is probably due to ***poor identification*** of early symptoms of disease and pest damage and knowledge of how weather influences their spread. ***Weeds*** should be controlled in new and established vineyards by both mulches and ground covers, mowing, pre-emergence and post-emergence herbicides.

Postharvest

Harvest bunches when maturity tests for drying, table and wine grapes indicate. ***Pests associated with drying grapes*** include raisin moths, driedfruit beetles and ferment flies.

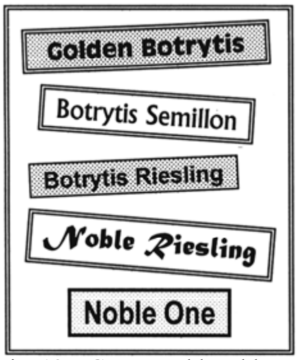

Fig. 127. Grey mould, noble rot (*Botrytis cinerea*).

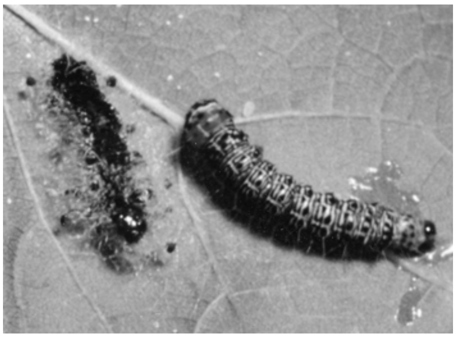

Fig. 128. Grapevine moth (*Phalaenoides glycinae*) caterpillars. ***Left :*** With a fungal disease. ***Right :*** Healthy caterpillar

Fig. 129. Grape phylloxera (*Daktulosphaira vitifolii*). ***Left :*** Aphid and eggs in leaf galls. ***Right :*** Galls on leaf undersurfaces.

Fig. 130. Grapeleaf blister mite (*Colomerus vitis*) damage and hormone herbicide injury**.**

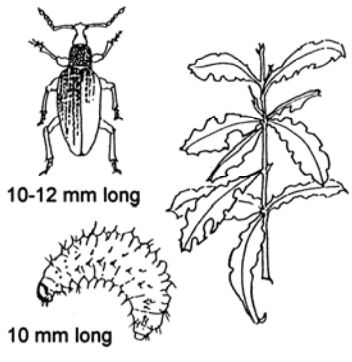

Fig. 131. Black vine weevil (*Otiorhynchus sulcatus.* ***Left :*** Adult and larva. ***Right :*** Damage by adults**.**

Fig. 132. Hen and chickens caused by poor fruit set.

Guava

Common guava (*Psidium guajava*)
Family Myrtaceae (myrtle family)

PESTS AND DISEASES
Parasitic
- **Fungal and algal diseases**
  - Anthracnose
  - Guava rust
- **Insects and allied pests**
  - Caterpillars
  - Fruit flies
  - Fruitspotting bugs
  - Thrips
- **Vertebrate pests**

Non-parasitic

PESTS AND DISEASES
Parasitic

FUNGAL AND ALGAL DISEASES

Anthracnose, black spot, ripe fruit spot (*Colletotrichum* sp.) causes deep sunken lesions on the skin of ripening fruit in the ***field*** and ***postharvest*** in humid conditions. See Fruit F 5.

Guava rust (*Puccinia psidii*) attack ***Myrtaceae*** plants, eg bottlebrush, eucalypt, guava, lilly-pilly, *Jambosa*, *Marlierea*, melaleuca, *Myrcia*, *Myrciaria*, *Paivaea* and pimento, causing leaf fall, reduced growth and death. ***It is not known to occur in Australia***. ***Quarantine precautions:*** Imports of susceptible plants are only permitted under strict quarantine conditions which include growth in post-entry quarantine and disease screening. ***Seed*** may be imported under prescribed conditions and may have to be grown in quarantine (Com. of Aust. 1985).

Others: Algal leaf spot, damping off, trunk canker.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Guava moth (*Coscinoptycha improbana*, Carposinidae) caterpillars resemble those of yellow peach moth. They bore into ***fruit*** of introduced and native plants, eg *Cassine australis*, *Schizomeria ovata*, citrus, guava, feijoa.
Others: ***Orange fruitborer*** (*Isotenes miserana*) and ***yellow peach moth*** (*Conogethes punctiferalis*) caterpillars bore into ***ripening fruit*** and may cause premature leaf fall. Caterpillars of ***bizarre looper*** (*Anisozyga pieroides*), *A. insperata* and ***mottled cup moth*** (*Doratifera vulnerans*) feed on guava ***foliage***. Caterpillars of ***Syntherata janetta*** feed on guava in northern Australia. See Fruit F 8

Fruit flies (Tephritidae, Diptera) are ***serious pests*** of ***fruit***, ***monitoring*** is often irrelevant. Insecticides are usually required. See Fruit F 9.

Fruitspotting bugs (*Amblypelta* spp.) may be ***major pests***. ***Fruit*** may develop corky lesions and be distorted. ***Monitor*** bug populations at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Fruit F 10.

Thrips (Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause silvering and browning of ***foliage***. Blemishing of ***fruit*** may be seen in late summer in sheltered sites. See Greenhouses N 24.
Redbanded thrips (*Selenothrips rubrocinctus*) may cause similar damage. See Mango F 81.

Others: ***Fruitpiercing moth*** (*Eudocima salaminia*). ***Various scales*** (Hemiptera) occur on ***foliage and young stems*** and may be controlled with summer oil.

VERTEBRATES

Fruit bats, flying foxes (*Dobsonia* spp., *Pteropus* spp.) eat ***fruits and blossoms***. See Fruit F 13.

Non-parasitic

Dimethoate (Rogor®) may injure leaves. ***Frost*** damages guava. ***Leaf analysis standards*** are available (Weir and Cresswell 1995).

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State/Territory Departments of Agriculture/Primary Industry eg
Guavas in the Garden (NSW Agfact)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Guavas are easily grown by seed, but some may be grafted or budded. Plants bear fruit when 2-3 years old. Guava is sensitive to ***frost***. Shelter young trees from wind. ***Water stress*** will cause immature fruit to fall. ***Heavy fertiliser applications*** are required to produce a worthwhile crop. Fruit should be ***ripened*** on the bush, it will not ripen properly if picked green.

Hazelnut

Barcelona nut, cob nut, filbert nut

Corylus avellana
Family Betulaceae (birch family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Apple mosaic virus may infect hazelnut but is not an important disease. See Pome fruits F 107.

BACTERIAL DISEASES

Bacterial blight, hazelnut blight (*Xanthomonas campestris* pv. *corylina*) can be a ***serious disease*** of hazelnut, especially of the cultivars Barcelona, Kentish Cob and Wanless Pride. Young succulent tissue is very susceptible. Tissue resistance increases with age. ***Leaves*** develop angular water soaked spots about 2-3 mm across, which turn reddish brown. ***On shoots and twigs*** cankers may develop which girdle stems causing twig dieback. Cankers on older shoots and limbs cause limb death. ***Buds*** may turn brown and die. ***Nuts*** and husks develop dark brown spots (1-3 mm across) which are usually superficial. Bacterial blight is ***spread*** by the introduction of infected nursery stock, during pruning on tools and by water splash. ***Favoured*** by wet seasons and high temperatures following wound infection. Young water-stressed trees are very susceptible. ***Control:*** Mulching and watering. Only propagate from disease-free plants and plant disease-free planting material. Where the disease is significant, protectant copper sprays may be applied in the late summer, autumn and early spring. See Stone fruits F 124, Walnut F 148

Others: ***Crown gall*** (*Agrobacterium* spp.) has been recorded on ***nursery stock*** overseas. See Stone fruits F 125.

FUNGAL DISEASES

Eastern filbert blight (*Anisogramma anomola*), which is not known to occur in Australia, is the ***most severe disease*** of hazelnut.

Fungal leaf spots (several species) affect hazelnut overseas. See Annuals A 5.

Grey mould (*Botrytis cinerea*) infects green ***husks and shells*** near maturity and after harvest, causing them to brown. It may be controlled with fungicides. See Fruit F 5, Greenhouses N 22.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*), ***phytophthora root rot*** (*Phytophthora* sp.). See Fruit F 7.

Others: ***Stem cankers*** (various species of fungi) may cause ***dieback***. Affected stems should be pruned out and destroyed. Fungi may enter stems via insect wounds or mechanical injury. ***Wood rots*** (various species of fungi) may damage old trees. ***Powdery mildew*** (*Oidium* sp) is a serious disease of hazelnut overseas.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Hazel aphid*** (*Myzocallis coryli*) may be a ***serious pest*** of new growth, colonising ***leaf undersurfaces***. Leaves curl, honeydew attracts ants and sooty mould grows on it. See Roses J 4.

Caterpillars (Lepidoptera) of various species may attack ***leaves*** and ***immature nuts***. See Annuals A 8, Fruit F 8.

Filbert bud mite (*Phytoptus avellanae,* Phytoptidae, Acarina) can be a ***serious pest*** of hazelnut. Infested buds, especially ***terminal buds***, become swollen, deformed, fleshy and pinkish. Light bud infestations cause injury to external bracts, which results in deformed, weak and sickly ***shoots***. Weakened buds produce no nuts. Damaged ***male catkins*** become rigid, brittle and produce little pollen. Mites ***overwinter*** in the enlarged buds and are ***spread*** by propagation from infested plants and the introduction of infested nursery stock. ***In spring*** when the mites migrate from enlarged buds to lay eggs on leaf undersurfaces and again from these infested leaves to terminal buds which become new big buds, ***more than 90% may be killed*** by being washed off the plant by rain, or desiccated by warm, dry air. If considered necessary, infested trees may be sprayed soon after budburst when mites are migrating to leaves.

Scales (Hemiptera)

Armoured scales (Diaspididae)
Oystershell scale (*Quadraspidiotus ostreaeformis*)
Soft scales (Coccidae)
Various species may produce honeydew which attracts ants and on which sooty mould grows.

See Citrus F 39, F 41.

Others: ***Fruit-tree borer*** (*Maroga melanostigma*) caterpillars may ringbark trees and weaken laterals. ***Giant grasshopper*** (*Valanga irregularis*) feeds on leaves of hazelnut in tropical and subtropical areas. ***Scarab beetle*** (Scarabaeidae) larvae may feed on the roots of nursery stock after planting out. Overseas various ***nut-boring beetles*** may feed in the nuts.

VERTEBRATE PESTS

Birds, especially large birds, eg cockatoos, may attack ripe nuts as their shell is relatively thin. ***Foxes, hares, rabbits, wallabies, and possums*** can cause severe losses in small hazelnut plantings. Protect with tree guards. See Fruit F 13.

Non-parasitic

Biennial bearing in some hazelnut varieties, lowers their average yield.

Environment: In areas with hot summers whitewash trunks to prevent ***sunburn***. ***Irrigate adequately*** to maintain tree growth, nut numbers and kernel quality. Young plants should be protected from ***hot winds***.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** (tentative) are available for hazelnut (Weir and Cresswell 1993).

Suckers: Most hazelnuts propagated on their own roots, produce suckers which should be ***removed frequently*** and at an early stage, either by mechanical means (pruning shears, motor driven or hand-held rotary weeders) or by herbicides which do not damage the parent tree.

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State/Territory Departments of Agriculture/Primary Industry eg

Filbert Nut Grafting using Hot Air (NSW Agfact)
Growing Filbert Nuts (NSW Bull. 1978)
Growing Hazelnuts (Vic Agnote)
Hazelnut Bacterial Blight (Vic Agnote)
Hazelnut Production (NSW Agfact)
Hazelnuts in the Garden (NSW Agfact)

Associations, Journals etc.

Australian Nut Grower (Jn of the Australian Nut Industry)
Hazelnut Growers of Australia (Growing Hazelnuts : Information Sheet)
Victorian Nut Growing Association (VNGA) : Hazelnut Research Sub-Committee Research Notes 1 and 2: Growing Hazelnuts
Victorian Nut Grower's Association (VNGA) : Hazelnut Sub-Committee. (1988): Hazelnut Growers Booklet
Victorian Nut Grower's Association (VNGA) : Important Diseases of Nut Trees in Victoria. Vol.4(2).
West Australian Nut and Tree Crops Assoc. (WANATCA)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

An overview of the industry has been presented by Coombs (1995). Hazelnuts bear separate male and female flowers on the same plant but are self-incompatible, requiring pollen of another variety to set nuts. Pollen is spread by wind. Only propagate from ***scale and mite-free plants***. ***Propagate*** by seed, rooted suckers, hardwood and herbaceous cuttings, grafting, layering. It may be necessary to dip roots of new trees in fungicide. ***Protect newly planted young trees*** from rabbits and other grazing animals with tree guards. Stake young trees to prevent wind damage. ***Prune*** initially to shape, later to improve light penetration. Most hazelnuts are borne on 1 year old twigs arising from older wood. ***Control suckers*** by cutting them off or by using a herbicide soon after they emerge. ***Eliminate weeds*** prior to planting out. If the site has been used before for growing crops, considerations should be given to treating soil prior to planting to eliminate any soilborne diseases and weeds. Weed control by mulching or by herbicides is important ***during the 1st year***, as cultivation encourages suckering. ***Harvest:*** Leave nuts on tree until mature, at which stage husks become harsh and brittle and nuts develop a rich brown colour. Nuts fall when mature. Gather as soon as they drop and store in a dry place to prevent the kernels becoming mouldy or off-flavoured. ***Storage:*** At harvest hazelnuts may contain 12-15% moisture (more in wet weather). Dry to between 6-8% either in sun or by hot air. If dried properly, nuts can be stored for > 1 year in a cool dry place, eg provided the relative humidity of storage area is < 65%.

Kiwifruit

Chinese gooseberry
Actinidia deliciosa
Family Actinidiaceae

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial blossom rot (*Pseudomonas viridiflava*) may rot ***flowers*** and ***young fruit*** in wet weather in NZ (Sale 1990). *P. viridiflava* does occur in Australia.

Crown gall (*Agrobacterium* spp.) may be a problem on ***nursery stock***. Galls develop at the base of stems. See Stone fruits F 125.

FUNGAL DISEASES

Fruit rots

Grey mould (*Botrytis cinerea*) affects ***flowers*** and ***fruit*** in the ***field*** and is the ***most serious postharvest disease*** of kiwifruit in ***cool storage***. Prune vines to encourage rapid drying. The ***incidence*** of *B. cinerea* in sepals and receptacles ***in the field*** overseas is used to predict grey mould decay in ***storage***. ***Fungicides*** are applied by commercial growers. Where there is a high incidence in the field, preharvest spray(s) 1-2 weeks before harvest significantly reduces fruit decay in storage (Michailides and Morgan 1996). See Greenhouses N 22.

Ripe rot (*Botryosphaeria dothidea*) causes a breakdown of ***fruit*** as it ripens. Infection occurs ***in the orchard*** from flowering onwards but is not obvious until the ripening process is underway. Cankers have been found on ***dead twigs*** of poplar trees and dead willow prunings on the orchard floor. Winter application of copper fungicides to deciduous shelter belts may help (Sale 1990).

Stem end rot (*Diaporthe actinidiae*) causes soft, water soaked spots at the ***stem end of fruit***, later white fungal threads develop on the lesions. Latent infections formed ***before harvest*** may develop postharvest, causing occasional losses. Remove dead or dying plant material from vines. Symptom development is prevented by storage at $1^{o}C$ but resumes again on removal to warmer conditions (Persley 1993).

See Fruit F 5.

Fungal leaf spots (*Alternaria alternata*, *Colletotrichum*, *Gomerella*, *Phoma*, *Phomopsis*) are prevalent in NZ after rainy weather (Sale 1990). Various species may cause leaf spotting in Australia. See Annuals A 5.

Root and stem rots

Armillaria root rot (*Armillaria luteobubalina*): Kiwifruit and willow used as ***windbreaks*** in NZ seem to be particularly susceptible. See Trees K 4.

Phytophthora root rot and trunk canker (*Phytophthora cinnamomi*) is perhaps the ***most serious disease in the field*** of kiwifruit and can cause the death of plants, particularly in poorly-drained situations. See Trees K 6.

Pythium root rot (*Pythium* spp.) may also cause a ***severe decline*** of vines planted in poorly-drained soils. Site selection, mounding and subsurface drainage help to avoid this problem.

Sclerotinia rot (*Sclerotinia sclerotiorum*) may cause a twig blight when a ***stem*** infection girdles a lateral causing its death beyond the lesion. ***Young fruitlets*** may also be infected. See Vegetables M 7.

See Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) may cause root galling and stunting of vines. Infested areas should be treated with a nematicide before planting. ***Root lesion nematode*** (*Pratylenchus penetrans*) have also been associated with kiwifruit. Also *Paratrichodorus* spp., *Xiphinema* sp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Bugs (Hemiptera)

Fruitspotting bug (*Amblypelta nitida*) is a ***serious pest*** close to rainforest and scrub areas. Adults and nymphs suck the ***fruit*** causing severe sunken spots with deep internal damage. Fruit is unsaleable. ***Monitor*** bug populations and damage at regular intervals. See Fruit F 10.

Wheat bug (*Nysius huttoni,* Lygaeidae) occurs in NZ, but is not known to occur in Australia. It does not attack kiwifruit but may be present in ***containers*** of export fruit.

Others: Green vegetable bug (*Nezara viridula*), ***Rutherglen bug*** (*Nyzius vinitor*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Cutworms and armyworms (Noctuidae) can attack ***nursery stock***. See Seedlings N 68.
Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars are ***serious pests*** of kiwifruit. They chew and roll the ***foliage*** on which they feed, and bore into the ***calyx end of fruit***. See Pome fruits F 112.

Monitor caterpillar populations in fruit at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Annuals A 8, Fruit F 8.

Fruit flies (Tephritidae, Diptera) are a ***serious pest*** of kiwifruit and may damage ***fruit*** in the ***field*** and ***postharvest***. Protection is needed from late January through to maturity. Stung fruit drop and without control measures severe losses may occur. ***Control*** is usually essential, particularly in coastal areas. See Fruit F 9.

Fruitpiercing moths (*Othreis* spp., *Eudocima* spp.) cause similar damage to fruit fly in that pierced fruit fall. Moths drill a neat hole in ***fruit*** to suck sap. To date there is no effective control. See Fruit F 9.

Mites (Acarina)

Redlegged earth mite (*Halotydeus destructor*) may invade plantings during the first season. See Vegetables M 16.
Twospotted mite (*Tetranychus urticae*) may infest ***leaves and fruit***. ***Six spotted mite*** (*Eotetranychus sexmaculatus*) may also infest kiwifruit but damage is minor. See Beans (French) M 29.

Passionvine hopper (*Scolypopa australis*) may cause ***young fruit*** to shrivel. If they are a problem, insecticides may be applied when nymphs are present on surrounding hosts, eg bracken. See Passionfruit F 92.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Greedy scale*** (*Hemiberlesia rapax*) may infest ***leaves, branches and stems*** (Sale 1990). ***Latania scale*** (*Hemiberlesia lataniae*) is a minor pest, infesting ***canes, leaves and fruit***. Populations build-up on vines as they grow older. Late in the season scales migrate to the fruit, and this could preclude the fruit from some interstate and export markets. See Avocado F 20. ***Red scale*** (*Aonidiella aurantii*) can be ***serious*** if excessive pesticide use disrupts wasp parasites. It infests ***canes, leaves and fruit***. Heavy infestation causes dieback. ***Biological control agents*** can be purchased. See Citrus F 39.

Ensure planting material is ***scale-free***. ***Monitor*** scale populations and parasitic wasp activity at regular intervals before applying an insecticide (Brough et al. 1994). See Citrus F 39.

Thrips (Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause ***leaf silvering***. See Greenhouses N 24.
Plague thrips (*Thrips imaginis*) may cause ***petals*** to brown and ***fruit*** not to set. See Roses J 6.

VERTEBRATE PESTS

Rodents, eg rabbits, may ring bark young vines. ***Birds*** peck individual fruit. See Fruit F 13.

Non-parasitic

Environment: ***Freezing*** damage may occur at < -6^{o}C; prolonged periods at < -9^{o}C may result in vine death through chill damage to ***trunks***. In such areas, young vines should have their trunks lagged with newspaper or sisalation during the first two winters. Once sap starts flowing in spring, vines become more sensitive to sub-zero temperatures. ***Young growth*** may be severely damaged by temperatures of -1.5^{o}C for 30 minutes. ***Fruit*** is also sensitive to frost in autumn. ***Sun*** may scorch fruit. ***Hail*** may damage leaves, canes and fruit. ***Waterlogging or dry conditions*** may kill vines when they are growing actively in spring, summer and autumn. ***Wind*** may burn young succulent shoots and blemish fruit.

Nutrient deficiencies, toxicities: Calcium, nitrogen and other deficiencies may occur. Vines must be ***fertilised heavily*** if crops are to be worthwhile. ***Leaf analysis standards*** are available for kiwifruit (Weir and Cresswell 1993, 1995).

Pesticide injury: ***Insecticides***, eg oil sprays and dimethoate (Rogor®), may cause leaf burn. Contamination with ***hormone herbicides***, eg 2,4-D, in the previous autumn may cause malformation of leaves and fruit the following season. ***Glyphosate*** (Roundup®) contamination may cause rolled leaves and abnormal fruit (Sale 1990).

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State/Territory Departments of Agriculture/Primary Industry eg

NSW Agfacts

Kiwifruit Growing in NSW
Kiwifruit in the Garden
Latania Scale in Young Macadamia Orchards (NSW Agnote)

SA ABG leaflets

Chinese Gooseberry or Kiwifruit

Vic Agnotes

Cool Storage of Chinese Gooseberries
Kiwifruit (Chinese Gooseberries)
Kiwifruit : Planting and Production
Kiwifruit : Trellising and Training
Kiwifruit : Varieties and Propagation
Maturity, Handling and Storage of Chinese Gooseberries
Trellising, Training + Pruning Kiwifruit on Tatura Trellis

WA Farmnotes

Growing Kiwifruit in Western Australia

Associations, Journals etc.

Australian Kiwifruit Growers Association (AKGA)
Good Fruit & Vegetables
State Kiwifruit Grower Associations

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Kiwifruit is a vigorous deciduous vine suited to mild or temperate climates with warm summer months free from frost. An overview of the industry has been presented by Coombs (1995). For successful fruit production, the winter ***chill factor*** is of prime importance, otherwise irregular bud break and fruit set may occur. For normal dormancy and bud break to proceed it is necessary to have between 500-700 hours below 7^{o}C depending on the cultivar. They have ***male and female flowers on separate vines***. Fruit is borne only on the female plant. One male plant will provide enough pollen for several females. Female vines take 4-5 years to bear and keep on bearing for at least 20 years. If space is limited, a male vine may be grafted on to a female vine but it must be cut back after flowering to keep its vigorous growth under control, and labelled so that its location is not forgotten. Bees are the most important pollinating agent.

Resistant varieties: Choose shelter trees that are not significant hosts for diseases or pests of kiwifruit.

Disease-free planting material: Make sure propagation material is free from scales.

Establishment and Maintenance

Propagation is by grafting on to seedling rootstock. Plants can also be grown from cuttings, root cuttings or by budding.

Cultural methods: The fibrous roots are shallow so regular watering is needed from spring to early winter when fruit ripens (usually May-June). Males should be planted 4-5 m from the female vine as they are much more vigorous than female vines. They should be provided with a well-drained soil, a sunny position sheltered from strong winds and plenty of water in summer. They benefit greatly from mulching in summer. ***Pruning*** ensures a good crop of fruit throughout the vine and prevents it from becoming rampant. Fruit is produced only on the current season's growth arising from old wood.

Biological control: Dip roots in ***Agrobacterium*** (No-Gall®) immediately before planting to protect cuttings from crown gall. ***Predatory mites*** may be purchased and released to control twospotted mites. ***Bacillus thuringiensis*** (Dipel®) may be applied to young caterpillars and ***parasitic wasps*** may be purchased to control red scale. These biological agents must be released or applied at the correct time.

Weed control: Control weeds before planting. Once vines are established, ***post-emergence herbicides*** may be applied, ***avoiding drift*** onto foliage or canes (a 300 mm high sisalation collar may be fitted to the base of each trunk to avoid the risk of damaging the bark and should remain in place for 3-4 seasons). Control weed hosts of pests in the orchard environment, eg bracken, to reduce winter egg laying sites of the passionvine hopper.

Pesticides: Where nematodes are a problem, pre-plant treat soil. ***Various pesticides*** are registered for diseases and pests of foliage and fruit. ***Growth regulators*** are used to increase yield. Maintain application machinery, calibrate properly, ensure correct rates are used and check efficiency of coverage (tracers may be used to ensure even coverage). For export crops only use pesticides registered for use on such crops.

Pest management: Regularly ***inspect*** crops and ***monitor*** pests during the growing season (weekly at least) for caterpillars, fruitspotting bugs, scales, twospotted mites and their parasites and predators, before applying an insecticide (Brough et al. 1994). If there is any doubt, ***seek advice***.

Postharvest

Harvest: Refractometers are used to measure fruit maturity as the percentage of soluble solids, there is a minimum percentage for kiwifruit. After harvest fruit is graded and packed. Unripe fruit can be ripened.

Storage: Fruit can be cool stored for months providing it has been harvested and cooled correctly.

Lychee

Lychee nut, litchi

Litchi chinensis
Family Sapindaceae

The main problems affecting lychee are insect pests.

PESTS AND DISEASES
Parasitic

FUNGAL AND ALGAL DISEASES

Fruit rots: ***Alternaria rot*** (*Alternaria alternata*), ***anthracnose*** (*Colletotrichum* spp.), ***aspergillus fruit rot*** (*Aspergillus* spp.), ***blue and green moulds*** (*Penicillium* spp.), *Phoma*, *Phomopsis*. See Fruit F 5.

Others: ***Algal spot*** (*Cephaleuros virescens*) may disfigure leaves or cause twig cankers, ***collar rot*** (*Botryodiplodia theobromae*), ***fusarium canker, root rots, wilts*** (*Fusarium* spp.), ***phytophthora trunk canker*** (*Phytophthora* sp.), ***pink limb blight*** (*Corticium salmonicolor*).

NEMATODE DISEASES

Dagger nematodes (*Xiphinema* spp.), ***root lesion nematode*** (*Pratylenchus* sp.), ***spiral nematode*** (*Helicotylenchus dihystera*), also *Criconema mutabile, Hemicriconemoides mangiferae, Paratrichodorus minor, Paratylenchus*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Bugs (Hemiptera)

Fruitspotting bugs (*Amblypelta* spp.) damage > 90% of ***green fruit*** causing it to fall. Brown lesions develop on the ***seed*** and small black pin pricks develop on the internal white surface of the skin. ***Mature fruit*** which is less attractive to the bugs may be damaged but does not fall and the damage may not be detected at harvest. ***Monitor*** green fallen fruit immediately after fruit set at regular intervals before deciding to apply insecticides (Brough et al. 1994). See Fruit F 10.

Others: ***Green vegetable bug*** (*Nezara viridula*), ***grey cluster bug*** (*Nysius clevelandis*), ***Rutherglen bug*** (*Nysius vinitor*) and ***litchi stink bug*** (*Lyramorpha rosea*, Tessaratomidae) which is related to the bronze orange bug (*Musgraveia sulvicentris*), may suck sap from ***fruit***. See Vegetables M 12.

Caterpillars (Lepidoptera)

Blues, coppers, hairstreaks (Lycaenidae): ***Prosotas duboisa*** caterpillars feed on ***flowers*** of lychee, macadamia, *Acacia leiocalyx*. ***P. felderi*** caterpillars feed on ***flower buds*** of lychee, macadamia, *Acacia leiocalyx*, *Alectryon coriaceus, Buckinghamia celsissima*). ***Rapala varuna*** caterpillars feed on ***flowers*** of lychee and *Alphitonia excelsa.*

Leafroller moths (Tortricidae): ***Macadamia nutborer*** (*Cryptophlebia ombrodelta*) is a ***major pest of lychee*** every year. Caterpillars bore into ***green, full size fruit*** in search of ***seed*** (Fig. 133). Fruit may either split or fall prematurely but caterpillars still develop to maturity. Caterpillars which bore in ***ripening fruit*** often drown in the juice if the skin is penetrated in the equatorial region. Entry on the shoulder or near the peduncle is more likely to ensure survival of the caterpillar which may then reach the seed. Fruit generally does not fall. ***Infested mature fruit*** weep and stain other fruit in clusters hanging below. Rind tissues around entry holes appear scalded and is often thought to be caused by ***fruit flies***. Lychee orchards near towns where hosts are plentiful are likely to suffer more damage than orchards in more remote areas. See Macadamia F 77. ***Orange fruitborer*** (*Isotenes miserana*) may also infest ***fruit***. See Citrus F 37.

Loopers (Geometridae): ***Gymnoscelis subrufata*** damages litchi ***flowers***, ***Pholodes sinistraria*** feeds on many plants, eg angophora, eucalypt, *Exocarpos*, wattle, apple, apricot, citrus, litchi, mint. ***Sauris malaca*** feeds on young ***foliage*** of litchi and red cedar (*Toona australis*). See Avocado F 19.

Lychee stem-girdler (*Carmenta chrysophanes,* Sesiidae) infests lychee, also several other hosts including woody galls on the branches of *Exocarpos cupressiformis*. Eggs are laid in the bark of branches and trunks and in branch crotches and the caterpillars bore within the ***wood***. Infested areas are covered with webbing and frass, parts of branches may die, crack and fall. Usually there are only 1-2 branches affected on a tree. Remove and burn dead branches.

Noctuids, semi-loopers (Noctuidae): Caterpillars can cause considerable defoliation of lychee after the wet season. ***Castor oil looper*** (*Achaea janata*) has both light and dark forms, is up to ***60 mm*** long and feeds on ***new leaves*** of growth flushes of small trees. ***Conspicuous looper*** (*Oxyodes tricolor*) is mainly black with yellow legs and 2 conspicuous red spots near the head. It also feeds on ***new flushes of leaves***. ***Dasychira mendosa*** feeds on eucalypt, *Bauhinia*, *Terminalia*, avocado and lychee. See Sweetcorn M 89.

Oecophorids (Oecophoridae): Caterpillars of ***Echiomima fabulosa*** feed on the ***bark*** of litchi (Common and Waterhouse 1981). See Fruit F 10.

Monitor caterpillars of macadamia nutborer in fruit, and loopers on new growth flushes of small trees (Brough et al. 1994). See Annuals A 8, Fruit F 8.

Elephant beetle (*Xylotrupes gideon*, Scarabaeidae, Coleoptera) is a sporadic pest of Bengal and other late maturing varieties especially in north Qld. Their feeding damages ***whole fruit*** and sometimes ***panicles***. Juice dripping from damaged fruit spoils undamaged fruit. Beetles are attracted to mulches for egg laying, and larvae feed on the organic matter. ***Monitoring*** of beetles will indicate likely losses. It may be necessary to manually remove mulch. No chemicals are recommended. See Eucalypt K 61, Trees K 16, Turfgrasses L 11.

Fruit flies, eg Queensland fruit fly (*Bactrocera tryoni*), is a minor pest of lychee. They may sting fruit but maggots do not develop. See Fruit F 9.

Fruitpiercing moths (*Othreis* spp., *Eudocima salaminia*) are a ***major pest*** of lychee. Just before harvest moths drill a neat hole in the skin of ***fruit*** through which they suck juice. The flesh beneath the drilled hole is opaque (undamaged flesh is taut and translucent). After a couple of days ***fermentation and moulds*** develop and fruit is obviously damaged. Fruit damaged the night before harvest may escape detection and can spoil a whole container as fermentation proceeds and juice leaks on to other fruit. If moth-damaged fruit is squeezed juice will squirt out. There are no satisfactory control measures as damage is so close to harvest. ***Natural enemies*** exert some control on the caterpillar stage in its natural habitat. See Fruit F 9.

Leaf beetles (Chrysomelidae. Coleoptera)

Redshouldered leaf beetle (*Monolepta australis*) swarms on to ***flowers*** and ***young leaves***. Only 1-2 trees may be affected in well-established orchards. Large swarms in young orchards will spread over more trees and cause proportionally more damage. ***Leaves*** are scorched when damaged and very young trees may become severely stunted if successive growth flushes are removed by beetles. ***Monitor*** beetle populations on flowers and new growth of young trees especially following the first substantial rains after a dry spell before making a decision to apply an insecticide (Brough et al. 1994). Consider bees at flowering time. See Fruit F 11.

Swarming leaf beetles (*Rhyparida* spp.) prefer new ***leaves, flowers and young shoots*** and may totally defoliate young plants and the tops of shrubs and large trees. The effect on the growth of young trees may justify the chemical control of swarms. Older plants usually recover. See Fruit F 11.

See Trees K 15.

Litchi erinose mite (*Eriophyes litchii*, Eriophyidae, Acarina) may be a ***serious pest*** of ***nursery stock, flowers, foliage and fruit***. This mite deforms plants, produces blisters on ***leaves*** (Fig. 134) and may cause ***flower and fruit drop***. In severe cases growing points are destroyed and setting of fruit is prevented. Fruit which does set may be damaged cosmetically. Older trees may recover, young ones may die. The mites, which are invisible to the naked eye, live on ***leaf undersurfaces*** and in ***terminal buds***. Damaged cells on leaf undersurfaces produce hairs which form a white velvety layer ***(erinose)*** which soon turns reddish-brown and finally dark brown. Mites ***overwinter*** on the host and are ***spread*** mainly on propagative material, also by wind, animals and birds which have brushed against infested plants, and on clothing. Mites move from older damaged leaves to new growth so that population peaks occur at each new flush of growth of the host. High temperatures, high humidity and heavy rainfall are ***unfavourable*** for mite development. ***Avoid purchasing nursery stock*** with leaves which are felted underneath and blistered on top. ***Prune out and destroy*** as much of the infested foliage from trees as possible. Several ***predatory*** mites and fly maggots prey on the erinose mite but none provide economic control. ***Monitor erinose*** on new growth and flowers at regular intervals before applying insecticides (Brough et al. 1994). See Grapevine F 62.

Soft scales (Coccidae, Hemiptera)

Green shield scale (*Pulvinaria psidii* = *Chloropulvinaria psidii*) is a ***major and common pest***, and produces honeydew on which sooty mould develops. ***Monitor*** leaves, stems and fruit for scales and sooty mould if conditions are mild or humid. Panicle infestation spoils fruit and is difficult to control. ***Mealybug ladybird*** (*Cryptolaemus montrouzieri*) kills a major proportion of green shield scales (and other soft scales), but is hindered by sprays used to control other pests. If infestation is in spring, spray to reduce populations before crawlers hatch and move to fruit clusters. Treat ants at base of tree if they are active.

Others: Long soft scale (*Coccus longulus*), ***green coffee scale*** (*Coccus viridus*).

See Citrus F 41.

VERTEBRATE PESTS

Fruit bats (*Dobsonia* spp., *Pteropus* spp.) eat large quantities of ***fruit*** in one night, and may fly considerable distances to do so. See Fruit F 13.

Non-parasitic

Environment: Young trees are killed by ***frost,*** and older trees can tolerate only light frosts. ***Drying winds*** may cause cracks in fruit and poor growth.

Mycorrhiza: The feeder roots of lychee are infected with ***symbiotic fungi*** which are beneficial to the host plant. If mycorrhiza is unavailable, it is recommended that some surface soil surrounding a large successful lychee tree be placed around newly planted trees. See Trees K 18

Nutrient deficiencies, toxicities: Lychee do not have much ***salt tolerance***. ***Leaf analysis standards*** are available based on diagnostic and research analyses (Weir and Cresswell 1995).

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State/Territory Departments of Agriculture/Primary Industry eg

Lychees in the Garden (NSW Agfact)

Lychee Varieties (NSW Agfact)

Associations, Journals etc.

Australian Lychee Growers Association (ALGA)

Good Fruit & Vegetables

National Lychee Seminar Procs.

See Fruit and nuts F 14

Remember, always check for recent references

MANAGEMENT

Lychee are compact, subtropical evergreen trees. An overview of the industry has been presented by Coombs (1995). A worldwide problem appears to be an inability to produce a good crop on the tree every year. Lychees succeed only in areas with warm to hot, humid springs and summers, and cool dry autumns and winters. Periods of cold are required to induce flowering. A smaller crop than usual may result from low humidity or dry soils during flowering or during the following few weeks. Rain during this time may adversely affect fruit set. ***Planting material*** must be free from erinose mite blisters and scales. ***Monitor*** caterpillars, fruitspotting bugs, litchi erinose mites, leaf beetles and scales, and their parasites and predators, before making a decision to apply an insecticide (Brough et al. 1994). ***Harvest*** when fruit is full red and the protuberances have flattened out. Cut off a small branch with the fruit cluster. Avoid picking fruit when it is wet as it will not keep well. Handle carefully. Dip fruit in recommended fungicide, cool before packing, and use plastic film to reduce water loss and browning. ***Store*** fruit at 5^{o}C.

Fig. 133. Macadamia nutborer (*Cryptophlebia ombrodelta*) caterpillar (up to 20 mm long) feeding in fruit.

Fig. 134. Blistered leaves caused by the litchi erinose mite (*Eriophyes litchii*) sucking sap from leaf under-surfaces.

Macadamia

Queensland nut

Macadamia tetraphylla, M. integrifolia
Family Proteaceae (waratah family)

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) causes galls on nursery stock just below ground level. See Stone fruits F 125.

FUNGAL DISEASES

Grey mould, flower blight, raceme blight (*Botrytis cinerea*) causes ***serious flower blighting*** resulting in poor nut set in bearing plantations, reducing yields by up to 40% (Fitzell 1994). See Fruit F 5, Greenhouses N 22.

Nut or husk spots are common but do not affect the shell and kernel, some cause nut fall.

Macadamia husk spot (*Pseudocercospora* sp.) causes brown circular spots 5-10 mm across on green husks of ¾ to full size ***nuts***. Infected nuts may fall early, causing ***major crop losses*** in trees > 12 years old. ***Spread*** by introduction of infected nursery stock, on infected husks on machinery, and during the mechanical harvesting of nuts; spores are ***spread*** by wind, rain splash . ***Overwinters*** on infected husks, radiata pine (*Pinus radiata*) which is an alternative host. Varieties vary in ***susceptibility***. Harvest crops as soon as nuts mature. Clean machinery of husks. Harvesting nuts manually, where practical.

Others: ***Anthracnose*** (*Colletotrichum gloeosporioides* var. *minor*), *Phomopsis* sp., *Lasiodiplodia* sp. and *Stilbella* sp. cause husk rots in most mature trees; some shedding of nuts may occur some years (Fitzell 1994). ***Spread*** by infected husks, spores are spread by rain splash. ***Overwinter*** on other hosts and can grow saprophytically (on dead organic matter) on bark, older leaves and on husks left in the canopy. ***Favoured*** by insect damage to husks, wet weather.

Fungicides are registered for nut spots. See Fruit F 5.

Root and trunk rots, stem cankers

Damping off: ***Alternaria sp***. may cause blights of new grafts and buds in wet weather and poorly ventilated nurseries (Fitzell 1994). ***Phytophthora trunk rot*** (*P. cinnamomi*) is a ***serious disease*** and may girdle stems of nursery stock. See Seedlings N 66.

Macadamia root decay (*Kretzschmaria cetrarioides*, Ascomycetes) is a ***minor disease*** of mature trees which decline over several years. Infected primary ***roots*** and the base of ***trunks***, have pockets of white wood decay with black-line patterns visible when the bark is removed. Clusters of small fruiting bodies develop months later on exposed root and butt sections in dark fungal encrustations up to 5 mm thick. ***Overwinters*** in infected roots and stumps. Spores are ***discharged*** after rain to other hosts. ***Favoured*** by wounding of trunks and main roots by wind, machines, and by moist conditions. Remove stumps and roots of native vegetation before planting. Avoid wounding roots during harvesting and when slashing for weed control. Provide windbreaks (Persley 1993).

Phytophthora root rot (*Phytophthora cryptogea*) is also a ***serious disease*** of mature trees (Fitzell 1994). See Trees K 6

Others include ***Armillaria root rot*** (*Armillaria* sp.) which is only important on newly cleared land. See Trees K 4. ***Dothierella canker*** (*Dothierella ribis*) may cause branch dieback in stressed trees. See Trees K 5. ***Pink limb blight*** (*Corticium salmonicolor*) may affect bark on older trees. See Trees K 8

PARASITIC PLANTS

Mistletoes (Loranthaceae) in large numbers, may weaken large trees. See Trees K 9.

NEMATODE DISEASES

Several nematodes have been found in association with macadamia, eg ***dagger nematodes*** (*Xiphinema* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematode*** (*Helicotylenchus* spp.). Also *Aphelenchus avenae*, *Paratrichodorus* sp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Black citrus aphid (*Toxoptera citricidus*) sucks sap from ***young leaves*** causing distortion, and from ***flower clusters*** reducing fruit set. Honeydew, sooty mould and ants are disfiguring. Natural enemies are usually ineffective. ***Monitor*** aphids weekly during flowering (Brough et al. 1994). See Citrus F 35, Roses J 4.

Bugs (Hemiptera)

Fruitspotting bugs (*Amblypelta* spp.) are ***major pests*** of macadamia especially during spring and autumn. Adults and nymphs suck sap from ***all stages of nuts*** even mature hard-shelled nuts, reducing yield and quality. Young nuts fall within a couple of weeks of feeding, while older nuts fall less readily. Kernels are often ruined. Spotting causes cells of the inner husk and soft shell to discolour and collapse; injured kernels become misshapen and translucent. In older nuts, injury may be detected on the outside by depressed areas and even splitting of the shell. However, kernels can be partly or wholly affected without any visible external injury to the shell. ***Banana-spotting bug*** also causes wilting and kills ***young shoots,*** particularly in autumn. Infestation is often severe on crops adjacent to natural bush where insects breed. Parasites and predators have little effect. See Fruit F 10.

Green vegetable bug (*Nezara viridula*) sucks sap from ***husks and immature kernels***. Damaged nuts may fall prematurely. Once shells start to harden most of the damaged nuts remain on the tree. At harvest the feeding sites on the kernel appear as circular white depressions. See Vegetable M 12.

Macadamia lace bug (*Ulonemia concava,* Tingidae) is a minor pest which may attack ***young foliage*** and ***flower clusters*** in elevated areas. Flower damage can result in poor flower set. See Azalea K 28.

Monitor bugs and damage before applying an insecticide (Brough et al. 1994). See Vegetables M 12.

Caterpillars (Lepidoptera)

Macadamia cup moth (*Mecytha fasciata*) caterpillars attack Proteaceae, eg banksia, *Lambertia*, *Persoonia*, macadamia, waratah. ***Moths*** are black and white, with a wingspan of 40 mm. ***Caterpillars*** are up to ***35 mm*** long, relatively smooth, oval, green and flat, with a distinct yellow stripe along the back but lack the tubercles and stinging hairs of other species. They often rest so that the stripe lies along the main vein of the leaf. They can defoliate young trees but feed mainly on ***mature leaves***. They ***pupate*** among debris on the soil surface at the bottom of the tree. ***Cup moth*** (*Anaxidia lozogramma*) caterpillars damage foliage of macadamia, camellia and *Dodonaea triquetra* in eastern Australia. See Eucalypt K 60.

Macadamia flower caterpillar (*Cryptoblabes hemigypsa,* Pyralidae) is a ***major pest*** of Proteaceae especially macadamia in Qld; also grevilleas, eg silky oak, Banks' red grevillea and woody pear (*Xylodeum pyriforme*) in eastern Australia. ***Moths*** are grey, and about 6 mm long. ***Caterpillars*** are about ***12 mm*** long, light green to red-brown with longitudinal stripes. Young caterpillars feed inside ***buds***; entry holes have a drop of sap exuding from them. Older ones feed mainly on the outside of ***buds and on flowers*** (Fig. 135). Masses of webbing (excreta and chewed pieces of plant) surround to damaged areas. Nut set may be greatly reduced. Caterpillars also attack ***young nuts*** set earlier in the season, or young lush shoots. Severe infestations on macadamia begin with moth migration from other hosts. Early flowers may escape attack. There are ***many generations*** each season. Caterpillars usually pupate in a silken cocoon in leaf litter on the ground. ***Parasitic wasps*** (*Agathis rufithorax, Trichogrammatoidea flava*), a ***predatory bug*** (*Termatophylum* sp.) and other natural enemies may regulate low populations.

Macadamia nutborer (*Cryptophlebia ombrodelta,* Tortricidae) is a ***major pest*** of macadamia, also lychee, poinciana, golden raintree, *Bauhinia*, bird of paradise tree, *Cupania*, Easter Cassia, Mimosa bush, *Schotia*, Tamarind. ***Moths*** have a wingspan of about 25 mm, are red-brown with a black triangular mark on the hind edge of each forewing. ***Caterpillars*** are up to ***20 mm*** long, and are pinkish with dark green spots in rows along the body. Young caterpillars enter the ***husk*** and tunnel into the kernel while the shell is still soft (Fig. 136); as the shell hardens feeding is usually confined to the husk. Infested nuts may have sawdust and webbing on the surface. Damaged nuts fall early and are expensive to sort. There are ***many generations*** each year. Eggs are laid singly on, or near the nut husks. Caterpillars are active in December-February, but some 'everbearing' *M. integrifolia* trees may be infested throughout the year. Early-maturing varieties may escape serious damage. Moths do not fly far, so orchards located well away from alternative hosts appear to be free of attack. ***Parasitic wasps*** (*Apanteles briareus*, *Gotra bimaculata*). ***Insect growth regulators*** and ***neem oil*** reduce incidence but not enough for commercial use. Spray during fruit-setting.

Macadamia twig-girdler (*Xylorycta luteotactella*, Oecophoridae) infests Proteaceae, eg banksia, grevillea, hakea, macadamia, *Persoonia*, *Protea*, *Telopea*, *Lambertia*, *Leucospermum, Stenocarpus*. ***Moths*** are satiny-white with a wingspan of about 25 mm. ***Caterpillars*** have a dark brown head with pale mottled brown bodies up to ***25 mm***. Rows of black dots along the body have bristles rising from them. They feed under a webbed shelter of sawdust-like excrement and plant debris (Fig. 137). Caterpillars also eat ***bark*** from twigs near forks or where whorls occur and may ring bark ***twigs***. Exposed rings are about 6-40 mm wide. They skeletonise and web ***leaves*** together. Young trees may be defoliated and damaged twigs snap off in wind or die back. Young trees may lack vigour and may die. If caterpillars tunnel in ***nuts,*** damage is similar to macadamia nutborer damage. There are ***several generations*** each year. Caterpillars pupate in the webbing. ***Spread*** by moths flying. Young larvae are ***abundant*** during spring and summer in elevated rainforest areas. ***Wasps*** (*Agathis*, *Goryphus turneri, Stiromesostenus albiorbitalis*) parasitise caterpillars and may regulate populations. ***Parasitic nematodes*** are being researched. If necessary after monitoring, spray young growth. See Fruit F 10.

Orange fruitborer (*Isotenes miserana*) is a minor pest of macadamia in Qld. It mainly feeds on ***foliage*** damaging growing points of nursery stock causing development of lateral buds and multiple shoots. It rolls young leaves, webs ***flower buds*** together, tunnels into young ***nuts*** and chews the outer husk of nuts. The protective silken tunnels made by the caterpillars are free of excreta (unlike other caterpillars on macadamia). Control is usually unnecessary except in ***nurseries***. See Citrus F 37.

Yellow peach moth (*Dichocrocis punctiferalis*) is a minor pest of macadamia in Qld. Caterpillars bore into ***nuts*** in clusters, sheltering, and filling the space with webbing and sawdust. Remove and destroy infested fruit. A ***fly parasite*** (*Argyrophylax proclinata*) exerts important control. See Stone fruits F 133.

Others: ***An anthelid caterpillar*** (*Anthela varia*) is a sporadic pest, eating chunks out of ***mature leaves***. See Trees K 13. ***Nut stemborer*** (*Paranepsia amydra*) is a minor pest, larvae tunnel in flower clusters, young shoots and in nuts (Brough et al. 1994). ***Other caterpillars*** feed on flowers, buds and nuts, eg, ***cornelian*** (*Deudorix epijarbas diovis*), ***doubleheaded hawk moth*** (*Coequosa triangularis*), ***flower looper*** (*Gymnoscelis subrufata*), ***pencilled blue butterfly*** (*Candalides absimilis*), ***kernel grub*** (*Cataremna sp.*), ***castor oil looper*** (*Achaea janata*), ***bizarre looper*** (*Eucyclodes pieroides*), ***brown looper*** (*Lophodes sinistraria*), ***brown tufted caterpillar*** (*Olene mendosa*), ***hairyline blue butterfly*** (*Erysichton lineata*), ***looper caterpillars*** (*Chrysodeixis* spp.) (Common 1990, Common and Waterhouse 1981).

Monitor eggs and caterpillars, and their parasites and predators before applying insecticides (Brough et al. 1994). See Annuals A 8, Fruit F 8, Trees K 13.

Flower thrips (*Scirtothrips* sp., Thripidae), a minor pest of macadamia, are tiny, slender, yellow to light-brown rasping and sucking insects. Large numbers can build up on ***flowers*** causing flowers to brown and buds to die. Feeding may continue on the young ***nuts*** after they are set, killing some nuts or scarring the outer husk which becomes light-brown instead of the usual green. Later in the season lush ***shoots*** may also be attacked and become discoloured and stunted. ***Favoured*** by low rainfall or abnormally dry seasons. Good rains reduce infestations. ***Monitor*** thrips in flowers before applying an insecticide (Brough et al. 1994). See Roses J 6.

Hibiscus mealybug (*Maconellicoccus hirsutus*) may be a serious pest. Mealybugs congregate and suck sap near shoot ***growing tips*** causing shoot distortion and leaf rosettes stunting terminals. Sooty mould and honeydew are also present. ***Predatory*** ladybirds and lacewing larvae suppress populations to tolerable levels. See Greenhouses N 25.

Macadamia leafminer (*Acrocercops chionosema,* Gracillariidae, Lepidoptera) is a ***major native pest*** of cultivated and wild macadamia, some hakeas, buckinghamias, *Polysoma*, *Stenocarpus*. ***Moths*** are small with a wingspan of 8 mm. They mostly lay eggs on upper surface of young leaves. ***Caterpillars*** have bright red bands and mine in ***young leaves***. Mines are at first a fine whitish serpentine line on leaves which gradually enlarges into blotches. ***Tree growth*** is reduced Damage is important only on young non-bearing trees in nurseries, heavily pruned trees, protected plantings, and in elevated areas > 180 m (where there are native hosts). Caterpillars pupate in debris on the soil surface. There are ***many generations*** each year. A ***parasitic wasp*** (*Elachertus*) may regulate populations. ***Spiders*** prey on fully grown caterpillars when they leave their mines to pupate. Two ***insect growth regulators*** affect the development of eggs or larvae or both. In a home garden young trees may be sprayed as soon as the first white lines are seen. ***Monitor*** damage on nursery trees (Brough et al. 1994). See Azalea K 28.

Redshouldered leaf beetle (*Monolepta australis*) predominantly feeds on ***flowers, buds and young nuts***. Favoured by using kikuyu as an interrow cover and where there are pasture legume mixtures closeby. ***Monitor*** swarms before spraying (Brough et al. 1949). See Fruit F 11, Trees K 15.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Latania scale*** (*Hemiberlesiae lataniae*): Severe infestations of ***branches and twigs*** cause leaf yellowing and trees to become unthrifty. Varieties vary in ***susceptibility***. See Avocado F 20. ***Macadamia mussel scale*** (*Lepidosaphes macadamiae*) mainly feeds on ***leaves***. Scales are 2-3 mm long, light brown, mussel-shaped. Leaves yellow around each scale, and may fall reducing tree vigour. ***Macadamia white scale*** (*Pseudaulacaspis brimblecombei*) is a minor pest in Qld and occurs on ***leaf undersurfaces*** and ***green nut husks***. Leaves may fall. Natural enemies may regulate numbers. See Citrus F 39.

Eriococcid scales (Eriococcidae): ***Macadamia felted coccid*** (*Eriococcus ironsidei*) is a ***major native pest*** of macadamia. ***Adults*** are 1 mm long and whitish-brown. Adult males are winged. Coccids infest all the above-ground parts of trees especially protected places, eg leaf axils, bark crevices, between buds and along the main veins under leaves. They cause distortion and stunting of ***young growth***, and yellowing and spotting of older ***leaves***. Heavy infestation reduces nut yields, causes dieback and may kill young trees. Many overlapping generations each year. ***Predatory ladybirds*** (*Midus pygmaeus*, *Rhizobius*, *Serangium*), ***parasitic wasps*** (*Aspidiotiphagus*, *Metaphycus*) and ***lacewings*** control populations except when the coccid is first introduced into an orchard. Varieties vary in ***susceptibility***. See Citrus F 41, Eucalypt K 63.

Soft scales (Coccidae): ***Long soft scale*** (*Coccus longulus*) may be a pest on ***non-bearing trees***, resulting in honeydew and sooty mould. Parasitic wasps, predatory ladybird beetles, and their larvae, and lacewing larvae usually provide acceptable control. See Citrus F 41.

Many ***parasites and predators*** feed on scales, including caterpillars of a moth (*Batrachedra arenosella*). ***Monitor*** scale and natural enemies on susceptible varieties before applying an insecticide. See Citrus F 39, F 41.

VERTEBRATE PESTS

Birds and ***rats*** eat nuts. See Fruit F 13.

Non-parasitic

Environment: Young trees are susceptible to ***frost***, but may be protected for the first few years by shade cloth at night. Varieties of *M. tetraphylla* are more tolerant of cool conditions than *M. integrifolia*. Rain or ***irrigation*** during summer is essential for a good crop. They must have good drainage. Trees crop well in semi-shaded positions but best results are obtained in full sun. Prevent ***sunburn*** damage to trunks and leaves and provide shelter from ***wind***.

Nutrient deficiencies, toxicities: Soil and leaf analyses determine nutritional requirements. ***Leaf analysis standards*** are available based on diagnostic and research analyses (Weir and Cresswell 1995). ***Magnesium deficiency*** is common, ***yellowing of new growth*** may be caused by a range of factors, not necessarily nutritional problems (Fitzell 1994).

Others: ***Macadamia decline:*** Macadamia trees > 10 years old especially Hinde (H 2) variety, develop a general decline which may lead to tree death. This appears to be caused by a complex of factors including *Phytophthora* root rot, marginal soils, low soil organic matter and poor development of proteoid roots. See Trees K 6 ***Glyphosate*** (Roundup®) drift may injure young trees. ***Graft failure*** may occur due to wood being cinctured and left too long on the donor tree before being cut or bacterial and fungal infections. Nuts of some species produce ***toxic cyanide compounds*** (O'Neill 1996). ***Fasciation*** may flatten stems.

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Vic Agnotes
Macadamia Nuts
Macadamias : Culture and Economics
WA Farmnotes
Sites, Layout and Irrigation for Nut Orchards
Associations, Journals etc.
Australian Macadamia Society (Technical Information)
Good Fruit and Vegetables
See Fruit and nuts F 14

Remember, always check for recent references

MANAGEMENT

An overview of the industry has been presented by Coombs (1995). Macadamia trees are large and evergreen. ***Cultivar selection*** is a key decision in profitability. Cross pollination between cultivars is beneficial in improving initial nut set. The introduced honeybee (*Apis mellifera*) and the stingless bee (*Trigonia carbonaria*) are important ***pollinators*** and so increase nut set (Bennet 1995). Introduction of beehives improves pollination and yield. Some varieties are ***resistant*** to cold and some nut spots. Only plant ***disease and pest-free*** nursery stock. Macadamia is ***propagated*** by budding and grafting on to rootstocks. Provide ***good drainage*** and ***windbreaks***. ***Fertiliser applications*** should be based on leaf and soil analysis. Use tensiometers or probes to monitor ***soil moisture*** levels. Water stress should be avoided during flowering and fruiting. ***Pruning*** is not normally required. ***Growth regulators*** may be used to aid harvest. ***Control weeds*** with a grassed interrow area and mulching along the tree rows. Any weeds which emerge through the mulch can be spot sprayed. Do not cultivate within 1 m of the trunk or use brush cutters. The ***most important pests*** include macadamia nut borers, flower caterpillars, fruitspotting bugs and felted coccids. ***Diagnostic programs*** are being developed at the University of Hawaii. ***Monitor*** pest populations weekly from flowering to nut maturity and only apply pesticides when economic damage is likely to occur. Pest monitoring minimises the number of pesticide application required as they are timed to obtain maximum effect (Brough et al. 1994, O'Hare and Vock 1990). Professional pest monitors may be consulted or employed. Nuts can be ***harvested*** directly from the tree provided they have tested mature, or from the ground. Nuts may be graded for market or stored.

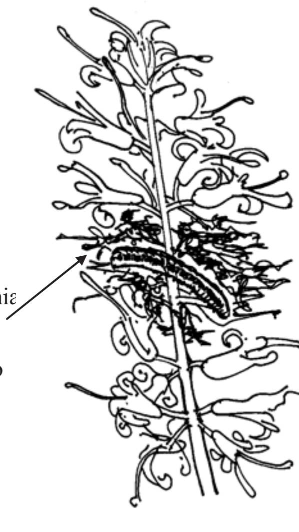

Fig. 135. Macadamia flower caterpillar (*Cryptoblabes hemigypsa*) is up to 20 mm long.

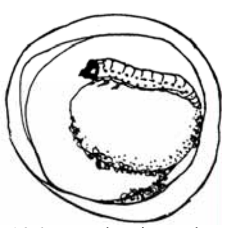

Fig. 136Macadamia nutborer (*Cryptophlebia ombrodelta*) is about 25 mm long

Fig. 137. Macadamia twig-girdler (*Xylorycta luteotactella*) is about 12 mm long.

Mango

Mangifera indica
Family Anacardiaceae (cashew family)

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial black spot (*Xanthomonas campestris* pv. *mangiferaeindicae*) commonly affects mango in the **field**, in high and low rainfall areas. It causes black raised angular areas on **leaves**, restricted by veins and often surrounded by a yellow margin (Fig. 138). Large areas may die. **Fruit** develop black oval raised areas with star-shaped cracks (Fig. 139). **Black stem cankers** are filled with gummy exudate. Kensington is very **susceptible** in windy areas and on trees lacking vigour. Select **resistant varieties**. **Copper fungicides** may be applied. See Stone fruits F 124.

FUNGAL DISEASES

Fruit rots

Anthracnose (*Colletotrichum* spp.) is an ***important field and postharvest disease*** of mango. Small black spots on **leaves** spread forming large dark dry areas. These often crack and fall out. Small, dark, irregular spots spread and coalesce to cause shedding and death of **flowers**. Small black specks on **fruit** enlarge to irregular dark areas. In moist atmospheres, ***pink spore masses*** appear towards the centre of these areas. Surface staining of fruit may result from spores washed over the fruit from diseased twigs or flower stalks. Infection of **young fruit** causes fruit drop. Anthracnose may invade green fruit and remain ***dormant*** until ripening. Cultivars vary in **susceptibility**. See Fruit F 5.

Alternaria rot (*Alternaria alternata*) is an ***important postharvest*** disease which develops only after ***prolonged storage.*** It causes small brown spots which develop into dark brown lesions at the **stem end of fruit**, a ***white-grey fungus*** may grow on the area Infection may occur before or after harvest but symptoms do not develop until fruit have ripened.

Rhizopus soft rot (*Rhizopus stolonifer*) is a minor sporadic ***postharvest*** disease of **fruit** cooled after harvest when ***moisture has condensed on the skin.*** Small pale spots develop in the peel, spreading rapidly in both peel and flesh. Under humid conditions, ***black spore bodies*** form on white whiskery fungal threads. See Fruit F 6.

Stem-end rots (especially *Dothiorella dominicana*, also *Lasiodiplodia theobromae* and *Phomopsis mangiferae*) are of ***moderate importance***. They cause dark brown firm decay starting at the **stem end** and spreading throughout the fruit. Fungus survives on dead **twigs and branches** where it produces large numbers of spores. Rot generally does not develop until fruit begins to ripen.

Minor rots: **Aspergillus rot** (*Aspergillus* spp., *A. niger*), **penicillium mould** (*Penicillium expansum*), **grey mould** (*Botrytis cinerea*), **mucor rot** (*Mucor circinelloides*), **stemphyllium rot** (*Stemphyllium vesicarium*).

See Fruit F 5.

Powdery mildew (*Oidium* sp.) sporadically affects **young shoots, flowers and small fruit** which are covered with white powdery growth. Affected **fruit** may fall prematurely, purplish-brown blotches appear on the skin of older fruit. ***Favoured*** by cool winter and spring weather when humidity is high. Mango cultivars vary considerably in their **susceptibility**. See Annuals A 6.

Root rots, wilts: ***Armillaria root rot*** (*Armillaria* sp.), ***phytophthora, grey fruit blotch*** (*Phytophthora nicotianae* var. *parasitica*), ***verticillium wilt*** (*Verticillium dahliae*). See Fruit F 7, Vegetables M 7.

Wood rots: **Pink limb blight**, pink disease (*Corticium salmonicolor*), **Fomes spp.** See Trees K 8.

NEMATODE DISEASES

Nematodes found associated with mango include ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematode*** (*Rotylenchulus reniformis*), also *Aphelenchoides* sp., *Lelenchus leptosoma* and *Paratrichodorus*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Noctuids, budworms (Noctuidae): **Mango shoot caterpillar**, large mango tipborer (*Penicillaria jocosatrix*) is grey-green and defoliates new shoots. Growth of nursery stock, young trees and top worked trees may be ***seriously set back***. Fruit stalks and young fruit may be damaged. Caterpillars pupate in soil. **Mango tipborer,** small mango tipborer (*Chlumetia euthysticha*) is a minor pest of mango and cashew. ***Caterpillars*** are yellow-green with rows of tiny red dots along the body. They bore into ***shoot tips*** causing them to wilt and die. Side shoots develop from just behind tips ***(witches broom)***. There are ***several generations*** each year. Eggs are laid on shoots. Caterpillars pupate in the tunnels. They can be controlled on young plants by pruning off damaged tips. Insecticides applied during growth flushes kill caterpillars before they tunnel into shoot tips. ***Others:*** ***Budworms*** (*Helicoverpa* spp.) and native ***flower eating caterpillars*** (several species) may feed on fruit stalks, young fruit. ***Monitor*** new growth regularly to determine mango shoot and mango tipborer egg numbers, caterpillars and damage before applying an insecticide (Brough et al. 1994). See Sweetcorn M 89.

Red-banded mango caterpillar (*Noorda albizonalis,* Pyralidae) tunnels in the ***flesh and seed*** of mango and kuini (*M. odorata*) and may cause heavy crop loss overseas. ***Quarantine risk:*** Red-banded mango caterpillar could be introduced in mangoes imported from areas where it occurs or from Papua New Guinea via the Torres Strait islands where mangoes are commonly grown (Com. of Aust. 1987).

See Annuals A 8, Fruit F 8, Trees K 13.

Fruit flies (Tephritidae, Diptera): ***Jarvis's fruit fly*** (*Bactrocera jarvisi*), ***lesser Queensland fruit fly*** (*B. neohumeralis*), ***mango fly*** (*B. frauenfeldi*). ***Mediterranean fruit fly*** (*Ceratitis capitata*) and ***Queensland fruit fly*** (*B. tryoni*) only attack mango fruit which is ***ripe or ripening***, especially of late-maturing varieties. ***Green fruit is not attacked***, and fruit picked in the green-mature stage need not be sprayed. Stung fruit often ripens and falls prematurely. Mangoes can only be sent to some interstate and overseas markets after prescribed fruit fly treatments. ***Papaya fruit fly*** (*B. papayae*) attacks ***fruit at a greener stage***, especially ***papaw, mango and banana***. See Fruit F 9, Papaw F 89.

Fruitpiercing moths (*Othreis* spp., others) pierce ***ripening fruit*** with their strong proboscises to suck juice leaving them honeycombed. ***Secondary fungi***, insects and mites may invade damaged fruit. Fermenting fruits may then be visited by ***secondary moth feeders***. Late maturing varieties are more ***susceptible***. See Fruit F 9.

Fruitspotting bugs (*Amblypelta* spp.) suck sap from ***young pink shoots*** causing them to wilt and die. ***Young fruit*** develop dark stains at puncture sites before falling and cracking, this may be accompanied by sap exudation. See Fruit F 10.

Leaf beetles Chrysomelidae, Coleoptera): ***Figleaf beetle*** (*Ponerida semipullata*) and ***redshouldered fruit beetle*** (*Monolepta australis*) chew ***leaves and flowers***. See Trees K 15.

Leafblotch miner (*Acrocercops* sp., Gracillariidae, Lepidoptera) is widespread and causes ***serious damage*** to neglected nursery stock, young trees in the field and topworked trees. Damage to older trees is slight. ***Leaves*** become blistered. See Azalea K 28, Macadamia F 78.

Mango planthopper (*Colgaroides acuminata,* Flatidae, Hemiptera) is a minor pest in north Qld during the fruiting period. Nymphs and adults suck plant sap from many plants including mango. These small, jumping, sap-sucking insects, with tent-like wings, congregate on ***shoots, leaf undersurfaces, flowers, fruit stalks and fruit***. Young fruit may fall. Areas adjacent to egg pods and nymphs are covered with a ***white powdery secretion***. Planthoppers secrete ***honeydew*** on which sooty mould grows which reduces fruit quality. ***Parasitic wasps*** exert considerable control on mangoes. ***Monitor*** planthoppers and eggs before applying an insecticide (Brough et al. 1994).

Mites (Acarina)

Mango bud mite (*Eriophyes mangiferae,* Eriophyidae) is a minor pest in summer. It sucks sap from lateral buds, twigs, flower panicles and new growth. ***New growth*** may be distorted, flowers and twigs may die. Trees may become leafless and non-producing. ***Bracts*** at the base of buds are darkly spotted. Severely prune in January then spray. See Citrus F 39.

Spider mites (Tetranychidae): ***Tea red spider mite*** (*Oligonychus coffeae*) sucks sap from tissue next to main veins, usually from the ***uppersurfaces*** of ***older leaves***. Leaves turn red-brown and may fall during in water stress. Cast skins of mites make leaves look dusty. Usually controlled by *Stethorus* and predatory mites which may be killed by overuse of pesticides. ***Monitor*** mite and egg populations at regular intervals. See Avocado F 19. ***Mango spider mite*** (*Oligonychus mangiferus*) may also infest mango. See Beans (French) M 29.

Redbanded thrips (*Selenothrips rubrocinctus,* Thripidae, Thysanoptera) infests avocado, cashew, guava, mango. ***Adults*** are dark with a red band on the 1st three abdominal segments. ***Nymphs*** are light orange with 1st and 2nd abdominal segments and anal segment bright red. Thrips suck plant sap from ***leaf undersurfaces*** causing silvering spotting with dark dried excreta. ***Monitor*** thrips numbers on leaf undersurfaces at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Greenhouses N 24.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Mango scales*** (*Aulacaspis tubercularis* and *Pseudaulacaspis cockerelli*) feed in clusters on both ***leaf surfaces***. They look like small white dots surrounded by a yellow halo. Leaves may fall and young trees die during hot dry weather. Scales on ***fruit*** is often ringed by a ***circle of pink tissue***. ***Female scales*** are circular, about 2 mm across and have conspicuous dark marks on one side. ***Male scales*** are more numerous, rectangular, about 1 mm long. Blemishes and presence of scales downgrade fruit quality. Postharvest pruning to open up tree canopy assists penetration of spray. ***Oriental scale*** (*Aonidiella orientalis*) also infests mango. See Citrus F 39, Papaw F 89.

Soft scales (Coccidae): ***Pink wax scale*** (*Ceroplastes rubens*), ***soft scale*** (*Coccus* sp.) and ***white wax scale*** (*Ceroplastes destructor*) are usually minor pests of neglected mango trees, infesting shoot tips, fruit stalks and fruit. Fruit size and tree vigour are reduced. Monitor scales. See Citrus F 41.

Weevils (Curculionidae, Coleoptera)

Mango seed weevil (*Sternochetus mangiferae*) infests mango, especially ***nursery stock***. ***Weevils*** are broad, hard, dark-brown and about ***10 mm*** long. ***Larvae*** are legless, cream with brown head capsules, and about ***18 mm*** long. Larvae feed within ***seeds***, destroying the kernel, and preventing germination in seedbeds. Flesh is not damaged. ***Complete metamorphosis*** (egg, larva, pupa, adult) with 1 generation each year. Weevils lay 1 egg on young fruit. Larvae bore through the flesh into ***developing seed*** and reach maturity in a few weeks when fruit is ripening. They pupate in seed. Adults may remain in the seed for many weeks before boring out through the seed cover and fruit. Adults ***overwinter*** in crevices in bark and sheltered sites near the tree on which they developed. ***Spread*** by introduction of infested mangoes. ***Plant quarantine:*** American, Japanese and middle east countries do not accept infested fruit. Qld Dept. of Primary Industries has a voluntary scheme to detect mango seed weevil in orchards before harvest. A phytosanitary certificate is issued to growers whose orchards are weevil-free. Fallen fruit must be removed from beginning to end of harvest. Do not introduce infested mangoes to weevil-free orchards. There is a recommended spray program (Brough et al. 1994).

Mango weevil (*Sternochaetus frigidus*) occurs overseas, eg in Irian Jaya. but is not known to occur in Australia. Larvae tunnel and feed in the flesh, making fruit unfit to eat. 80% of fruit may be attacked. ***Quarantine risk:*** Because there are no external signs of infestation, any mango fruit from areas where mango weevil occurs must be considered suspect (Com. of Aust. 1990).

Others: ***Aphids*** (Aphididae) and ***mealybugs***. Pseudococcidae). ***Fig leafhopper*** (*Dialecticopteryx australica*) causes leaf speckling. ***Termites*** (Isoptera) may attack trees in the NT, eating out the interior of branches. Strong winds or the weight of fruit will break damaged branches.

VERTEBRATES

Cockatoos and rabbits may chew branches or bark of young trees. ***Fruit bats*** (*Dobsonia* spp., *Pteropus* spp.) and possums damage fruit. See Fruit F 13.

Non-parasitic

Environment: Mangoes are easily damaged by ***frost***. Young trees are killed by even a light frost.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available based on diagnostic and research analyses (Weir and Cresswell 1995).

Postharvest diseases: Chilling, sapburn, lenticel spotting, failure of skin to yellow, sunburn, hot water scald, brushing and pressure damage and abnormal ripening cause ***external blemishes*** only (Bagshaw et al. 1989). Stem end cavity, jelly seed, impact damage and premature ripening cause ***internal symptoms*** (Bagshaw et al. 1989).

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NT Agnotes/Technotes etc.
Bacterial Black Spot of Mango
Dried Mango and Banana Marketing Summary
Electrified Mango Trees, Darwin (NT Technote)
Exporting Mangoes to Overseas Markets
Flowering & Fruiting in Mango in the Top End with Paclobutrazole
Growing Mangoes
Mango Anthracnose
Mangoes in the Backyard
Mango Irrigation Management Guidelines
Mango Management : Flowering to Market
Mango Pruning in the Top End
Mango Seed Weevil : A Major Quarantine Threat
Monitoring for Common Insect Pests of Mangoes

Others
Bacterial Black Spot of Mango at Kununurra (WA Farmnote)
Mangoes : Diseases and Disorders (Qld Farmnote)
Mango Growing in WA (WA Bull. 4125)
Mangoes in the Garden (NSW Agfact)

Associations, Journals etc.
Committee of Direction of Fruit Marketing (COD) : Mango Workshops, Mango SubCommittee
Qld Dept. of Primary Industries including the Horticulture Post-Harvest Group at Hamilton, Agricultural Research Laboratories at Indooroopilly, Maroochy Research Station

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

The mango is an evergreen tropical tree. Mango fruit have been treasured for at least 4,000 years and ancient travellers considered them to be the world's most delicious fruit. Today there are about 500 mango varieties; 98% of commercial mango plantations are of the ***Kensington cultivar***. Choose varieties with ***some resistance*** to bacterial blight, eg Sensation. Plant ***scale-free trees.*** Careful selection and vegetative propagation helps maintain the quality of cultivars. ***Propagation:*** Grafted trees bear fruit after 2-3 years. Seedlings need a year or two longer. ***Cultural methods:*** Avoid water stress during fruit development and maturation. Strategic pruning after flowering forces the development of new growth and reduces stem end rots. ***Sanitation:*** Remove litter and prunings from young orchards. ***Pest monitoring*** is essential. Use ***biological methods*** where possible. ***Effective control of postharvest pests and diseases*** in the ***field and in storage*** is important in ***reducing postharvest losses***. ***Harvest*** fruit at the correct stage. Fruit is often rejected because it is overripe. Cool immediately after harvest and store in well ventilated containers. ***Postharvest*** treat fruit as recommended. ***Cool store and control ripening*** to prevent postharvest diseases and ensure that fruit arrives in the state of ripeness preferred by the intended market. ***Plant quarantine:*** Disinfestation of mangoes to kill insect pests may be a quarantine requirement of many importing countries and for the movement of fruit into interstate markets. An overview of the industry has been presented by Coombs (1995).

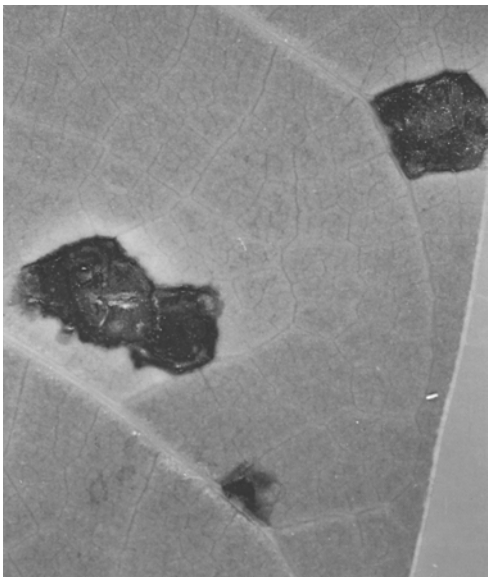

Fig. 138. Bacterial leaf spot (*Xanthomonas campestris* pv. *mangiferaeindicae*).
Left : Mango leaf lesions. ***Right :*** Leaf lesions often have a yellow margin and are bordered by leaf veins.
(Shivas, R. *Bacterial Black Spot of Mango at Kununurra.* WA Farmnote, WA Dept., of Agric.).

Fig. 139. Bacterial leaf spot (*Xanthomonas campestris* pv. *mangiferaeindicae*).
Lesions on mango fruit, variety Kent. (Shivas, R. *Bacterial Black Spot of Mango at Kununurra*. WA Farmnote, WA Dept., of Agric.).

Mulberry

Morus spp.
Family Moraceae (mulberry family)

PESTS AND DISEASES
Parasitic
Bacterial diseases
Bacterial blight
Fungal diseases
Fungal leaf spots
Grey mould (*Botrytis*)
Nematode diseases
Insects and allied pests
Fruit flies
Leafhoppers
Redshouldered leaf beetle
Silkworm
Scales
Twospotted mite
Vertebrate pests
Birds
Non-parasitic
Messy fruit

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial blight, bacterial leaf spot (*Pseudomonas syringae* pv. *mori*) is a ***serious disease*** of mulberry (more serious than fungal leaf spot). Both diseases are ***common*** and may occur simultaneously on the same tree, spoiling appearance and reducing fruit production. Premature leaf fall may cause sunscald. Twigs may generally dieback and young trees are stunted. Small irregularly shaped black spots (Fig. 140) surrounded by a yellow halo develop on new ***leaves,*** causing curling or distortion. Distortion does not occur when mature leaves are attacked. ***Expanding buds*** develop large blackened areas. Long, ragged, black, depressed cankers develop on ***young shoots,*** which often die. Bacteria ooze out from these cankers during wet weather. Bacteria ***overwinter*** in infected shoots and are ***spread*** by water splash and wind from infected leaves and twigs and also by the movement of infected nursery stock and other plant material. ***Favoured*** by wet weather and overhead irrigation of nursery trees. ***Control is difficult*** if trees are large. Routine use of sanitation and pesticides will gradually reduce the incidence of disease. In favourable seasons disease may flare up and cause extensive damage. In autumn, before leaf fall, ***prune out*** and burn all dead shoots to reduce bacterial carry-over to next season. During spring, prune out and burn blighted shoots when observed. In Australia, ***only protectant non-systemic fungicides***, eg copper fungicides, are available. They should be applied during budswell, 2 weeks later and after fruit set. However, trees usually grow too large to be sprayed safely. Overseas, the systemic antibiotic streptomycin may be used. If symptoms appear later, further sprays may be applied at about monthly intervals until new growth is disease-free. See Stone fruits F 124.

Others: ***Crown gall*** (*Agrobacterium* spp.) is a sporadic disease of mulberry. ***Large galls*** develop on ***trunks*** either at or below ground level. See Stone fruits F 125.

FUNGAL DISEASES

Fungal leaf spot (*Phleospora maculans,* Imperfect Fungi) may affect mulberry; other fungi may also cause leaf spotting, eg *Cercospora moricola, Mycosphaerella mori* and *M. morifolia*. Only ***leaves*** are attacked. Small dark brown dead spots the size of a pin-head develop on leaves early in spring, surrounded by a halo of greenish-yellow tissue. As leaf spots increase in size, they become ***circular*** and the centre becomes whitish but the margins remain dark brown (Fig. 141). Small pinpoint black dots (fruiting bodies) develop on the whitish centres. ***Sanitation*** easily controls this disease. In autumn rake up and destroy/burn all fallen leaves to remove the overwintering fungus. This should be done every year. Apply ***fungicides*** to new leaves and after fruit set to young trees (trees usually grow too large to be sprayed safely). The need for further applications depends on the weather. If bacterial blight and fungal leaf spot occur simultaneously on the one tree, then the spray program and sanitation measures recommended for blight control will also control leaf spot. See Annuals A 5.

Grey mould (*Botrytis cinerea*) develops on ***over-ripe fruit*** and as ***postharvest disease*** under humid conditions. See Fruit F 5, Greenhouses N 22.

Others: ***Armillaria root rot*** (*Armillaria* sp.), ***stem and twig cankers*** (*Fusarium lateritium*, *Gibberella moricola*), ***twig blight*** (*Fusarium lateritium* f.sp. *mori*), ***wood rots*** (various species).

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) have been recorded on white mulberry (*M. alba*) and other species. Small galls develop on roots. ***Root lesion nematode*** (*Pratylenchus coffeae*) on *Morus* sp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Fruit flies (Tephritidae, Diptera)
Queensland fruit fly (*Bactrocera*) *tryoni*)
Mediterranean fruit fly (*Ceratitis capitata*)
See Fruit F 9.

Leafhoppers (Cicadellidae, Hemiptera) suck sap from ***leaves*** causing leaf speckling. See Trees K 3 (Fig. 211), Vegetables M 15.

Redshouldered leaf beetle (*Monolepta australis*) feeds on ***foliage, flowers and fruit*** in spring and late summer. ***Twigs*** may become sunburnt and dieback. See Fruit F 11, Trees K 15.

Silkworm (*Bombyx mori,* Bombycidae, Lepidoptera) is used commercially overseas to produce silk. In Australia it is found only in domestication and feeds on white mulberry (*M. alba*), overseas also *M. multicaulis*. Some silkworms in China and India feed on oak leaves. **According to Chinese legend**, silk was discovered about 2,700 BC when the emperor ordered his wife to find out what was damaging his mulberry trees. She found that 'white worms' were eating them and spinning shiny cocoons. She is reputed to have accidentally dropped a cocoon into hot water. A delicate cobweb separated from the cocoon. On removing it from the water she found that a slender thread (silk) was unwinding itself from the cocoon. The Chinese guarded the secret of silk-making for about 3,000 years. Children keep silkworms today as pets. **Moths** have a wingspan of about 50 mm. They have a short and thick body and stout legs. **Caterpillars** (silkworms) are whitish and about ***80 mm*** long and nearly ***25 mm*** thick. There is a ***complete metamorphosis*** (egg, larva, pupa, adult) with several generations each year. Silk is produced in China by farmers. Female moths lay 300-500 eggs in early summer on special strips of paper and die soon afterwards. The eggs undergo tests to ensure they contain perfect disease-free caterpillars and are then put in cold storage. Next spring eggs are incubated to hatch into tiny silkworms which feed on mulberry leaves. When fully grown, they spin silken cocoons which are harvested (insects killed) before the pupa changes into a moth and emerges breaking the long silk thread. Some cocoons are allowed to develop into moths to provide eggs for the next crop.

Scales (Hemiptera)
Cottonycushion scale (*Icerya purchasi*)
San Jose scale (*Quadraspidiotus perniciosus*)
Natural enemies provide some control but **winter oil sprays** may be required. See Citrus F 39, F 41.

Twospotted mite (*Tetranychus urticae*) may suck sap from **leaf undersurfaces** causing them to become speckled. See Beans (French) M 29.

Others: **Green stink bug** (*Plautia affini*) may suck sap from ***ripening fruit***. **Orange fruitborer** (*Isotenes miserana*) may tunnel in ***fruit***. **Borers** (various species) may damage trunks of old trees.

VERTEBRATE PESTS

Birds are the ***most serious pest***. They damage ripening ***fruits***, it may be better to grow smaller trees (prune in summer or grow in pots) and cover with netting. See Fruit F 13.

Non-parasitic

Messy fruit: Mulberries tend to drop their fruit before it is fully ripe. Fruits are juicy and purple, and may ***stain*** if trees are planted near concrete paths or where they may be tramped inside.

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State/Territory Departments of Agriculture/Primary Industry eg
Mulberries in the Garden (NSW Agfact)
Two Common Diseases of Mulberries (NSW Agfact)
See Fruit and nuts F 14

Remember, always check for recent references

MANAGEMENT

Mulberries grow well in subtropical, temperate and cool climates and are often grown for summer shade. Fruit from white mulberry (*M. alba*) is generally not as sweet or the berries as large, as fruit from the purple varieties (*M. nigra*). ***Propagate*** by cuttings, budding and from trees ***free from*** bacterial blight and scale, also by seed. Trees usually bear fruit in the 2nd year. Mulberry trees are large and spreading, so need plenty of space. Apart from initial shaping, ***little pruning*** is needed except to contain size and remove unwanted limbs, and for easier picking and spraying. It is necessary to ***water*** regularly during summer to ensure good fruit production. The ***most serious problems*** are birds, bacterial blight, mulberry leaf spot and size. The flesh of fruit is soft making them difficult to transport and market. If the fruit is picked too early the taste is very sour, however, if left too late, fruit will drop off. Trees grow too large to be safely sprayed by home gardeners.

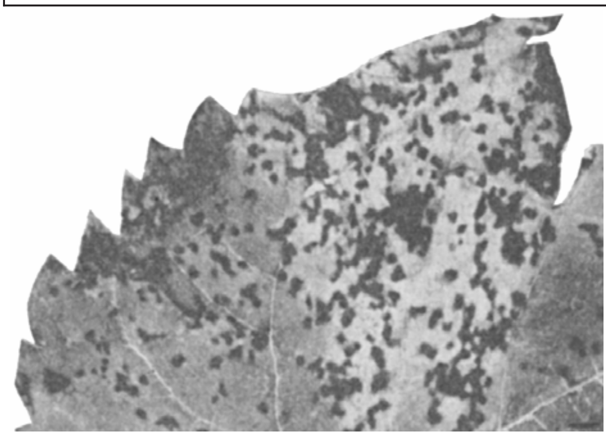

Fig. 140. Bacterial blight (*Pseudomonas syringae* pv. *mori*). Small black angular spots. Dept. of Agric., NSW.

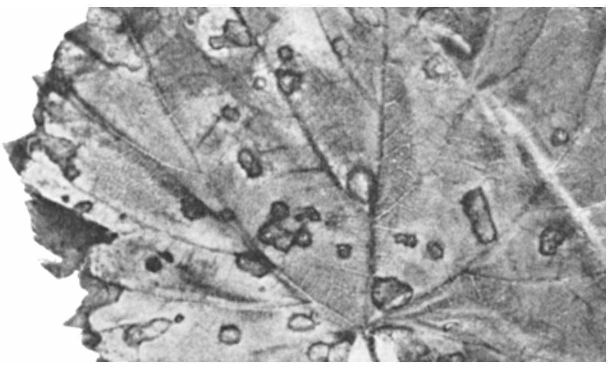

Fig. 141. Fungal leaf spot (*Phleospora maculans*). Large spots with dark margins and light-centres. Dept. of Agric., NSW.

Olive

Olea spp.
European olive (*Olea europaea*)
Family Oleaceae (olive family)

Australia is free of many of the serious diseases and pests of olives found in other countries.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas strawberry latent ringspot, cherry leaf roll, arabis mosaic, cucumber mosaic, olive latent ringspot, olive latent virus-1 and olive latent virus-2, are common on European olive (*O. europaea*) (Henriques 1994). ***Symptoms*** include sickle-shaped leaves, misshapen fruits, fasciated stems and tree decline; some are symptomless. Viruses may affect rooting of cuttings, vigour, and ability to withstand environmental stress.

BACTERIAL DISEASES

Bacterial gall, olive knot (*Pseudomonas syringae* subsp. *savastanoi* pv. *oleacae*) affects some Oleaceae including European olive (*Olea europaea*) in Europe and America but is not known in Australia (Fahy and Persley 1983). Small galls develop on ***twigs***. Infection takes place through wounds caused by hail, pruning, harvesting and frost. Varieties vary in resistance. See Oleander K 103.
Crown gall (*Agrobacterium* spp.) occurs occasionally on roots of olive trees. See Stone fruits F 125.

FUNGAL DISEASES

Fungal leaf spots

Peacock spot, flyspeck, olive leaf spot (*Cycloconium oleaginium*, Imperfect Fungi) causes round black spots on ***leaves, leaf petioles, fruit and fruit stalks*** of olives during wet years. If trees are weakened by insect damage, environmental stress or age, leaf fall and poor fruit set may be serious in a few localities.
Others: ***Leaf and fruit spot*** (*Cercospora cladosporoides*) may cause minor leaf spotting.

See Annuals A 5.

Others: ***Anthracnose*** (*Glomerella cingulata*), ***phytophthora root rot*** (*Phytophthora cinnamomi*), ***verticillium wilt*** (*Verticillium dahliae*), ***wood rot*** (*Heteroporus biennis*). ***Overseas*** also ***anthracnose***, soapy olive (*Gloeosporium olivarum*) which affects flowering and causes fruit rots, also ***olive shield*** (*Macrophoma dalmatica*) (IOOC 1993).

NEMATODE DISEASES

Citrus nematode (*Tylenchus semipenetrans*)
Root knot nematode (*Meloidogyne* spp.)
Sheath nematode (*Hemicycliophora arenaria*)
Also *Paralongidorus eucalypti*
See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Australian privet hawk moth (*Psilogramma menephron menephron*, Sphingidae) caterpillars feed on ***Oleaceae***, eg olives (*Olea* spp.), native mock olives (*Notelaea* spp.), privet (*Ligustrum* spp.), jasmine (*Jasminum*), ***Bignonaceae***, eg *Pandorea* spp., *Dolichandrone heterophylla,* ***Caprifoliaceae, Rosaceae, Scrophulariaceae,*** and ***Verbenaceae.*** ***Caterpillars*** are light green with diagonal white and lilac stripes on the body and a long stiff spine at the end of the body. They pupate in soil or leaf litter under the plant. Control is not usually necessary.
Eastern flat (*Netrocoryne repanda*, Hesperiidae) caterpillars feed on native mock olives (*Notelaea fasciculosa, N. longifolia*).
Emperor moth (*Syntherata janetta,* Saturniidae) caterpillars feed on citrus, guava, olive, pepper (*Schinus molle*), ***Rutaceae***, eg *Euodia elleryana*, *Geijera salicifolia*, ***Euphorbiaceae***, eg *Glochidion ferdinandi*, *Petalostigma quadriloculare*. Also *Aegiceras, Ceriopis, Terminalia*, *Timonius rumphii* and *Podocarpus spinulosus* (Common 1990).
Olive moth (*Prays oleae*, Yponomeutidae) caterpillars feed on ***flowers, fruit kernels*** and bore into ***leaves***, but is not known to occur in Australia.

See Annuals A 8, Fruit F 8.

Olive lace bug (*Froggattia olivinia*, Tingidae, Hemiptera) infests ***Oleaceae*** including the native olive (*Notaleae longifolia*) and European olive (*Oleae europaea*) in subtropical and temperate regions and may be a ***serious pest*** in some inland areas. ***Adult bugs*** are about ***3 mm*** long and brown with lacy wings. ***Nymphs*** are spiny. Nymphs and adults suck sap from ***leaf undersurfaces*** causing a yellow mottling of ***leaves*** which may brown and fall. Undersurfaces become covered with a tarry excrement. Olive lace bug also forms ***flower galls*** on the introduced olive (CSIRO 1991). On native olives, lace bug is usually controlled by ***natural enemies.*** On commercial olives, if damage has been severe the previous season, insecticides may be applied, commencing in spring when new growth emerges. See Azalea K 28.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Oleander scale*** (*Aspidiotus nerii*) (female) is about 1-2 mm across, circular, whitish-brown. See Oleander K 104. ***Olive parlatoria scale*** (*Parlatoria oleae*) is usually an uncommon pest of olives. ***Adult females*** are dirty grey, broadly oval, about 1.5 mm long and darker towards the head end. ***Males*** are elongate and much smaller than the females. There seems to be only 1 generation per year. Scales infest ***leaves, twigs and fruit***. If infestation is heavy, fruit may be deformed. On ripening fruit, single scales are often surrounded by a dark purple coloration. ***Red scale*** (*Aonidiella aurantii*) is an ***important pest*** of olives in dry inland areas, or where trees grow in dusty sites. Unchecked infestations may cause ***leaf fall, and twig and branch dieback***. ***Fruit*** may be reduced in size and pock marked, making it unfit for either picking or oil production. See Citrus F 39. ***Ross's black scale*** (*Lindingaspis rossi*) is black and sticks very tightly to the leaf surface. See Banksia K 32.

Soft scales (Coccidae): ***Black scale*** (*Saissetia oleae*) is a ***serious and common pest*** of olive and may cause ***leaf drop***, shoot shrinkage and a decrease in flowers. Do not confuse with lenticels on the stems which are very obvious. ***Soft brown scale*** (*Coccus hesperidum*) may also infest olive but is smaller and flatter than black scale. Both scales produce honeydew on which sooty mould grows, disfiguring fruit and leaves. See Citrus F 41.

See Citrus F 39, F 41.

Others: ***Black vine weevil*** (*Otiorhynchus sulcatus*) and other weevils may chew leaf edges and fruit. Larvae feed on roots. ***Twospotted mite*** (*Tetranychus urticae*) may infest leaves. ***Pests not known to occur in Australia*** include ***olive fruit fly*** (*Dacus oleae*), ***olive moth*** (*Prays oleae*), ***olive psyllid*** (*Euphyllura olivina*), a ***pyralid moth*** (*Glyphodes unionalis*), a ***scolytid beetle*** (*Pholeotribus scarabeoides*) and ***olive thrips*** (*Liothrips oleae*) (IOOC 1993).

Non-parasitic

Environment: Spring flowers may be damaged by ***late frosts*** in highland areas. Olives are shallow-rooting, but have narrow leaf surfaces and so are ***fairly drought tolerant***. Trunks and fruit may be ***sunscalded***.

Others: Excessive use of ***oil sprays*** (>1% petroleum oil) affects the appearance of fruit and makes it less suitable for processing, and can also harm trees. Olive trees may become ***urban weeds***.

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Olive Growing in Australia (H. T. Hartmann,
Olive Growing in California (H. T. Hartmann,
Olives in the Home Garden (NSW Agfact)
Olive Varieties (H. C. Mort, NSW Agric)

Associations, Journals etc.

Australian Olive Assoc.
Australian Olive Oil Assoc.
GrowSearch (database, Qld DPI)
International Olive Oil Council (IOOC) (magazine Olivae)
Internat. Symp. on Olive Growing (Acta Hort) 1989, 1993
Olive Growing in Australia Pioneering Assessment
Olive growing in California
RIRDC Dryland Olive Growing and Oil Processing in SA
Irrigated Olive Growing and Oil Processing in SA

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Olives are evergreen trees grown as ***ornamentals*** or for their ***fruit,*** which may be pickled in brine or pressed for olive oil. An overview of the industry has been presented by Coombs (1995). Cold winters and long hot summers and good water supply during fruit formation are necessary for good fruit production. Olives have a tendency to ***biennial bearing***, which is increased by high nitrogen mulches (eg grass clippings), well maintained trees and hard pruning. Olives do shed a certain amount of fruit after set but rarely sufficient to ensure good fruit size at harvest. Fruit may be ***thinned*** with growth regulators or by hand. Sevillano usually produces sufficiently large fruit without thinning. Only plant ***scale-free nursery stock*** and plant in ***disease and pest-free soil***, eg free from black vine weevil. ***Propagate*** by budding or grafting onto seedling rootstocks, also by hardwood and tip cuttings. Cuttings imported into Australia are screened for specified viruses and olive knot, then grown in ***post-entry quarantine***. Plant any time from autumn to spring in ***well drained soil*** to discourage *Phytophthora* root rot. Keep roots moist during transplanting and water well during the first summer to encourage development of a good root system. In dry summers ***irrigate*** regularly to prevent fruit drop. Olives have higher tolerance to alkaline and saline soils than many other fruit crops. Olives produce most of their fruit on shoots arising from the previous year's wood, so need ***little pruning*** other than to open up the tree centre to allow better control of black scale and check vigorous growth. ***Weeds*** should be controlled. For green pickling, ***harvest*** fruit when mature but not coloured (skin can vary from green to pale straw). For ripe pickling, pick when fruit are firm and dark blue or purple. Bruised fruit does not pickle well.

Papaw

Papaya, pawpaw

Carica papaya
Family Caricaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Dieback, mosaic and yellow crinkle (phytoplasma): Dieback is the ***most serious*** of these and 10-100% of trees may die; it is the ***most serious limiting factor*** of the Australian papaw industry (Gibb et al. 1996). ***Dieback*** typically causes a bunched appearance of the ***inner crown leaves***, with one or more of these shrivelling and dying. ***Larger crown leaves*** rapidly ***yellow***, then die. Young plants invariably die from dieback, older plants may have a recovery phase if the affected stem is cut and apparently healthy side shoots develop from lateral buds. ***Leaf mosaic*** is sporadic and of minor importance. ***Yellow crinkle disease*** causes a pronounced yellowing of leaves about halfway up the canopy, accompanied by a bending of the petioles. ***Flowers*** are green leaf-like structures. ***Young fruit*** fall in the early stages of disease but larger fruit may remain. ***Favoured*** by epidemics of ***common brown leafhopper*** (*Orosius argentatus*) after hot dry weather when it migrates from weeds to papaw and other hosts. Remove and burn affected trees. Plant excess trees, diseased trees can be removed without greatly reducing the stand.

Papaya ringspot virus was detected in Australia in 1991 in south east Qld and the area quarantined. It affects papaw and cucurbits causing mottling, vein-clearing and distortion of young ***leaves***, rings and spots on ***fruit***, and streaks on ***stems*** and ***petioles***. Plants are stunted, fruit set is reduced. ***Spread*** by melon aphid (*Aphis gossypii*), green peach aphid (*Myzus persicae*), not by seed. Leaf distortion is favoured by cool weather. Use ***resistant*** or tolerant cultivars, observe ***quarantine regulations***, destroy diseased trees as they will not produce a good crop and are a source of infection (Com. of Aust. 1992).

See Fruit F 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas caricapapayae*) is a minor disease causing small angular brown spots on papaw ***leaves***. See Vegetables M 5.

Papaw crown rot bacterium (PCRB) (*Erwinia caricae*) causes ***dieback*** in the Philippines. Young leaves yellow and die. Stem tips die, older leaves wilt.

FUNGAL DISEASES

Fruit rots

Fruit is susceptible to a number of different rots.

Anthracnose (*Colletotrichum* spp.) is a ***common*** and ***serious postharvest*** disease.

Black rot (*Phoma caricae-papayae*) commonly causes black shrunken rots of ***young fruit*** and a stem end rot ***post harvest***. See Fruit F 2 (Fig. 97).

Black spot (*Asperisporium caricae*) causes spots on ***fruit*** and ***leaves***.

Phomopsis rot (*Phomopsis caricae-papayae*) causes moderate ***postharvest*** fruit losses.

Phytophthora fruit rots (*Phytophthora nicotianae, P. palmivora*) are ***serious*** in hot wet regions. They affect ***green fruit, fruit, stems and leaves.***

Rhizopus soft rot (*Rhizopus stolonifer*) is a sporadic ***postharvest*** transit rot.

Others: Fruit spot (*Botryodiplodia theobromae*), ***fusarium fruit rot*** (*Fusarium solani*), ***stem end rot*** (*Mycosphaerella* sp.), ***leathery fruit spot and stem-end rot*** (*Alternaria alternata*), also *Botryosphaeria ribis.*

Symptoms occur more often towards the ***stem end of the fruit***. Rots are often only skin deep but spoil appearance and reduce marketability. Some of these fungi spread to the fruit when ripening begins. Others remain ***dormant in green fruit tissue*** until it begins to ripen when they develop rapidly. ***Favoured*** by wet weather and fruit injuries. Trees planted in cold exposed places, and low winter temperatures favour disease development by prolonging ripening and giving the fungi more time to develop. Fruit exposed to cold, wind and sun often ripen prematurely and are prone to rotting. ***Minimise disease incidence*** by planting varieties which have some ***resistance*** to fruit rot, and which ripen quickly and evenly. Establish plantations in warm sheltered areas. ***Remove*** all rotting fruit from the vicinity of the packing shed. Handle fruit carefully to avoid injury. Harvest fruit at correct ***maturity***, ie pick early and ripen artificially. Spray with a ***fungicide*** prior to harvest and dip fruit postharvest to control fruit rots (Persley et al. 1993). See Fruit F 5.

Fungal leaf spots

Angular leaf spot (*Leveillula taurica*) initially affects ***older leaves*** and moves upwards. causing small scattered angular patches of white mildew on ***leaf uppersurfaces*** (delimited by veins) and yellowish patches with diffuse margins on ***uppersurfaces***.

Brown spot (*Corynespora cassicola*) causes brown rounded spots up to 5 mm across on ***leaves***, elliptical brown spots on ***stems***, and sunken spots on ***fruit***. Control measures are not warranted.

See Annuals A 5.

Powdery mildew (*Sphaerotheca* spp.) causes white powdery areas on ***leaves, stems and fruit***. As fruit develops the white mould disappears leaving light grey scarred areas. It can cause ***serious fruit blemishes***. Spores are ***spread*** by wind and rain. Most active during winter months. It disappears with spring growth but fruit harvested in midsummer may show scars from early infections. Fungicides are registered for control. See Annuals A 6.

Root and trunk rots, wilts

Damping off (*Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani*) may occur on ***seedlings***. See Seedlings N 66.

Phytophthora root rots (*Phytophthora cinnamomi, P. palmivora*) may occur. See Trees K 6.

Pythium root and trunk rot (*Pythium* spp.) may occur in the NT. ***Leaves*** yellow and wilt, starting with the older leaves first. The ***root system*** is much reduced and the remaining roots have a soft rot which may extend into the trunk. ***Trunk rot*** is usually associated with scale infestation, even with quite light levels of infestation.

Others: ***Sclerotinia rot*** (*Sclerotinia sclerotiorum*), ***sclerotium stem rot*** (*Sclerotium rolfsii*), ***verticillium wilt*** (*Verticillium dahliae*).

See Fruit F 7, Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.) may cause ***severe damage*** to ***roots***, in all areas, especially in sandy soils. Other nematodes have also been recorded in association with papaw, eg ***burrowing nematode*** (*Radopholus* sp.), ***foliar nematode*** (*Aphelenchus avenae*), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus dihystera, Rotylenchus* spp.), also *Criconema mutabile, Macrosposthonia* spp., *Paratrichodorus* spp., *Scutellonema brachyurum.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Fruit flies (Tephritidae, Diptera), eg ***Mediterranean fruit fly*** ***(MFF)*** (*Ceratitis capitata*) in WA, can cause damage throughout the year but is more ***serious*** during the warmer months. In the eastern states, infestation by the ***cucumber fly*** ***(CF)*** (*Bactrocera cucumis*) which is a minor pest, may be more likely than by ***Queensland fruit fly*** ***(QFF)*** (*B. tryoni*). ***QFF*** is dark reddish-brown, whereas ***CF*** is pale yellow-brown and has a conspicuous yellow stripe along the middle of the upper thorax, which is not on ***QFF***. Fruit flies may be a problem if fruit is left to mature on the tree. Fruit picked green-mature for interstate trade is unlikely to be infested. Fruit flies are active in warm, humid weather and generally come into papaws from alternative hosts, not from within the crop. ***CF*** is attracted into sheds where cucurbits (especially zucchinis) are being packed. If ripe papaws are being packed at the same time they may be infested. Dipping in insecticide after harvest may be required for some markets, eg Melbourne. ***Papaya fruit fly*** ***(PFF)*** (*B. papayae*) unlike existing fruit fly pests in Australia, attacks ***fruit at a greener stage***, especially ***papaw, mango and banana***. It has a wide range of host species and is considered to attack all botanical fruit except pineapple, chokos, beans, peas and macadamias. ***PFF*** has a black thorax, paler abdomen with a distinctive black T-shape marking on its back (QLD DPI Inspector's Manual 1995). See Fruit F 9.

Fruitpiercing moths (*Eudocima* spp., *Othreis* spp.) may pierce ***fruit*** and cause damage late in summer-autumn. Harvest fruit when 'mature green'. See Fruit F 9.

Fruitspotting bugs: ***Fruitspotting bug*** (*Amblypelta nitida*) and ***banana-spotting bug*** (*A. lutescens*) are ***major pests*** of papaws in some areas. Damage is worse in late summer and autumn. Adults and nymphs suck sap from ***growing points*** on young papaw trees, causing severe stunting in plant growth and crinkling of the young leaves. Damaged ***fruit*** develop dark sunken spots where sucking occurred, the skin at these sites may crack, making fruit unmarketable. ***Adults and nymphs*** are difficult to see and usually the first sign of their presence is the damage they have caused. See Fruit F 10.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) is a minor pest. Affected ***leaves*** have prominent veins, down-curled edges, bronzed and shiny undersides, and are thick and brittle. Leaves become distorted. Affected trees usually recover. See Greenhouses N 26.

Twospotted mite (*Tetranychus urticae*) and other spider mites (*Tetranychus* spp.) may cause ***extensive damage*** throughout the year but more seriously during the warmer months. Feeding produces pale mottled areas on ***leaves*** initially adjacent to the midribs. Mite damage is detected first on the older, lower leaves where infestation has developed for a longer time than on the younger leaves. These older leaves appear yellow-brown and in severe infestations the fine webbing spun by the mites can be seen. See Beans (French) M 29.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Oriental scale*** (*Aonidiella orientalis*) is flat, circular and yellow, orange or pinkish and may be a ***serious pest*** of papaw. It also attacks mango. It affects trunks, leaves and fruit. Damage to the ***trunk*** will cause a complete collapse of the tree. Scale on ***fruit*** causes uneven fruit ripening around each scale. ***Natural enemies*** include a small black parasitic wasp (*Comperiella lemniscata,* Encyrtidae) which parasitises adult scales, another wasp (*Encarsia*) parasitises up to 95% of immature scales, and predators (*Chilocorus* spp., *Telsimia* sp., Coccinellidae). The parasitic wasp (*Aphytis melinus*) used to control red scale (*Aonidiella aurantii*) may also control this scale. Some of these agents can be purchased. ***Insecticide*** spraying may increase scale populations by destroying natural enemies. Oil-based sprays will only be moderately successful because of coverage problems (fruit clusters around the trunk). Ensure that trunk, leaves and fruit are sprayed to run-off. Several applications will be necessary until the scale is observed to be dead (live scale exude fluid when a thumb nail is pressed into the top of them). See Citrus F 39.

Soft scales (Coccidae): ***Soft brown scale*** (*Coccus hesperidum*) may infest papaw. Parasitic wasps (*Metaphycus* spp.) provide some control. See Citrus F 41.

See Citrus F 39.

Yellow peach moth (*Conogethes punctiferalis*) caterpillars often feed in the ***main growing point*** of papaw and cause dieback. Branches further down may start growing vigorously. Caterpillars may also tunnel into ***fruit***, usually where one fruit touches another. If control is necessary, remove and destroy infested fruit, and/or apply insecticides soon after petal fall. See Stone fruits F 133.

Others: ***Grasshoppers*** (Acrididae, Orthoptera) cause minor damage in Kununurra in WA if fruits are allowed to ripen on the tree. Harvest while fruit is a 'mature green'.

VERTEBRATE PESTS

Birds, fruit bats and ***possums*** can attack ripe fruit. Harvest fruit when they are 'mature green'. See Fruit F 13.

Non-parasitic

Environment: Exposure to ***frost***, slows growth and reduces fruit production. Light frosts damage ***leaves*** and continued frosty conditions may kill ***established trees***. Star-shaped greyish spots about 6 mm across may occur on the surface of exposed sides of ***green fruits*** after frosts and very cold weather. In cooler areas grow mountain papaw (*C. candamarcensis*) which is frost hardy once established and fruits well in cool climates. Provide good ***drainage*** to avoid root rots.

Milky sap of papaw trees can be irritating to human skin and eyes. It may damage fruit on tree.

Nutrient deficiencies, toxicities: ***Potassium deficiency*** causes yellowing of young leaves, death of the stem tip and dieback. ***Leaf analysis standards*** are available for papaw (Burt and Toohill 1989, Weir and Cresswell 1995).

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Babaco (NSW Agfact)
Costs and Returns for Papaws (NT Agnote)
Diseases of the Papaw (NSW leaflet)
Growing Papaws (NT Agnote)
Pawpaw Growing (NSW Agfact)
Papaw in the Garden (NSW Agfact)
Papaws : Site Selection, Plantation Layout and Land Preparation (Qld Farm Note)
The Mountain Pawpaw (Vic Agnote)
The Papaya Fruit Fly (Qld DPI, Inspector's Manual, 1995)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Papaws prefer high temperatures, humidity and rainfall. An overview of the industry has been presented by Coombs (1995) and Douglas (1995). They bear male flowers only, female flowers only, or are hermaphrodites with bisexual flowers. It is therefore necessary to have female plants to bear fruit and male plants to produce the pollen. It is not possible to tell male from female plants until they flower. Select varieties with some ***resistance*** to ripe fruit rots and only plant ***Phytophthora-free*** plants in disease-free soil. ***Propagated*** by seed. ***Replacement trees*** should continually be planted because bearing only continues for about 5 years and there are fewer pests and disease problem; also plants get too tall and unmanageable. Replanting areas which have been affected by *Phytophthora* should be avoided. Do not thin overcrowded fruits on trees as ***sap from cut fruit stems*** will blemish remaining fruit. ***Harvest*** fruit when it is mature but before it is fully ripe. It will ripen off the tree in a warm room. In warm weather, rapid cooling is essential to maximise shelf life.

Passionfruit

Purple or black passionfruit (*Passiflora edulis*)
Family Passifloraceae (passionflower family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cucumber mosaic virus (CMV) causes symptoms similar to passionfruit woodiness virus at lower temperatures. ***Fruit*** are woody, ie small and misshapen with an abnormally thick, hard rind and small pulp cavity. ***Young fruit*** may have a distinct dark green, lumpy mosaic. The skin may develop bright red blotches which changes to a diffuse yellow. Yield is affected, in cold winters all fruit may be woody. ***Spread*** by more than 60 species of aphids, by mechanical inoculation, by handling and by sap carried on hands, clothes and tools, sometimes by seed, vegetative propagation and grafting. See Cucurbits M 50.

Passionfruit woodiness virus (PWV) causes an important disease of most cultivated and wild *Passiflora* spp., also peanut, centro (*Centrosema pubescens*), soybean, *Phaseolus atropurpureus*, *P. vulgaris, Cassia coluteoides*, many Fabaceae. Strains occur and symptoms may be hardly noticeable (mild strains) to severe stunting (severe strains). ***Leaves*** may show yellow mottles or flecks (Fig. 142), become crinkled and develop light and dark green mosaic patterns. Translucent areas between veins or vein clearing may occur. ***Fruit*** may have ringspots, blisters or be woody, ie small and misshapen with an abnormally thick, hard rind with a small pulp cavity (Fig. 143). Generally there are projecting bumps on the fruit (do not confuse with fruit fly stings). Some or all fruit may be affected. ***Spread*** by cotton aphid (*Aphis gossypii*), green peach aphid (*Myzus persicae*), by grafting, by mechanical inoculation (hands, tools).

Tip dieback (PWV and CMV) may initially cause wilting of young leaves, which yellow and later die. Laterals curl downwards. Stems become thick and brittle and easily snap off. Within 3-4 weeks the whole vine shows a general tip dieback. ***Older leaves*** develop yellow ringspots and fruit skin develops bright red blotches then a diffuse yellow colour. Fruit is malformed, flabby, fails to fill, rind is abnormally thick. Young fruit may have a lumpy mosaic.

Overwinters in infected host plants, weeds. Temperature influences ***symptoms*** of both ***PWV*** and ***CWV+PWV***, the most obvious appearing from 10-15^{o}C. Infected leaves formed at high temperatures may show no apparent symptoms. Select vines during winter when symptoms are more obvious. Symptoms also appear more in vines under stress, eg waterlogging, drought. ***Control:*** Once vines become infected they cannot be cured; take measures to minimise losses. ***Cultural methods:*** Plant in a warm site with a northerly aspect, sheltered from wind. Plant in spring so vines are well established before the following autumn. Keep vines growing vigorously. Control leaf spot diseases which weaken vines. Install soil moisture measuring instruments and maintain soil moisture at recommended levels. ***Sanitation:*** Destroy all infected vines, if they have grown into adjacent vines, vines on either side should also be cut out. Keep plantations and surrounds weed-free. ***Resistant varieties:*** Purple passionfruit (*P. edulis*) is highly susceptible to ***PWV*** but cultivars react differently. Some hybrids, eg *P. edulis* Sims x *P. edulis* f. *flavicarpa,* tolerate severe strains, ie develop few woody fruit but develop leaf mosaics. Redlands Triangular is very susceptible to ***PWV***. ***CMV*** can infect all hybrids, Lacey hybrid appears more tolerant. ***Disease-free planting material:*** Major commercial passionfruit plantings carry a mild infection of ***PWV*** that does not adversely affect vines. This was bred into hybrids in the 1950s in order to prevent field infection by more virulent strains that appeared at the time. Severe strains can overcome this mild strain protection. They do not occur frequently but when they do they may cause a rapid degeneration of vines. Plant grafting tips or scionwood that has been approved by ***Passionfruit Scionwood Accreditation Schemes***. ***Pesticides:*** Aphid vectors may be controlled in commercial plantings. See Fruit F 4.

BACTERIAL DISEASES

Grease spot (*Pseudomonas syringae* pv. *passiflorae*) and ***Xanthomonas campestris pv. passiflorae*** have been recorded on passionfruit (*P. edulis*) (Fahy and Persley 1983). Grease spot causes round dark green greasy blotches on ***fruit*** and brown spots with a wide pale yellow halo on ***leaves***.

FUNGAL DISEASES

Fungal leaf and fruit spots

Alternaria spot (*Alternaria alternata*) has a wide host range, is common and can cause serious losses. Small dead spots surrounded by yellow halos up to 6 mm wide with diffuse margins develop on young ***leaves***. On older leaves, dead tissue is surrounded by a yellow or light orange halo. ***Fruit*** develop small brown greasy spots surrounded by dark green tissue up to 5 mm across. A tear stain effect occasionally develops down the side of fruit.

Anthracnose (*Glomerella cingulata*) is a ***pre-harvest*** disease most easily recognised on ***leaves, stems and fruit*** as tiny brown-black fruiting structures on dead tissue. As a ***postharvest*** disease it develops following infection of ***mature fruit*** in the field. Fruit collapse and develop a wrinkled appearance. Symptoms develop quickly after harvest. Removal of affected fruit at packing is essential to prevent breakdown during transport to market. The fungus is a common inhabitant of dead tissue and is spread by wind and water. It is ***favoured*** by warm wet weather. See Fruit F 5.

Brown spot (*Alternaria passiflorae*) affects *Passiflora edulis*, some wild *Passiflora* spp., particularly white passion flower (*P. subpeltata)*, stinking passion flower (*P foetida*) and *P. quadrangularis.* ***Leaves*** develop small circular spots, at first brown but later developing a lighter coloured central area. Older spots, circular to angular in outline, may be up to ***25-30 mm*** in size. Severely affected vines may lose nearly all their leaves. ***Stems and canes*** develop elongated dark brown areas. These usually commence at the point of attachment of a leaf and develop along the cane. Canes may be completely ringbarked, so that they suddenly wilt and die. ***Fruit*** develop light brown circular sunken spots which enlarge and wrinkle and may cover one side of the fruit, which shrivel and fall. Under wet conditions secondary soft rot organisms may gain entry. ***Favoured*** by warm moist weather.

Grey mould, *Botrytis* fruit rot (*Botrytis cinerea*) may affect fruit ***postharvest***. See Fruit F 5, Greenhouses N 22.

Phytophthora blight (*Phytophthora nicotianae* var. *parasitica*) affects many crops, eg citrus, passionfruit, pineapple, strawberry, tomato, tobacco. ***Young tip growth*** blackens and dies. Large watersoaked areas on leaves become light tan. Affected ***leaves*** fall readily and vines may be defoliated. Diseased areas on ***stems*** are at first purple and later turn brown above the graft union. These areas may girdle stems causing wilting; vines may die. ***Fruit*** develops large grey-green watersoaked areas. Fruit fall readily and in wet weather become covered with a white fungal growth. ***Overwinters*** in soil. Spores are initially produced in wet soil beneath vines and splashed onto lower leaves. Further spread occurs during wet, windy weather. Grow grass under vines. See Trees K 6.

Scab (*Cladosporium herbarum*) causes small circular translucent spots, which later become covered with grey powdery spores, to develop on ***leaves, stems and young fruit*** (on fruit the spots become raised and scabby). ***Favoured*** by cool humid weather.

Septoria leaf spot (*Septoria passifloricola*) causes brown spots up to 2 mm across with minute black dots (fruiting bodies) develop on ***leaves*** which fall, defoliating vines. ***Fruit*** develop light brown blotches studded with minute black fruiting bodies. Blotches may join together to cover large areas which ripen unevenly. ***Favoured*** by warm moist weather.

Spores are ***spread*** during windy wet weather. All are ***favoured*** by extended wet weather, close planting, dense vine growth and old vines. Do not plant vines too closely, permit as much open growth as possible. ***Train vines*** systematically to facilitate future pruning. Vines should be regularly and ***systematically pruned*** to remove infected canes, reduce density and allow better spray penetration. A spray program may be required. See Annuals A 5, Fruit F 5.

Root, stem and crown rots, wilts

Fusarium wilt (*Fusarium oxysporum* f.sp. *passiflorae*) can be a ***serious disease*** of *Passiflora* spp. In hot weather the whole vine can suddenly wilt and die. The disease is first noticed as a wilting of one or more shoots and is often followed by a total collapse of the plant. If an infected stem is examined, the ***water-conducting tissues*** will be discoloured brown or reddish-brown. Avoid disease by buying vines that have been grafted on to ***Fusarium-resistant seedling rootstock*** of the golden passionfruit (*P. edulis* f. *flavicarpa*). A seed line highly resistant to Fusarium wilt is available from Qld Department of Primary Industries. See Vegetables M 9.

Others: ***Armillaria root rot*** (*Armillaria* spp.), ***damping off*** (*Phytophthora*, *Pythium*, *Rhizoctonia solani*), ***phytophthora blight*** (*Phytophthora* sp.), ***pythium root rot*** (*Pythium* spp.), ***rhizoctonia root rot*** (*Rhizoctonia solani*), ***sclerotinia rot*** (*Sclerotinia sclerotiorum*). See Vegetables M 7.

Trunk and twig cankers

Twig canker (*Botryosphaeria obtusa*)
Trunk canker (*Phytophthora* sp.)
See Trees K 5.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) causes vines to look unhealthy and grow poorly, small feeder roots have galls. ***Other nematodes***, eg ***root lesion*** (*Pratylenchus* sp.), ***spiral nematode*** (*Helicotylenchus dihystera*), *Paratrichodorus minor* and *Scutellonema* sp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Bugs and hoppers (Hemiptera)

Fruitspotting bug (*Amblypelta nitida*) sucks sap from ***fruit***, causing minor sunken dark spots and making fruit unmarketable. See Fruit F 10.

Green mirid bug (*Creontiades dilutus*) in late spring-summer sucks sap from ***terminal shoots*** of young vines, stopping growth. Growing points wither and eventually fall out. If attack continues lateral tips may also be attacked and destroyed. See Vegetables M 12.

Green vegetable bug (*Nezara viridula*) sucks sap from ***young green fruits*** causing sunken spots. Fruit is unmarketable. If bugs are numerous, fruit will fall. A minor pest. See Vegetables M 12.

Passionvine bug (*Fabrictilis gonagra*, Coreidae) is a minor pest of passionfruit, citrus, cucurbits and many other plants. ***Adult bugs*** are about ***18 mm*** long, dull black with a red band behind their heads and red spots on the body underside (Fig. 144). Bugs suck sap from developing ***green fruits***, causing sunken spots and making fruit unmarketable.

Passionvine hopper (*Scolypopa australis*, Ricaniidae) is a native ***sporadic minor pest*** of passionfruit. It attacks a wide range of native and cultivated plants, including passionfruit and weeds. ***Adults*** are about ***8 mm*** long with brown bodies and mottled brown and clear areas on the wings. They are often mistaken for small moths (Fig. 145). They hop or fly when disturbed. ***Nymphs*** are wingless, squat, brownish and have ***white filaments like tail feathers*** (Fig. 145). Adults and nymphs suck sap from ***stems***

and leaves in late spring and summer. Heavy infestations may cause wilting and yellowing of leaves and leaf fall. ***Honeydew*** is produced which encourages sooty mould. ***Young green fruit*** may shrivel and fall when bugs feed on the fruit stalks. There is a ***gradual metamorphosis*** (egg, nymph and adult) with one to several generations each year. An ***egg parasite*** (*Centrodora scypopae*), other parasites and predators probably provide some control. If ***insecticides*** are considered necessary, spray insects on the vine, and escaping insects on the ground beneath, thoroughly.

Rutherglen bug (*Nysius vinitor*) is a small grey silver winged native bug which may swarm on vines, feeding on ***stems and foliage***. It can kill plants and ***fruits*** up to the size of a walnut. Even larger fruit wilt and may fall (caused by the bugs clustering on the fruit stalks, hidden at first by the dried-up floral parts that form a collar around it). Water stress may also cause young green fruits to shrivel. It is important to ***diagnose*** the problem correctly. See Stone fruits F 130, Vegetables M 12.

Monitor green vegetable bug, passionvine bug, and fruitspotting bugs regularly prior to making a decision to apply an insecticide (Brough et al. 1994). See Vegetables M 12.

Fruit flies (Tephritidae, Diptera) may sting young ***green fruit***, producing boil-like swellings which persist to maturity and lower market quality of fruit. Very young fruit shrivel and fall but older fruit may grow to maturity. Most eggs do not hatch except in thin skinned fruits where maggots may reach the fully fed state and pupate inside the fruit. The emerging flies are imprisoned inside the hard rind and die. ***Control fruit fly*** on nearby ***hosts***, eg citrus, guava, peach, tropical fruit. ***Monitor male fruit fly*** numbers by hanging pheromone traps and count ***stung fruit*** regularly, prior to apply an insecticide (Brough et al. 1994). If monitoring is not carried out, apply fruit fly bait or sprays at the first sign of infestation. See Fruit F 9.

Mealybugs (Pseudococcidae, Hemiptera)

Citrus mealybug (*Planococcus citri*) are about ***3-4 mm*** long and covered with a white mealy powder. They gather at ***leaf bases*** and under ***dead leaves*** where they pierce the vine, suck sap, and produce honeydew which leads to ***sooty mould*** on ***leaves*** and ***fruit***. The combined effect of sap sucking and sooty mould results in loss of vigour, leaf drop, fruit malformation, and may kill the vine. Citrus mealybug is usually suppressed by predators. See Citrus F 38.

Passionvine mealybug, Pacific mealybug (*Planococcus pacificus*) especially during late summer and autumn, congregate at ***leaf nodes***, infest ***runners and fruit*** and can also found on the ground under dead leaves and debris. Mealybugs can be a ***major pest*** and heavy infestations cause defoliation. Excreted honeydew promotes sooty mould on fruit and leaves. ***Ants*** attend mealybugs and interfere with the natural parasites and predators. ***Female mealybugs*** are white, oval and about ***3-4 mm*** long; they lay eggs in a loose, cottony mass. There are ***many generations*** each season. ***Parasitic wasps*** (*Leptomastidea abnormalis, Ophelosia* spp.) and ***predators***, eg maculate ladybird (*Harmonia octomaculata*), lacewing larvae (*Oligochrysa lutea*) and the mealybug ladybird (*Cryptolaemus montrouzieri*), regulate populations. *Cryptolaemus* is the ***most important predator***, and if absent, should be released. Because of the difficulty of obtaining good spray coverage, chemical control is only partially successful. Keep weeds down and vines up off the ground to assist ant control. ***Monitor*** mealybug numbers and *Cryptolaemus* regularly prior to making a decision to apply a pesticide (Brough et al. 1994).

See Greenhouses N 25.

Mites (Acarina)

Passionvine mite (*Brevipalpus phoenicis,* Tenuipalpidae) may be a ***major pest*** of passionfruit. It also attacks mango, citrus, lychee, guava, coffee, pawpaw, grevillea and other plants in summer and autumn in Qld and north coast NSW. ***Adult mites*** are sluggish, reddish-brown and about ***0.25 mm*** long. They lie very flat on the plant surface and feed in colonies sucking plant sap in leaf axils, along grooves of terminal shoots and leaf stalks and along the main veins of leaves. Large scabby areas appear on ***stems and branches***. Heavy infestations may cause defoliation. Stems and branches may die. Fruit damage is not as common. There is a ***gradual metamorphosis*** (egg, 3 nymphal stages, adult) with several generations each year. Bright red oval eggs about 0.1 mm long are stuck firmly to leaf undersurfaces or crevices on stems. ***Spread*** by vegetative propagation from infested plants, and mites crawling. ***Predatory mites*** provide some natural control. ***Monitor*** mite populations at regular intervals before applying an insecticide (Brough et al. 1994).

Twospotted mite (*Tetranychus urticae*). See Beans (French) M 29.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Red scale*** (*Aonidiella aurantii*) can be a ***major pest of older vines***, infesting ***stems, runners, leaves and fruit***. Leaves yellow and fall, reducing plant vigour and killing vines. See Citrus F 39.

Soft scales (Coccidae) produce abundant ***honeydew*** which attracts ***ants*** and encourages ***sooty mould*** which disfigures leaves and fruit. Soft scales are minor pests. ***Black scale*** (*Saissetia olea*) is common on vines. Adult females are concave, bun-shaped, dark brown and about 3 mm long and 2 mm wide. They cluster along stems and main veins of ***leaves***, especially on undersurfaces. ***Soft brown scale*** (*Coccus hesperidum*) infests individual vines, clustering along ***leaf*** and ***fruit stalks*** and along the main veins of ***leaves***. Copious honeydew attracts ants. See Citrus F 41.

To assist ***ant control***, keep vines off the ground and control weeds. Ensure planting material is ***scale free*** and avoid establishing new blocks adjacent to heavily infested plantings. Control scale on old plantings or remove infested vines ***before introducing new scale-free plants***. Dip plants before planting out. ***Monitor*** scales and natural enemy activity, before applying insecticides (Brough et al. 1994). High scale populations usually require ***treatment*** of the whole block but heavy infestations on main stems or on individual vines may be spot sprayed. Thorough application is essential when most scales are young. See Citrus F 39, F 41.

Weevils (Curculionidae, Coleoptera)

Fuller's rose weevil (*Asynonychus cervinus*) is ***8-10 mm*** long and feeds on ***leaf edges*** in summer and autumn. It produces a saw-tooth effect and may severely restrict growth, especially of plants just climbing up wires. Weevils feed at night but can usually be found during the day clustered among the foliage or in the growing tips. They do not attack fruit. See Roses J 6.

Ground weevil (*Mandalus* sp.) is small, brown and about ***3 mm*** long. It chews ***young shoots and leaves*** at night, and halts growth of newly planted vines in early summer. As new plants are often covered with brush to prevent scorch and to reduce transpiration and evaporation, damage may be very advanced before it is noticed. Weevils shelter in soil by day and remain motionless when disturbed.

Whitestriped weevil (*Perperus lateralis*) is small, light grey, about ***6 mm*** long and has a white stripe along the length of each wing cover. It may be troublesome in spring in the high districts near Gosford. It feeds at night by gnawing the ***growing tips and green bark*** of the main stem, retarding growth of young vines.

Others: ***A weevil*** (*Oemethylus triangularis*) chews ***stems*** bases at ground level of newly-planted vines leaving them looking like frayed rope. Older established plants are not susceptible.

Control as for other weevils, eg spray over plants and soil surrounding them at transplanting. See Trees K 17, Vegetables M 17.

Others: ***Ants*** are attracted to honeydew produced by mealybugs and soft scales, sooty mould grows on the honeydew. ***Aphids*** (Aphididae, Hemiptera), eg ***cotton aphid*** (*Aphis gossypii*) and ***green peach aphid*** (*Myzus persicae*), are minor pests; they feed on passionfruit while migrating through an area and spread virus diseases. ***Earwigs*** (Dermaptera) may chew holes in leaves. ***Fig longicorn*** (*Acalolepta vastator*) larvae tunnel in the stems. Many old vines have a single larvae in the stems but sometimes 4-5 are found in a swollen root base. ***Fly leafminer*** (Agromyzidae) maggots occasionally tunnel in leaves of young passionfruit, stunting growth. It is thought that it is kept in check by parasitic wasps. No control is necessary. ***Greenhouse thrips*** (*Heliothrips haemorrhoidalis*) in late summer may damage ***foliage and fruits*** on heavily-foliaged vines in protected situations. Leaves become leaden grey and are marked by spots of black excrement from thrips. Leaves turn brown and fall. Fruit surfaces are similarly blemished. ***Redshouldered leaf beetle*** (*Monolepta australis*) may repeatedly swarm on vines during spring and summer chewing ***leaves and green shoots***. Also ***African black beetle*** (*Heteronychus arator*), ***painted apple moth*** (*Teia anartoides*), ***termites*** (Isoptera).

Non-parasitic

Environment: Passionfruit damaged by ***frost*** are more susceptible to diseases. ***Soil dryness*** in the early stages of fruit development may cause fruit drop. In later stages fruit may crinkle. Fruit is also severely affected by very high or very low ***temperatures***, wet weather during blossoming or by watering flowers, all of which damage the pollen. ***Wind*** may damage fruit.

Nutrient deficiencies, toxicities: ***Excess nitrogen*** causes vines to grow lushly but may result in a failure of fruit to set. ***Too little nitrogen*** may cause leaves to yellow. ***Leaf analysis standards*** are available (Weir and Cresswell 1993, 1995).

Pesticide injury: High rates of ***copper sprays*** can leave unsightly residues on fruit. ***Maldison-protein hydrolysate baits*** applied to the vine itself may cause leaf and flower drop (McMaugh 1994).

Poisonous passionfruit: ***Wild passionfruit*** (*Passiflora subpeltata*) is toxic to cattle, pigs and sheep. Young green plants are more toxic than the fruits (McBarron 1983).

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A Strategy for Controlling Passionfruit Disease (NSW Agnote)
Avocados : Cultural and Financial Aspects (NSW Agfact)
Avocado Diseases (NSW Agfact)
Brown Spot of Passionfruit (NSW Agfact)
Establishing Passionfruit Vines (NSW Agnote)
Growing Passionfruit in Western Australia (WA Farmnote)
Insect Pests of Passionfruit (Qld DPI Leaflet 1345 1976)
Passionfruit Diseases (Qld DPI Leaflet 1346 1978)
Passionfruit in the Garden (NSW Agfact)
Passionfruit Varieties (NSW Agnote)
Woodiness & Dieback Diseases of Passionfruit (NSW Agfact)

Association, Journals etc.

Budwood schemes
Good Fruit and Vegetables

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Purple passionfruit (*P. edulis*) is generally grown in cooler and temperate zones of Australia for fresh fruit or processing. It is a subtropical vine which only tolerates light frosts. In sub-tropical and frost-free areas hybrids are grown, some of which have ***some resistance*** to severe strains of woodiness virus and *Fusarium* wilt, eg *P. edulis* x *P. flavicarpa* is tolerant of passionvine woodiness virus. Some selections of golden passionfruit (*P. flavicarpa*) are used as rootstocks because they have some ***resistance*** to *Fusarium* wilt. Unfortunately they are easily killed by frost. Purchase and plant ***disease-free*** nursery stock, tips and scionwood from certified budwood schemes. ***Propagation*** by seed, by grafting onto rootstock. Passionfruits are ***pruned*** mainly to allow light into the vine to assist in promoting healthy growth. This will result in the vine bearing fruit for a longer period each year. In cooler areas plant in areas sheltered from frost and wind. ***Pesticides:*** Spraying may be necessary for fruit rots and fungal leaf spots. Passionfruit is difficult to spray thoroughly. ***Monitor*** scales and other pests and disease. ***Harvest*** when skin is purple, it is liable to drop at this stage. Fruit picked green and cool stored may not colour evenly after removal from storage. Treatment may overcome colour problems. Skin readily loses its moisture causing it to shrivel but this does not affect the juicy interior. To avoid shrivelling, harvest early in the morning and store in plastic bags or coat with a thin layer of petroleum jelly. ***Store*** to reduce moisture loss. Pulp may be frozen or canned.

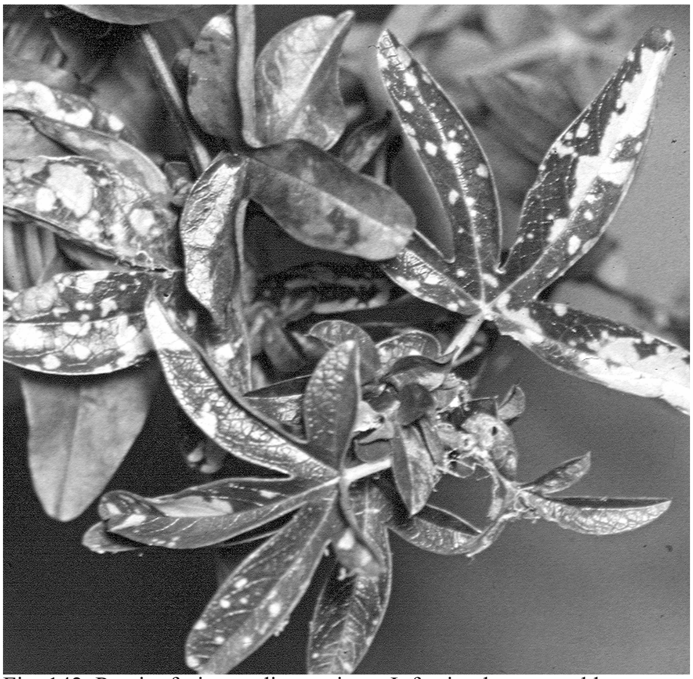

Fig. 142. Passionfruit woodiness virus. Infection has caused leaves to develop a yellow mottle.

Fig. 143. Passionfruit woodiness virus.
Left : Thick skinned woody fruit.
Right : Healthy fruit. Dept. of Agric., NSW.

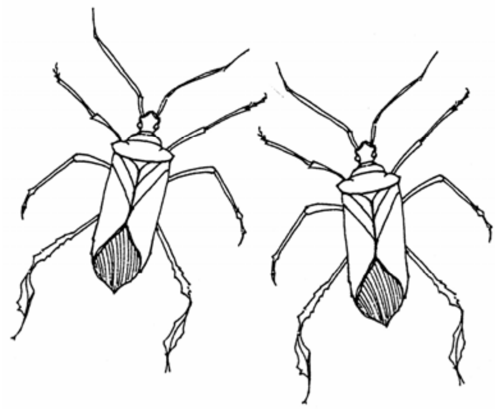

Fig. 144. Passionvine bug (*Fabrictilis gonagra*) (about 18 mm long).

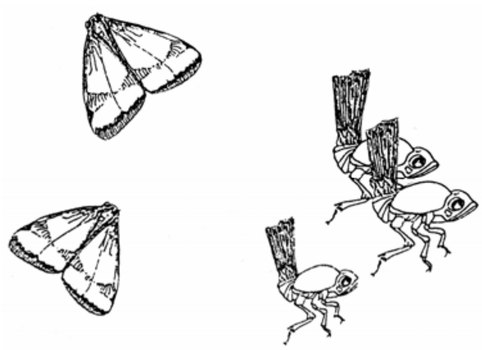

Fig. 145. Passionvine hopper (*Scolypopa australis*). ***Left :*** Moth-like adults (about 8 mm long). ***Right :*** Nymphs with 'tail feathers'.

Peanut

Ground nuts, earth nuts, monkey nuts
Peanut (*Arachis hypogaea*)
Family Fabaceae (pea family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Salmonella
- **Fungal diseases**
  - Aspergillus pod mould
  - Fungal leaf spots
  - Root and stem rots, wilts
  - Rust
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Leafhoppers
  - Peanut mite
  - Pineapple mealybug
  - Postharvest pests
  - Scarab beetles
  - Whitefringed weevil
- **Vertebrate pests**

Non-parasitic
  - Environment
  - Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Peanut mottle virus affects peanut, gambia pea, soybean, burr medic, sieva bean, French bean, pea, adzuki bean. It causes a mild mottle or patches of dark green tissue on ***leaves***, but no obvious reduction in growth. Occasionally it results in small and poor ***quality seed***. ***Spread*** by cowpea aphid (*Aphis craccivora*), cotton aphid (*A. gossypii*), sowthistle aphid (*Hyperomyzus lactucae*), green peach aphid (*Myzus persicae*), oat aphid (*Rhopalosiphum padi*), by seed in some hosts to a variable percentage. Initial infection in a crop generally results from use of diseased seed, but it may also be spread by aphids from volunteer peanut plants and other peanut crops. Spread may be rapid and disease incidence high. No is control available.

Peanut stripe virus or peanut mild mottle virus, is not known to occur in Australia. If introduced it may cause significant losses in peanut and other crops. Symptoms on peanut vary with the cultivar and the virus isolate but it commonly results in green blotches on ***leaves***. Some isolates produce discontinuous dark green stripes along lateral veins on young leaves and these develop into a mosaic pattern of green islands, or an oak-leaf pattern as plants age. Symptoms persist in older leaves. Plants infected when young are stunted. ***Spread*** by green peach aphid (*Myzus persicae*), cowpea aphid (*Aphis craccivora*) between and within crops, by seed (up to 37% in some cultivars). ***Plant quarantine risk*:** Illegal imports of infected seed or accidental spillage of peanuts imported for food. Eradication would be difficult because of rapid spread by aphids and wide host range. Legal imports of peanut and other legume hosts are grown post-entry in quarantine for testing. (Com. of Aust. 1990).

Others: ***Bunchy plant*** (a mycoplasma-like organism (MLO), possibly tomato big bud) is a minor disease. ***Spread*** by leafhoppers. Affected plants have spindly pale green shoots with large numbers of small leaflets in leaf axils. Stems are shortened towards tips and plants appear bunched. Flowers may be green but are usually replaced by green shoots with miniature leaflets. Pegs turn upwards instead of entering the ground and forming pods. See Tomato M 97. ***Passionfruit woodiness virus*** causes dead and yellow areas or streaks, mottling and wrinkling. Symptoms persist. ***Spread*** by cotton aphid (*Aphis gossypii*), green peach aphid (*Myzus persicae*) and by mechanical inoculation. See Passionfruit F 91. ***Rugose leaf curl*** (rickettsia-like organism) is a minor disease. Plants are stunted, with small upright, narrow, pale green leaves. Youngest leaves may be pinched and curled. ***Spread*** by spotted leafhopper (*Austroagallia torrida*). Hosts include legumes, eg clovers and lucerne. ***Tomato spotted wilt virus*:** Plants may be stunted with small distorted leaves with green/yellow ringspots. Brown spots and streaks may also develop on leaves, leaf stalks and stems. Plants may look bunchy. Stem tips may die. ***Seed*** from diseased plants is distorted, smaller and often marked, yield is reduced. Incidence is high only if numerous weed hosts are present nearby. Differences in susceptibility amongst cultivars cannot be attributed to differences in thrips populations (Culbreath et al. 1994). See Tomato M 96.

Shoot meristem cultures are being researched to ***eliminate viruses*** from vegetatively maintained peanuts. See Fruit F 4.

BACTERIAL DISEASES

Salmonella bacteria may contaminate peanuts used for the manufacture of peanut butter.

Others: ***Bacterial wilt*** (*Pseudomonas solanacearum*) has been recorded on peanut in Qld but is rare.

FUNGAL DISEASES

Aspergillus pod mould, gold-green mould (*Aspergillus flavus*) can produce an ***aflatoxin*** which is toxic to humans and livestock. Aflatoxin in a batch of peanuts renders them unmarketable, or involves stringent and costly cleaning procedures. ***Pods*** may be infected with *A. flavus* before or after harvesting. Infection of pods before harvesting is ***favoured*** by water stress in the podding zone during the 30-40 days before maturity, and insect damage. After digging, infection in the field or in store is ***favoured*** by humid conditions due to late rains or storing pods at too high a moisture level. No chemical control is known. ***Avoid preharvest infection*** by late season irrigation or early planting to avoid late season water stress. Maintain healthy plants and control soil pests. ***Avoid postharvest infection*** by good aeration of field curing peanuts after digging, storing peanut pods with a kernel moisture of < 12%, and keeping storage humidity low. See Fruit F 5.

Fungal leaf spots may cause ***serious damage*** during wet seasons, ***defoliating plants and reducing yield***. The type of irrigation and nutrition may affect the severity of leaf spots.

Leaf spotting fungi include:
- Early leaf spot (*Cercospora arachidicola*)
- Late leaf spot (*Cercosporidium personatum*)
- Leaf spots (*Mycosphaerella* spp.)
- Net blotch (*Didymosphaeria arachidicola*)
- Pepper spot and scorch (*Leptosphaerulina trifolii*)

See Annuals A 5.

Root and stem rots, wilts

Aspergillus rot (*Aspergillus niger*) is a common soil inhabitant and spores are always present in the air. May cause pre-emergence ***damping off*** of seeds or post-emergence death of seedlings. Occasionally near mature plants may develop ***lower stem rot***. Seed dressing is essential. Also avoid stress including over-wet or drought conditions. See Fruit F 5, Peanut F 96.

Damping off, pre-emergence rots (*Aspergillus flavus, A. niger, Fusarium, Penicillium*, *Pythium*, *Rhizopus arrhizus*, *Rhizoctonia solani*). See Seedlings N 66.

Other stem and root rots: ***Cylindrocladium black stem and root rot*** (*Cylindrocladium crotalariae*) causes decay of ***tap roots***. ***Diplodia blight or stem rot*** (*Diplodia natalenisis*, Imperfect Fungi) causes rapid wilting of one or more branches due to ***stem infections***. ***Also pythium root rot*** (*Pythium myriotylum*), ***sclerotinia rot*** (*Sclerotinia sclerotiorum, S. minor*), ***sclerotium crown rot*** (*Sclerotium rolfsii*), ***verticillium wilt*** (*Verticillium dahliae*). ***Rhizoctonia stem rot,*** rhizoctonia limb blight (*Rhizoctonia solani*) is a major disease overseas.

See Fruit F 7, Vegetables M 7.

Rust (*Puccinia arachnidis*) can ***defoliate bushes*** and ***reduce yields***. See Annuals A 7.

Others: ***Black rot*** (*Calonectria crotalariae,* ***grey mould*** (*Botrytis cinerea),* ***pod rot, seedling blight*** (*Botryodiplodia theobromae*).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne hapla*)
Root lesion nematodes (*Pratylenchus* spp.)
Burrowing nematode (*Radopholus nigeriensis*)
Also *Macroposthonia ornata.*
See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Cowpea aphid*** (*Aphis craccivora*) and ***green peach aphid*** (*Myzus persicae*) transmit virus diseases of peanuts but cause only minor feeding damage. See Roses J 4.

Bugs (Hemiptera): ***Peanut trash bug*** (*Elasmolomus sordidus,* Lygaeidae) and ***green vegetable bug*** (*Nezara viridula*) are minor pests. See Vegetables M 12.

Caterpillars (Lepidoptera)

Budworms (Noctuidae) feed on leaves:
- Cluster caterpillar (*Spodoptera litura*)
- Corn earworm (*Helicoverpa armigera*)
- Native budworm (*H. punctigera*)
- See Sweetcorn M 89.

Lucerne seed web moth, etiella moth (*Etiella behrii*, Pyralidae) is a ***major pest*** of peanuts and native and cultivated legumes. Caterpillars tunnel in the soil and enter developing ***peanut pods***, chewing the ***seed*** and allowing entry of *Aspergillus flavus*.

See Annuals A 8, Fruit F 8.

Leafhoppers (Cicadellidae, Hemiptera)

Lucerne leafhopper (*Austroasca alfalfae*) is yellow-green. Nymphs and adults suck plant sap from ***leaves*** causing silvery spots on foliage and yellowing of the leaf tips.

Vegetable leafhopper (*A. viridigrisea*) is blue-green, ***3-4 mm*** long, and causes damage similar to the lucerne leafhopper. See Vegetables M 15.

Leafhoppers only need to be controlled if damage is severe and plants are stressed due to lack of moisture. See Vegetables M 15.

Peanut mite (*Paraplonobia* sp., Tetranychidae, Acarina) may attack peanuts during dry weather. ***Adults*** are spider mites about ***0.5 mm*** long, dark green to blackish, sometimes with reddish markings, and 4 pairs of legs. ***Young nymphs*** have 3 pairs of legs and develop through several moults. Nymphs and adults feed on ***leaves*** causing yellowing and leaf drop. ***Young seedlings*** may die during dry weather. Eggs are laid in soil at the base of plants, where they hatch in a few days. Mites ***overwinter*** as eggs in soil and ***spread*** by crawling. ***Clean fallow*** after each peanut crop to reduce infestation of the subsequent crop. ***Rain*** reduces populations. See Beans (French) M 29.

Pineapple mealybug (*Dysmicoccus brevipes*) is a minor and sporadic pest causing stunting and ***poor nut quality***. It is usually only a problem on poorly drained sites. See Greenhouses N 25, Pineapple F 104.

Postharvest pests include:
Angoumois grain moth (*Sitotroga cerealella*)
Bean weevil (*Acanthoscelides obtectus*)
Cockroaches (Blattodea)
Confused flour beetle (*Trilobium confusum*)
Dried fruit beetles (*Carpophilus* spp.)
Flat grain beetles (*Cryptolestes* spp.)
Granary weevil (*Sitophilus granarius*)
Indian meal moth (*Plodia interpunctella*)
Lesser grain borer (*Rhizopertha dominica*)
Mediterranean flour moth (*Ephestia kuehniella*)
Merchant grain beetle (*Oryzaephilus mercator*)
Mites (Acarina)
Psocids, booklice (Psocoptera)
Redlegged ham beetle (*Necrobia rufipes*)
Rice weevil (*Sitophilus oryzae*)
Rust-red flour beetle (*Trilobium castaneum*)
Sawtoothed grain beetle (*Oryzaephilus surinamensis*)
Tropical warehouse moth (*Cadra cautella*)
Warehouse beetle (*Trogoderma variabile*)
Others: The introduced ***bruchine beetle*** (*Caryedon serralis*) feeds in stored peanuts. See Seeds N 75.

Scarab beetles, white grubs (Scarabaeidae, Coleoptera) may be ***major and frequent pests***.

Canegrubs (*Lepidiota* spp.) feed on soil humus and plant ***roots***. Older larvae attack ***shells*** and ***peanut kernels***, reducing yield and quality.
Peanut scarabs, white grubs (*Heteronyx* spp.): ***Beetles*** are brown and ***6-7 mm*** long. ***Larvae*** are creamy-white with a dark head capsule, curled into a C-shape and are about ***25 mm*** long. Young larvae feed on ***plant roots and humus***. Older larvae feed on developing ***nuts and shells***. Only 1 generation each year. Eggs are laid in soil at base of plants and hatch within 3 weeks. Pupation occurs in soil and beetles emerge after rain from November to March.

See Turfgrasses L 11.

Whitefringed weevil (*Graphognathus leucoloma*) chew ***tap roots*** causing plants to lose vigour or die. See Vegetables M 17.

Others: ***Redshouldered leaf beetle*** (*Monolepta australis*) is a minor and sporadic pest. ***False wireworms*** (*Gonocephalum* spp., *Pterohelaeus* spp.) and ***thrips*** (Thripidae) may also damage peanuts.

VERTEBRATE PESTS

Mice and rats damage stored peanuts. Seed is not only eaten but contaminated with faeces as well.

Non-parasitic

Environment: Plants are very susceptible to ***frost***. ***Computer simulations*** identify soil types and climates suitable for peanut growing.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for peanut crops (Weir and Cresswell 1994).

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Diseases of Peanuts (NT Agnote)
Field Crop Insect Control in Peanuts (NT Agnote)
Fungicidal Influence on Peanut Seed Gemination (NT Technote)
Growing Peanuts in the Northern Territory (NT Agnote)
Peanut Drying : In Storage Drying (Qld Farmnote)
Peanuts : Control of Important Diseases in Southern Queensland (Qld Farmnote)
The Economics of Peanut Production (NT Agnote)
Weed Control in Peanuts (NT Agnote)
Associations, Journals etc.
Grain Research and Development Corporation
Peanut Marketing Board of Queensland

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Peanuts are eaten raw, roasted, ground for peanut butter or crushed for peanut oil. An overview of the industry is presented by Coombs (1995). Peanuts are semi-erect annual legumes like beans and peas. Virginia Bunch and Red Spanish are the two most widely grown varieties in Australia. ***Resistant varieties:*** Select varieties with ***some resistance*** to stem rots which attack lower stems and crowns near soil level, eg Virginia Bunch. ***Varieties resistant*** to ***cylindrocladium black stem and root rot*** (*Cylindrocladium crotalariae*), ***fungal leaf spots*** (*Cercospora arachidicola*, *Cercosporidium personatum*) and ***root knot nematodes*** (*Meloidogyne* spp.) are being developed overseas (Shew et al. 1995). ***Disease-free planting material:*** Plant high quality seed free from diseases, eg virus diseases, and pests, and which has been treated with fungicide. ***Propagated*** by seed which should be dusted with fungicide before sowing. Peanuts are grown in tropical, subtropical and warm temperate climates and need a long warm growing season of 5 months. They prefer sandy well drained soil through which pegs can penetrate easily. ***Practise crop rotation***, cultivate to eliminate weeds, crop debris and volunteer peanut plants. ***Weeds*** may also be controlled by post-emergence or pre-emergence herbicides. Water adequately and regularly. The crop is ready to dig about 16-22 weeks after sowing. ***Harvest:*** After flowers are pollinated, the flower pegs (called pegs by peanut growers) lengthen and push downwards into the soil. The pods, containing 1-4 kernels, develop underground. Samples of pods are made prior to harvest to ensure correct timing. ***Storage:*** Avoid peanuts becoming contaminated with *Aspergillus flavus* or *Salmonella* bacteria which are injurious to human health. Pods must be dried postharvest either naturally or artificially prior to storage, which should be water-proof, vermin-proof and preferably with ventilation control.

Pecan

Carya illinoensis
Family Juglandaceae (walnut family)

Numerous serious diseases and pests which do not occur in Australia, affect pecan trees overseas.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Bunch diseases are undetermined but are thought to be caused by virus-like organisms. They are not known to occur in Australia (Com. of Aust. 1991).

BACTERIAL DISEASES

Crown gall (*Agrobacterium* spp.) may cause galls to develop at or just below ground level on nursery stock. See Stone fruits F 125.

FUNGAL DISEASES

Nut rots (*Pestalotia* sp., other species) may develop during wet weather. The role of the ***green vegetable bug*** (*Nezara viridula*) in the development of some nut rots is being researched. See Fruit F 5.

Pecan scab (*Cladosporium caryigenum*, Imperfect Fungi) is the ***most destructive disease*** of pecan in the USA, but is not known to occur in Australia. It attacks the rapidly growing tissues of ***leaves, shoots and nuts*** during humid weather. Affected nuts are worthless and may drop prematurely. ***Plant quarantine:*** The introduction of propagating material represents the major quarantine risk. Besides pecan scab there are several other diseases of pecan which are not at present in Australia. These include downy spot (*Mycosphaerella carygena*), liver spot (*Gnomonia caryae*) and zonate disease (*Cristulariella pyramidalis*) (Com. of Aust. 1991).

Root rots, cankers

Armillaria root rot (*Armillaria luteobubalina*) may attack roots in newly cleared land. See Trees K 4.
Phytophthora trunk canker (*Phytophthora* spp.) may infect pecans in poorly drained sites. See Trees K 6.

INSECTS AND ALLIED PESTS

Borers

Fruit-tree borer (*Maroga melanostigma*, Oecophoridae, Lepidoptera) caterpillars may tunnel in the ***forks of branches*** and are a ***major pest***. Methods of monitoring its incidence are being devised. ***Echiomima spp.*** is also a pest of pecan trees. See Fruit F 10.
Elephant weevil (*Orthorhinus cylindrirostris*) may tunnel in ***trunks and large branches***. See Trees K 12.
Large auger beetle (*Bostrychopsis jesuita*) may attack weak or unthrifty trees. Larvae are thickset, white and have small legs. Their ***tunnels*** are tightly packed with frass and wood fragments. This tunnelling can ***kill limbs or whole trees***. After pupating at the end of the tunnel, the glossy black adult emerges through a ***circular exit hole*** during spring/summer. See Trees K 11.
Poinciana longicorn (*Agrianome spinicollis*) larvae tunnel in ***trunks and main limbs***. ***Beetles*** are up to ***50 mm*** long and have long antennae, usually held back over the body. ***Larvae*** are whitish, thickset, and up to ***80 mm*** long. They may live for several years. They become adults and emerge as beetles between August and March, leaving ***oval-shaped exit holes*** and masses of wood fibres at the base of the tree. ***Control*** is mainly by destroying larvae individually by pruning and by probing tunnels with wire. To help prevent attack, keep trees in good condition by providing adequate drainage, irrigation and fertiliser. See Trees K 11.

See Trees K 10.

Bugs (Hemiptera)

Fruitspotting bugs (*Amblypelta miserana*, *A. nitida*) feed on the ***nuts*** and spoil the kernels. See Fruit F 10.
Green vegetable bug (*Nezara viridula*) may feed on developing ***nuts***. See Vegetables M 12.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.), ***orange fruitborer*** (*Isotenes miserana*) and ***yellow peach moth*** (*Conogethes punctiferalis*) caterpillars bore into ***nuts***. See Citrus F 37, Stone fruits F 133.
Caterpillars of an ***anthelid moth*** (*Anthela varia*) feed on pecan ***foliage***. See Trees K 13.

Scarab beetles (Scarabaeidae, Coleoptera)

Elephant beetle, rhinoceros beetle (*Xylotrupes gideon*) feeds on ***nuts***. See Lychee F 74.
Others: Black beetle (*Metanastes vulgivagus*), and ***Christmas beetles*** (*Anoplognathus* spp.).

See Trees K 16, Turfgrasses L 11.

Others: ***Apple weevil,*** curculio beetle (*Otiorhynchus cribricollis*, Curculionidae) may be a pest in Western Australia chewing ***leaf edges*** giving them a sawtoothed appearance. It may strip young trees almost completely. ***Mites*** (Acarina) and ***scales*** (Hemiptera) may also infest pecan in Australia. ***Aphids*** (Aphididae, Hemiptera) infest new shoots overseas.

VERTEBRATE PESTS

Cockatoos and other large birds cause extensive damage to nuts and bark. ***Rabbits, rats and possums*** may eat nuts on the ground. See Fruit F 13.

Non-parasitic

Environment: Limbs may become ***sunburnt***.

Nutrient deficiencies, toxicities: ***Nutrient standards*** based largely on diagnostic leaf analyses are available for pecans (Weir et al. 1993).

Remember, always check for recent references

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State/Territory Departments of Agriculture/Primary Industry eg
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Growing Pecans (Vic Agnote)
Pecans in the Garden (NSW Agfact)
Sites, Layout and Irrigation for Nut Orchards (WA Farmnote)

Associations, Journals etc.
WA Nut and Tree Crop Assoc. (WANATCA) : Australian Tree Crops Sourcebook 1994-95 (Pecan : An Emerging Crop; Pecans : Cultivation)

See Fruit and nuts F 15

PLANT MANAGEMENT

An overview of the industry has been presented by Coombs (1995). Pecan is a large, long lived deciduous tree up to 10 m tall. Nuts are oblong and thin-shelled. They are eaten fresh and used in confectionery, pies and cakes. Varieties carry male and female flowers separately on the same tree. Some varieties shed pollen before the female flowers are receptive and cross pollination is necessary to ensure nut production. Preferably grow at least 2 trees. Because ***pecan scab has occurred in NZ***, varieties with some ***resistance*** to the disease should be chosen for large plantings. Ensure that grafting material and other propagation material is ***scale-free*** and free from other pests and diseases. ***Propagation*** is by budding on to seedling trees, grafting and seed. Nuts produced by seedling trees may be variable in quality and quantity. Pecans are normally trained to 1 main trunk to produce a pyramid-shaped tree. Pinch out side shoots on young trees so the trunk is clean to 1.5 m. Grow in a sheltered position where minimum and maximum temperatures are not extreme. Trees need deep well drained slightly acid soil. During long dry periods irrigate frequently to keep soil moist. Fertilise in February and prune in winter. ***Control weeds*** under trees. ***Harvest*** when husks mature (late autumn) by separating into 4 sections and releasing the nut, which falls to the ground. Gather nuts regularly to avoid damage by weather and rodents. Nuts should be cleaned to improve appearance and storage. Nuts must be promptly dried and stored in a well ventilated area for several weeks. ***Pest management programs*** for pecan crops are still being researched and include the development of ***monitoring techniques*** for the major pests and the possible use of biological control agents.

Persimmon

Oriental or Japanese persimmon (*Diospyros kaki*)
Family Ebenaceae (ebony family)

PESTS AND DISEASES

Parasitic
- **Bacterial diseases**
  - Bacterial blast
  - Crown gall
- **Fungal diseases**
  - Fruit rots
  - Fungal leaf spots
  - Grey mould
  - Phytophthora root and collar rot
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Fruit flies
  - Fruitspotting bug
  - Greenhouse thrips
  - Mealybugs
  - Mites
  - Scales
- **Vertebrate pests**

Non-parasitic
  - Environment
  - Nutrient deficiencies, toxicities

Many more diseases and pests have been recorded in Japan (Kitagawa and Glucina 1984).

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial blast (*Pseudomonas syringae* pv. *syringae*) causes dark ***leaf spots***, blackening of ***petioles*** and basal parts of leaves, and may attack ***small twigs and small branches*** during late winter and early spring during cool, moist weather in exposed situations. See Stone fruits F 124.

Crown gall (*Agrobacterium* spp.) is a ***serious disease*** of persimmons. Plant only ***disease-free nursery stock***. Inspect roots of purchases carefully and dip roots in *Agrobacterium* (Nogall®) culture before planting, especially when planting into alkaline soils. Remove trees that develop galls from the orchard. Avoid using *D. lotus* rootstock as it is ***highly susceptible***, *D. kaki* is ***resistant***. See Stone fruits F 125.

FUNGAL DISEASES

Fruit rots: ***Blue and green moulds*** (*Penicillium* spp.) are ***important postharvest diseases***. See Fruit F 6.

Fungal leaf spot (*Pseudocercospora* sp.) causes small dark ***leaf spots*** on both upper and lower leaf surfaces. Spots enlarge and eventually leaves fall prematurely in autumn. Spots are very obvious on yellow senescing leaves. Uncontrolled infection may result in ***lower yields*** and ***smaller fruit size***. Other fungi may also cause leaf spotting in Australia and overseas. Some only occur late in autumn and therefore have little effect on tree vigour. See Annuals A 5.

Grey mould (*Botrytis cinerea*) may cause a blighting of ***young leaves*** and may be a problem at ***flowering*** when petals do not fall cleanly but adhere to small fruitlets. See Fruit F 5, Greenhouses N 22.

Phytophthora root and collar rot (*Phytophthora* spp.) may ***kill persimmons***. Provide good drainage and keep tree bases weed-free. See Fruit F 7, Trees K 6.

NEMATODE DISEASES

Nematodes recorded in association with persimmon include ***citrus nematode*** (*Tylenchus semipenetrans*), ***dagger nematode*** (*Xiphinema*), ***reniform nematode*** (*Rotylenchus*), ***ring nematode*** (*Criconema*), ***root knot*** (*Meloidogyne javanica*), ***spiral nematode*** (*Helicotylenchus*), ***stunt nematode*** (*Tylenchorhynchus capitatus*) (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers: ***Fruit-tree borers*** (Oecophoridae, Lepidoptera) and ***longicorn beetles*** (Cerambycidae, Coleoptera) damage persimmons. See Trees K 11, K 12.

Caterpillars (Lepidoptera)

Orange fruit borer (*Isotenes miserana*) may bore into ***fruit***. See Citrus F 37.
Lightbrown apple moth (*Epiphyas postvittana*) caterpillars chew ***developing shoots and buds***. See Pome fruits F 112.
Lychee stem-girdler (*Carmenta chrysophanes*) caterpillars burrow under the ***bark*** of lower parts of the tree causing ***severe damage***. ***Branches*** may die and fall and whole trees may die from ring barking. It may cause ***major losses*** and so far there is no control. See Lychee F 73.
Others: ***Cephenes blue*** (*Pseudodipsas cephenes*, Lycaenidae) caterpillars feed on ***leaves*** of *Diospyros fasciculosa* or in sheltered positions along ***twigs*** or in holes in ***trunks***. Pupae are found in hollow branches. Caterpillars and pupae are attended by black ants (*Iridomyrmex gilberti*). Caterpillars of ***Addaea polyphoralis*** feed gregariously between joined leaves of *Diospyros ferrea* and pupate in leaf litter.

See Annuals A 8, Fruit F 8.

Fruit flies (Tephritidae, Diptera) are a ***major pest*** of persimmons. ***Fruit*** that have been ***'stung'*** develop black blemishes and are seriously downgraded. The tannin content in immature fruit is considered to be antagonistic to maggot development, although maggots do develop in mature fruit. As fruits ripen late in the season, they are often subject to heavy attack by the many fruit flies which have bred on other fruit during summer. ***Regular insecticide applications*** are required in commercial orchards to prevent significant loss and damage. See Fruit F 9.

Fruitspotting bug (*Amblypelta nitida*) is a ***major and frequent pest*** in orchards close to bush causing dark spots on fallen fruit. Damage extends 10 mm in depth. ***Monitor*** fruit for bugs and damage (Brough et al. 1994). See Fruit F 10.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) causes grey speckled blemishes on ***fruit*** when they feed where fruits are in contact or a leaf lies against a fruit. ***Monitor*** fruit for presence of thrips (Brough et al. 1994). ***Other thrips*** (Thysanoptera) may occur in the ***flowers***. See Greenhouses N 24.

Mealybugs (Pseudococcidae, Hemiptera): ***Citrus mealybug*** (*Planococcus citri*) infests ***trees and fruit***. Their presence may present a problem on export fruit and associated sooty mould reduces fruit value. ***Monitor*** fruit for mealybugs and predators before applying insecticides (Brough et al 1994). Winter oil used during the dormant season may control mealybugs. See Citrus F 38, Greenhouses N 25.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) may cause ***leaves*** to curl under. See Greenhouses N 26.
Twospotted mite (*Tetranychus urticae*) causes ***leaf and fruit drop***. See Beans (French) M 29.

Scales (Hemiptera)

Oleander scale (*Aspidiotus nerii,* Diaspididae) may blemish ***fruit***. Scales are mostly found on fruit uppersurfaces near the calyx. Infestation of leaves and twigs is minor. ***Female scales*** are circular, sometimes irregular, whitish brown and 1-2 mm in diameter. ***Male scales*** are smaller and rather elongate. See Oleander K 104.
White wax scale (*Gascardia destructor,* Coccidae) can heavily infest persimmons, disfiguring ***ripe fruit*** with the associated ***sooty mould.*** See Citrus F 41.

See Citrus F 39, F 41.

VERTEBRATE PESTS

Birds can be a nuisance when fruit is hanging late. See Fruit F 13.

Non-parasitic

Environment: Dormant persimmon trees are tolerant of ***frost*** but new growth may be damaged.

Nutrient deficiencies, toxicities: ***Nutrient standards*** based on diagnostic leaf analyses are available for persimmon (Weir and Cresswell 1993, 1995).

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The Persimmon : An Alternative Fruit Crop (Vic Agnote)
Associations, Journals etc.
Australian Persimmon Export Company

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Persimmon trees are deciduous, beautiful and functional. When leaves fall in autumn, fruit hang on naked branches for weeks. In cool districts, the foliage of some varieties has glorious autumn colours. Rootstocks of *D. lotus* are ***susceptible*** to crown gall. Rootstocks of *D. virginiana* are ***tolerant*** of drought but sucker severely, trees propagated on them are not always uniform in size or vigour. Inspect nursery stock for crown gall and scales, etc. ***Propagated*** by budding and grafting of seedling rootstocks. Seedlings do not reproduce true-to-type. Persimmon require a ***sunny well drained site.*** Purchase bare rooted plants, plant immediately; irrigate and fertilise well in summer for good fruit production, especially in the first few years. Excessive nitrogenous fertiliser, high autumn temperatures, high humidity, moisture stress and vigorous growth can contribute to a range of ***fruit disorders***, eg skin russetting, calyx separation, calyx end cracking and fruit drop. ***Prune*** lightly as hard pruning encourages excessive leafy growth and premature fruit drop. Fruit develops on the current season's growth. ***Biennial fruit bearing*** is a problem, especially with late-maturing cultivars. Some pests should be ***monitored***, eg fruit fly, fruitspotting bugs, greenhouse thrips and mealybugs. ***Harvest*** fruit by clipping fruit from the tree with the calyx and a short stem attached to the fruit. Handle fruit carefully as the thin skin is easily marked. Pick when fruit is well developed, firm and has the characteristic colour for the variety. ***The fruit of astringent varieties,*** if eaten too early, leaves an unpleasant feeling in the mouth. Unless treated to remove astringency, fruit should be eaten when flesh is soft and gelatinous. ***Non-astringent varieties*** have lost their astringency once colour has developed. Fruit should ripen after harvest. Sugar content increases and fruit develop good flavour and consistency. If fruit is harvested while immature it does not soften evenly, and may remain partly astringent. An overview of the industry has been presented by Coombs (1995).

Pineapple

Ananas comosus
Family Bromeliaceae (bromeliad family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Marbling
- **Fungal diseases**
  - Thielaviopsis diseases
  - Penicillium diseases
  - Phytophthora diseases
  - Pythium root rot
  - Yeasty rot, yeasty spot
- **Nematode diseases**
- **Insects and allied pests**
  - Bugs
  - Mites
  - Pineapple mealybug
  - Pineapple scale
  - Scarab beetles, canegrubs, white grubs
  - Symphylids
- **Vertebrate pests**

Non-parasitic
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Pineapple wilt virus is thought to be the cause of symptoms produced by the feeding of ***mealybugs*** on pineapple roots, but the disease has not been verified. ***Pineapple mealybug*** is known to spread a disease referred to as ***'mealybug wilt'***, the cause of which is ***'unknown'***. Leaves die back from the tip and may change colour to pale green or yellow. Inner heart leaves usually remain normal. There is no chemical control, and it ***may be serious.*** See Pineapple F 104.

Tomato spotted wilt virus (yellow spot) has been recorded on pineapple but is rare in Qld. See Tomato M 96.

See Fruit F 4.

BACTERIAL DISEASES

Marbling (*Erwinia ananas*) and ***pink disease*** (various bacteria including *E. ananas*) are ***spread*** by insects and mites from decaying fruit near flowering fields. They are minor diseases of pineapple fruit. There are no external symptoms but ***internal tissue*** may be light pink or watersoaked ***(pink disease)***. During canning affected tissue turns brown. There is no control. Bacteria infect fruit through open flowers during cool weather.

FUNGAL DISEASES

Thielaviopsis diseases (*Thielaviopsis paradoxa*) ***commonly*** occur in the ***field*** and ***postharvest***. The fungus is important in the breakdown of pineapple residues after cropping.

Base rot of planting material causes a grey rot of ***soft butt tissue*** leaving stringy fibre and cavities. If infected crowns are planted, butts decay, growth is reduced, and plants may die. ***Favoured*** by planting material harvested from parent plants (fungus enters through ***wounds***), warm, wet weather, and storage of planting material in heaps. Infections develop during storage but may not be obvious at planting. Tops (crowns) used for planting are particularly susceptible. Do not leave portions of fruit attached to crown or knobs attached. ***Planting material to be stored*** must be dried rapidly. If it is to be ***stored outdoors*** during prolonged wet weather spray upturned butts with fungicide. If material is to be planted immediately after removal without drying, treat with fungicide. Improve soil drainage and avoid planting during wet weather.

Water blister of fruit may be a ***major postharvest*** disease of ***fresh fruit***, causing a soft watery rot of the flesh during summer. Disease takes 3-4 days to develop after harvest. Infection occurs through ***injury***, eg broken fruit stalks, bruises and growth cracks on the fruit. Fresh fruit marketed with crowns left on, eliminates a major point of entry for the fungus. Handle fruit carefully to avoid injury. Reject sunburnt and damaged fruit. If fruit is harvested during warm, wet weather, ***dip*** after harvest. Remove pineapple debris and rejected fruit from in and around packing sheds, and disinfect packing sheds every week.

White leaf spot causes minor small brown spots on ***leaves,*** especially along leaf margins where leaves have been rubbing other leaves in strong winds. Spots elongate until they are about 20 mm long and may spread to the leaf tips. See Annuals A 5.

The fungus ***overwinters*** on pineapple crop debris and rejected fruit in packing sheds. It is ***spread*** by infected planting material and ***favoured*** by warm wet weather in summer, and wounds. See Fruit F 7, Vegetables M 7.

Penicillium diseases (*Penicillium funiculosum*)

Fruitlet core rot and green eye is an internal browning of the centre of ***fruitlets*** which vary in colour from a speck to an area covering one or more of the fruitlets. Affected fruit on Smooth Cayenne do not show any external symptoms at harvest. Fruit of the rough-leaf Queen group may produce fruitlets which fail to colour (green eye). ***Favoured*** by certain temperatures. *Fusarium moniforme* also causes fruitlet core rot (Broadley et al. 1993a).

Interfruitlet corking (IFC): Wounds caused by mites feeding on fruit hairs allow entry for the fungus. A corky tissue develops on the skin between the fruitlets on patches. ***Fruits*** crack. Corkiness on one side prevents even growth so that fruit are distorted. Only found on fruit initiated in early autumn.

Leathery pocket has no external symptoms. Internally corky tissue develops on fruitlet walls and makes them leathery and brown. A sporadic disease.

See Fruit F 6.

Phytophthora diseases (*Phytophthora cinnamomi*) are ***serious diseases*** of pineapple.

Green fruit rot causes an internal watersoaked rot behind green fruitlets in contact with soil. This progresses to a general rot. Spores are splashed from the soil on to fruit. Usually a minor disease but may be serious in ratoon crops following heavy rain when plants have fallen as a result of root rot. Application of systemic fungicides for heart and root rots will control green fruit rot.

Heart rot (top rot) may affect plants of all ages but crown plantings are most susceptible. Heart leaves yellow or brown, wilt, and edges roll under and die. Once symptoms are visible, young plants are easily pulled from the soil. Basal leaf white tissue is rotted and has a foul smell. *P. nicotianae* may also cause heart rot.

Root rot causes heart leaves to turn yellow or light brown with reddish tinge, due to death of the root system Plants are easily pulled from soil.

See Citrus F 35, Fruit F 7, Trees K 6.

Pythium root rot (*Pythium* spp.) may occur in areas with poor drainage or overwatering. Avoid disease by using well ***drained soils***, careful field selection, and planting ***on raised beds*** at least 230 mm high. Construct drains to intercept runoff before it reaches the plantation, and within the plantation itself; use plastic mulch to keep beds dry in some circumstances. See Vegetables M 7.

Yeasty rot, yeasty spot (*Saccharomyces* spp.) is a minor disease of overripe or damaged ***fruit*** in the ***field***. Frost or rapid changes in fruit growth due to changes in temperature (cold/dry to warm/wet weather), may cause skin to crack between fruitlets; juice oozes out and is invaded by yeast organisms. Protect fruit ripening in frost prone areas. ***Do not consign fruit with minor cracks to market***. To minimise losses during processing, pick cracked fruit in the field at the earliest stage of fruit maturity.

NEMATODE DISEASES

Nematodes are a ***serious pest*** of commercial pineapple crops. They infest roots and stunt growth, causing symptoms similar to those caused by white curl grubs. More than 30 species may attack pineapples. ***Root knot*** (*Meloidogyne* spp.) causes distinct terminal swellings on roots, ***root lesion*** (*Pratylenchus brachyurus*) produces brown areas which may girdle roots and cause premature death, ***reniform nematode*** (*Rotylenchus* spp.) reduces lateral and feeder roots (McLeod et al. 1994). Also ***burrowing nematode*** (*Radopholus similis*), ***spiral nematodes*** (*Helicotylenchus* spp., *Rotylenchus* spp.). ***Monitor*** nematode populations prior to making decisions about control measures. Practise ***crop rotation*** to reduce populations. ***Treat/fumigate*** soil ***before*** planting and replanting and in areas with a history of nematode problems. ***Post-plant*** nematicide treat if monitoring indicates that it is necessary. ***Pineapple decline*** can probably be attributed mainly to soil nematodes, and damage by scarab beetle larvae is often aggravated by parasitic nematodes. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Bugs (Hemiptera): ***Grey cluster bug*** (*Nysius clevelandensis*) and ***Rutherglen bug*** (*N. vinitor*) may suck sap from ***leaves*** causing spots and lesions. See Vegetables M 12.`

Mites (Acarina)

Pineapple flat mite, pineapple red mite (*Dolichotetranychus floridanus*, Tenuipalpidae) is a false spider mite which feeds on tender white tissue at the ***base of pineapple plants***. Feeding injury is insignificant, but affords entry for bacteria and fungi, which cause the bud to rot. Apply an insecticide and a fungicide to the buds, depending on rain and dew to carry the pesticides down into the buds.

Pineapple mite (*Phytonemus ananas,* Tarsonemidae) may injure pineapple ***fruit*** by its feeding activities which may initiate fungal infections. Some segments of fruit remain green and become rotten inside. Mites may also injure ***young plants***. ***Spread*** by crawling and by propagation (Jeppson et al. 1975).

Pineapple mealybug (*Dysmicoccus brevipes*) may be a ***serious pest*** of pineapple, other bromeliads and weeds. Probably other mealybugs may also infest pineapple. ***Pineapple mealybugs*** are small, white, oval soft sucking insects found mainly in ***sheltered parts of plants***, eg bases of fruits, leaf axils, rhizomes. Infested areas are covered with white mealy material. Green and yellow spots develop on leaves, plants may ***'wilt'***. See Pineapple F 103. About 3 generations are produced per year and adults give birth to 30-100 young. ***Sooty mould*** grows on ***honeydew***, which also attracts ***ants***. Ants move mealybugs from plant to plant, and feed on the honeydew. This benefits the mealybugs as the honeydew would create a messy environment if it was allowed to accumulate and fungi grow on it. Ants deter parasites and predators and often build protective covers of soil over their colony so that very little natural control of mealybugs can take place in a pineapple field. ***Spread*** by planting material and by attendant ants in the field. ***Favoured*** by close planting, and warm weather. In fields with low incidence of mealybugs ***remove and destroy plants*** with wilt symptoms. In severely affected areas, after harvest, remove and destroy all plants, and weeds from surrounding areas. Only ***plant wilt-free planting material*** from areas which are wilt-free or have only a low level of disease. ***Monitor*** mealybugs and ants regularly before applying insecticides (Brough et al. 1994). See Greenhouses N 25.

Pineapple scale (*Diaspis bromeliae,* Diaspididae, Hemiptera) is an introduced scale which infests pineapple and other bromeliads. ***Females*** are about ***2 mm*** across, circular, flat, greyish white and live mainly on leaves. ***Males*** are oblong, whitish, with 3 longitudinal ridges. Heavily infested ***foliage*** appears scurfy and may die. Plants are stunted, and ***fruit*** may be undersized, pinched and unsaleable as fresh fruit. Most common in ratoon crops and on suckers and fruit shaded by foliage. There are several generations each year. Females deposit eggs under their bodies. Young scales hatch and wander over the plant before settling in their permanent positions. ***Spread*** by infested planting material. ***Remove and burn/destroy*** infested plants when first noticed. ***Natural enemies*** include small ***parasitic wasps*** (*Aphytis* sp., *Aspidiotiphagus* sp.) and ***scale-eating ladybirds*** (*Rhyzobius lophanthae, Orcus* sp. and *Lindorus lophanthae*). Only plant ***scale-free stock.*** ***Monitor*** scales and natural controls before applying insecticides (Brough et al. 1994). See Citrus F 39.

Scarab beetles, canegrubs, white grubs (Scarabaeidae, Coleoptera), eg ***caudata canegrub*** (*Lepidiota caudata*), ***Christmas beetle*** (*Anoplognathus porosus*), ***Nambour canegrub*** (*Antitrogus mussoni*) and ***pasture white grubs*** (*Rhopaea* spp.) are ***sporadic major pests*** of pineapples. ***Scarab beetle larvae*** feed on ***roots*** and may prune the entire root system. Plants may become yellow and stunted. Affected plants are easily pulled out. Butts or rhizomes may be channelled and cored. Older plants tolerate some injury. A population of 5 larvae/plant may produce wilting and yellowing. ***Favoured*** by planting young plants in ground previously planted to grass for years; large grubs, deprived of grass by cultivation, move directly to the young pineapples; by nematode attack and some soils, eg red volcanic soils of some coastal districts. Since larvae live in the soil it is almost ***impossible to monitor and treat larvae*** during a crop cycle. ***Remove volunteer plants and debris*** by thorough cultivation before planting when soil is dry; this maximises mechanical injury to larvae by the dry soil aggregates and deprives larvae of food. ***Fungal infections*** sometimes provide good control of larval populations. ***Birds*** also eat many larvae exposed during cultivation. ***Insecticidal treatments*** before planting are not sufficiently effective to be recommended. ***African black beetle*** *Heteronychus arator*) may damage pineapples. See Eucalypt K 61, Turfgrasses L 11.

Symphylids (Symphyla) are white, ***4 mm*** long, centipede-like and may cause serious damage to ***root tips*** resulting in short, branching roots.

Others: ***Armyworms*** (*Leucania* sp.), ***driedfruit beetles*** (*Carpophilus* spp.), ***grasshoppers*** (Acrididae), ***sugarcane weevil borer*** (*Rhabdoscelus obscurus*).

VERTEBRATE PESTS

Birds, rats and wildlife, eg wallabies, feral pigs are partial to ripening fruit. See Fruit F 13.

Non-parasitic

Nutrient deficiencies, toxicities: ***Regular fertilising*** is necessary for maximum production. Once the fruit has formed, cease fertilising until after harvest. Do not drop solid fertiliser into the growing top. ***Leaf and soil analyses*** information is available for pineapple crops (Broadley et al. 1993a, Weir and Cresswell 1995).

Others: ***Environmental problems*** include hail, frost and sunscorch. ***Pesticide injury*** may occur. Many ***non-parasitic problems*** affect the fruit (Broadley et al. 1993a).

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Home Fruit Growing (NSW)
Growing Pineapples at the Top End (NT Agnote)
Pineapple Growing (NSW Agfact)
Pineapples in the Garden (NSW Agfact)

Associations, Journals etc.

Good Fruit and Vegetables
Qld Dept. of Primary Industries
Qld Fruit and Vegetable Growers (QFVG)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

An overview of the industry has been prepared by Coombs (1995) and management programs are available (Broadley et al. 1993a, 1993b, Persley 1989, 1993). ***Planting material*** should have the desired ***horticultural characteristics*** and be ***free from*** diseases, scales and other pests. ***Propagated*** vegetatively by shoots or suckers, bearing plants need to be replaced regularly. Close planting favours some problems, eg mealybugs and scales. ***Pre-plant soil treatments***, eg fumigation, control nematodes, scarab larvae, symphylids and weeds. ***Weed control*** is essential either by hand weeding, plastic mulches or by post and pre-emergence herbicides. ***Monitor*** diseases and pests. ***Growth regulators*** may be used, eg to induce flower initiation, fruit setting, fruit ripening, sunburn protection and to extend shelf life. ***Pesticides*** are registered for disease and pest control of ***planting material***, ***preplant soil treatments*** for soil nematodes and insect pests, and for ***postharvest treatments***. ***Harvest:*** Regular inspections are required to assess maturity. Time of harvest depends on the market. Ripe pineapples deteriorate quickly so should be eaten shortly after purchase. ***Store*** in a cool place, out of direct sunlight.

Pistachio

Pistachio, green almond (*Pistacia vera*)
Family Anacardiaceae (cashew family)

PESTS AND DISEASES

Parasitic

Many pests and diseases may affect pistachio overseas.

FUNGAL DISEASES

Fungal leaf spots (*Septoria* spp.) may affect new leaves in wet seasons. ***Damping off*** (*Pythium* spp.) may occur during propagation. ***Root and collar rots and wilts*** may weaken and kill trees, eg armillaria root rot (*Armillaria* sp.), fusarium root rot (*Fusarium* sp.), phytophthora root rot (*Phytophthora* spp.) and verticillium wilt (*Verticillium* sp.). ***Various fungi***, eg *Aspergillus,* may spoil the nuts, and mycotoxins (fungal poisons) may be produced (Doster and Michailides 1994, 1995).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* spp.) may be a problem. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest new growth, ***leafeating beetles*** (Coleoptera) may be a problem on young trees, ***fruitspotting bugs*** (*Amblypelta* spp., Hemiptera) may suck sap from young nuts, ***fruit-tree borers*** (Oecophoridae) may tunnel in forks of branches, various ***beetle larvae*** (Coleoptera) and ***caterpillars*** (Lepidoptera), eg Indian meal moth (*Plodia interpunctella*), may feed on stored nuts. Overseas ***bud moth*** (*Recurvaria pistacicola*, Gelechiidae) caterpillars and ***wasp larvae*** (*Megastigma pistaciae,* Torymidae) cause severe crop losses.

VERTEBRATE PESTS

Birds and ***possums*** eat buds and nuts.

Non-parasitic

Nuts may suffer from many ***non-parasitic disorders***, eg abraded kernels, lateral stain, malformations, pericarp stain, split and unsplit nuts (Maggs 1982). ***Leaf analysis standards*** are available (Weir and Cresswell 1993).

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Pistachio Nut Growing (NSW Agfact)
Pistachio Nuts (Vic Agnote)
Pistachios : Planting and Management (Vic Agnote)
Pistachios : Production and Propagation (Vic Agnote)
Pistachios in the Garden (NSW Agfact)
The Pistachio : Orchard Establishment and Economics (NSW Agfact)

Associations and Journals etc.
Pistachio Growers Australia Incorporated (PGAI)

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

An overview of the industry has been presented by Coombs (1995). Pistachio are small deciduous trees up to 5-7 m tall. They need a cold winter followed by a hot dry summer to establish nut set. Male and female flowers are borne on separate trees so trees of both sexes are required for nut production. They are wind-pollinated and have ***biennial*** cropping habits. *P. vera* is ***susceptible*** to root knot nematode and has a straggly habit making it awkward to bud if used as rootstock. *P. terebinthus* is ***resistant*** to *Phytophthora* root rot, root knot and tolerant of drought and both acid and alkaline soils. *P. atlantica* is ***resistant*** to root knot and is suited to heavy soils. ***Propagated*** by budding on to seedling rootstock of *P. atlantica* or *P. terebinthus*. Pistachios prefer sunny areas with low rainfall and good drainage. Avoid damp areas. Fruit is produced from lateral buds on growth made the previous year so heavy ***pruning*** is not recommended. If necessary moderately prune in winter after heavy bearing. ***Harvest*** in autumn by shaking the tree till the nuts fall, or by using tree shakers. Australian Quality Standards are available. ***Stored*** nuts may be attacked by insect pests.

Pome fruits

Apple (*Malus domestica*)
Loquat (*Eriobotrya japonica*)
Medlar (*Mespilus germanica*)
Nashi (*Pyrus pyrifolia*)
Pear (*P. communis*)
Quince (*Cydonia oblonga*)
Family Rosaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

At least 11 viruses affecting pome fruits have been identified in Australia, most can infect only some varieties. Many are ***latent*** (cause no visible symptoms) in certain hosts, eg apple chlorotic ringspot in pears. Viruses in pome fruits are ***decreasing in importance*** with the widespread use of virus-tested propagating material.

Apple flat limb virus, Gravenstein twist, mostly affects Gravenstein, occasionally Delicious, Granny Smith. Only the sides of deformed areas grow, the wood of ***branches or trunk*** becomes flattened. This is very obvious on large branches or trunks. Foliage may become pale and sparse, affected branches become less productive and may die. ***Wood surface*** below the bark of flattened areas may be pitted.

Apple green crinkle virus affects Granny Smith. Fruit about 12 mm across develop small depressed areas on skin. ***Fruit*** becomes distorted, irregularly rusetted and cracked in the depressions. Irregular swellings may occur on the skin. Under the depressions and swellings the vein system in the flesh is distorted and green, this may extend to the core. Symptoms are favoured by a cool spring. Usually only 1-2 branches are affected but the ***entire tree*** can be affected. Severely affected apples are reduced in size. Infected apples store as well as healthy ones. ***Do not confuse*** with boron deficiency, apple dimpling bug, hail or frost injury.

Apple mosaic virus mostly affects Jonathan, wild crab apple, horse chestnut, hazelnut, hop, plum, sour cherry and rose. Symptoms include light and dark green ***leaf mosaic***, or just patches of yellowish-white tissue (Fig. 146), or bands of yellow tissue along the veins. Yellow tissue may be sunburnt and may die. Symptoms are usually only seen on leaves which have developed at < 27^{o}C. ***Fruit yield*** is reduced by ***30-40%***. Does not spread in nature.

Apple proliferation mycoplasma is a ***serious disease*** of apples in Europe, reducing ***size*** by as much as ***50%*** and ***weight*** by up to ***75%***. It also affects quality of fruit and tree vigour. A leafhopper is suspected as aiding its spread (Com. of Aust. 1988).

Apple ringspot virus affects Granny Smith, also Delicious, Jonathan. ***Immature fruit*** develop brown areas which later become russetted with a scaly margin. At maturity a smooth narrow band of brown tissue may develop around the margin of many spots (a reliable diagnostic feature). ***Do not confuse*** with russet caused by spray or frost injury, or powdery mildew. Symptoms and number of fruit affected vary from season to season.

Apple russet ring virus affects Granny Smith, occasionally Jonathan. ***Fruit*** develop complete or partial rings of russetted skin tissue, usually 12-25 mm across. Internal tissues are not affected. Concentric rings do not occur as with apple ringspot virus.

Pear stony pit virus causes ***fruit*** of pear to become pitted and deformed. Tissue at the base of the pits becomes hard, fruit may be ***difficult to cut***. Severely affected fruit are unmarketable. Symptom severity varies from season to season and only one branch may show symptoms.

Others: Apple chlorotic leaf spot virus, apple rubbery wood virus, apple stem grooving virus, apple stem pitting virus, pear decline, quince sooty ringspot (suspected virus), sowbane mosaic virus.

Pome fruit viruses in Australia are ***spread*** by vegetative propagation (budding and grafting), not generally by any known vectors, not by seed (seedlings are virus-free), rarely by root grafts in orchards, not by leaf contact and rarely by secateurs. Spread in nature is by unknown means. Overseas, spread is also by nematodes and insects. ***To minimise losses*** plant only certified virus-free nursery trees propagated from virus-tested stock and budwood sources. See Fruit F 4.

BACTERIAL DISEASES

Bacterial canker, bud blight, pear blossom blast (*Pseudomonas syringae* pv. *syringae*) infects ***flowers of pears*** especially Packham's Triumph, causing blackening and dieback of the blossom truss. Black spots develop at the calyx end of

young fruit and may spread until the whole fruit and stalk are affected. Fruit drop may occur. Infected fruits and bearing spurs die, and ***branch dieback*** can occur. Bacteria ***overwinter*** in buds and leaf scars of trees. Bacteria are ***spread*** by wind and rain and enter the plant through natural openings and wounds. ***Favoured*** by cold, wet spring weather during flowering or when plants are affected by late frosts. Prune out and burn diseased twigs and branches. ***Copper fungicides*** may be applied at green tip stage. See Stone fruits F 124.

Fireblight (*Erwinia amylovora*) is a ***destructive disease*** of pears and apple trees and other Rosaceae in North America, Europe and NZ but is not known to occur in Australia. ***Quarantine risks:*** Introduced vegetatively propagated material represents the major quarantine risk. Australia has severely limited the introduction of susceptible host material. Seed free of pulp is not considered a quarantine risk. ***Quarantine precautions: Propagating material*** of the genera of all ornamentals susceptible to fireblight is ***totally prohibited***. Introduction of these may be made only as seed free of pulp. Propagating material of new varieties of pome and stone fruits is introduced under strict quarantine control, eg treated and held in post-entry quarantine for at least 2 growing seasons before release (Com. of Aust 1990).

Others: ***Bacterial stem canker*** (*Pseudomonas syringae* pv. *eriobotryae*) may cause ***bud rot*** and stem cankers on loquat. See Stone fruits F 124. ***Crown gall*** (*Agrobacterium* spp.) and ***hairy root*** (*A. rhizogenes*) may cause ***galls*** at the base of stems of nursery stock. See Stone fruits F 125.

FUNGAL DISEASES

Bitter rot

Bitter rot, anthracnose (*Glomerella cingulata,* Ascomycetes = *Colletotrichum* sp., Imperfect fungi) affects all apple and pear varieties in the ***field*** and ***postharvest***. Symptoms appear on ***apples*** usually when ***fruit*** is almost full-sized but may start earlier. Small, light brown circular spots enlarge rapidly and become sunken. Affected ***fruits*** may have only one spot about 10 mm or more across, or many smaller ones. Spots become dark brown to black with age. Fungal growth form ***pink masses*** (acervuli) on the brown spots, and may be arranged in ***concentric circles***, giving the spots a target-like appearance. Rot penetrates deeply into the flesh and the entire fruit is eventually rotted. Decayed tissue remains dry unless secondary organisms invade the affected tissue. Rotted fruit may fall, but some cling as ***mummies*** throughout winter. Although called bitter rot, the diseased tissue often has no bitter taste. Cankers may develop on ***twigs*** and spurs, irregular small brown spots may develop on ***leaves*** during wet warm weather. On ***pears*** symptoms are usually most obvious on the fruit, but twigs and leaves may be affected. See Fruit F 5.

Black spot, scab

Apple scab, pear scab

Black spot is a ***serious fungal disease*** of apples and pears, especially in wet growing regions.

Scientific name/Host range: Ascomycetes:

Black spot of apple (*Venturia inaequalis*) affects apple, and overseas some species of *Pyrus,* eg wild carab. On apple other fungi may also cause leaf spotting, eg *Alternaria alternata, Phoma* spp., *Phyllosticta* spp., *Pleospora herbarum.* In Asia, Japan and USA, ***alternaria blotch*** (*Alternaria mali*) infects leaves and fruit, aphids may increase damage.

Black spot of pear (*Venturia pyrina*) causes black feathery spots on leaves of pear and hawthorn.

Black spot of loquat (*Spilocaea eriobotryae*).

Symptoms: The ***most serious effect*** is reduced yield and downgraded fruit quality. In early spring small spots appear on ***leaf undersurfaces***. Later light green spots develop on ***uppersurfaces***. These later turn brown then black. Spots may cover the entire surface of the leaf. Infected leaves may curve inwards and become blistered and distorted. ***Infected pear twigs*** develop a flaky appearance, bark becomes blistered and split in places. ***Flower stalks*** may develop black lesions which cause stalks and then flowers to shrivel and die. ***Fruit*** at first develop small, black, circular spots. If numerous they coalesce, forming large scabby areas (Fig. 147). Spots become corky and restricted in growth. ***Fruit infected early*** in the season become very ***distorted and cracked***. Fruit infected later are not so badly affected. A whitish band of raised loosened skin may surround scabs.

Overwintering: As developing fruiting bodies (perithecia) within infected leaves that fall in the autumn, also as mycelium in twigs and bud scales but this is thought to be relatively unimportant.

Spread: Spores (ascospores) in spring are spread by wind to developing leaves etc. Spores (conidia) produced later in the season are spread by water splash and wind to other plant parts.

Conditions favouring: Cool, wet weather in spring, summer and autumn.

Control:

Sanitation: It should be possible to control scab by collecting and destroying all infected fallen leaves. This is not practical.

Resistant varieties: Some apple cultivars are being marketed in Australia as ***scab-resistant***. In favourable seasons some varieties regarded as fairly resistant may become infected. Identifying scab-resistant cultivars ***(SRC)*** is a constant topic of research (Merwin et al. 1994).

Pesticides: The disease is controlled effectively by a ***preventative spray program*** commencing at green tip and a clean up spray applied after harvest, but before leaf fall, to prevent development of fungus in fallen leaves during winter and reduce the source of spring infection. ***Apple scab warning services*** operate to provide disease control reliability with minimal use of fungicides.

Branch and trunk cankers

Botryosphaeria canker and dieback, black rot (*Botryosphaeria ribis = Dothierella* sp.) may cause losses in Granny Smith apples and pears. Sunken oval cankers develop on ***branches*** which may become girdled and die. Tiny black ***fruiting bodies*** of the fungus develop in the bark of affected limbs. The tree gradually declines. Greyish-brown spots with darker surrounding zones develop on ***leaves***, giving a ***'frog-eye'*** appearance. Small brown circular spots develop on ***fruit***. These rapidly increase in size until they cover the whole skin, which turns black. Eventually fruit becomes ***mummified***. Moderate losses of fruit occur when wet conditions persist prior to harvest. The fungus ***overwinters*** in cankers and mummified apples and on other host plants. Spores from fruiting bodies in fruit mummies or cankers are ***spread*** during wet weather by wind and rain. ***Prune out*** and destroy infected twigs and mummified fruit during winter to reduce carryover of the disease. Only ***propagate*** from disease-free plants. ***Fungicides*** used for black spot will assist control. The disease is difficult to control. See Trees K 5.

Others: **Canker** (*Botyrodiplodia theobromae*), ***eutypa canker*** (*Eutypa armeniacae*) on pear, ***black rot*** (*Botryosphaeria obtusa*) on quince. Also *Coniothyrium chromatosporium, Diplodia sarmentorum, Leptosphaeria coniothyrium, Nectria galligena.*

Fleck

Scientific name: *Diplocarpon mespili*, Ascomycetes (= *Fabraea maculata*) is a serious disease of quince.

Host range: Quince, pear, loquat, hawthorn, apple, probably other Rosaceae. In NZ, also some Rosaceae, eg medlar, *Aronia*, *Cotoneaster*, *Photinia*, *Sorbus, Raphiolepsis*.

Symptoms: ***Quince:*** Infection of ***leaves*** occurs soon after bud-burst. Initially spots are very small, raised purple with a small, central white dot. They enlarge and become brownish and then dark grey. Spots may coalesce, resulting in irregular dead areas. ***Leaf stalks*** can be killed and there is premature defoliation, trees may produce new leaves, blossom again and may set fruit only to be prematurely defoliated again. On ***nursery stock***, premature defoliation seriously restricts their growth. Small cankers may girdle ***shoots*** which then die. ***Fruit*** develop dark brown spots which enlarge, becoming black and slightly sunken (Fig. 148). Spots may coalesce to form large irregular spots which result in misshapen and cracked fruit Fruit may fall prematurely. ***Pear:*** In early spring, small reddish spots appear on ***leaf uppersurfaces***. These enlarge, become almost black, and affect both leaf surfaces. Premature defoliation may occur, and this may restrict growth of nursery stock. Cankers may girdle ***shoots*** which then die. ***Fruit*** develop small circular reddish spots, which later become reddish-brown with black centres and may crack. ***Loquat*** is not commonly affected but leaves and fruit may be damaged (Fig. 148).

Overwintering: In cankers on infected shoots and possibly on dead leaves on the ground.

Spread: Spores are washed by rain or irrigation or blown by wind from infected host plants and possibly infected fallen leaves to hosts, etc.

Conditions favouring: Wet spring weather.

Control:

Sanitation: ***Prune*** to remove all dead or spent wood. Home gardeners may rake up and burn all the fallen leaves in the autumn.

Pesticides: ***Fungicides*** may be applied to ***nursery stock*** at the first sign of infection. Further applications may be necessary if weather remains ***wet***. Spray programs to bearing trees may be commenced at green tip. Sprays for black spot on pear usually control fleck.

Fruit rots

Bitter rot, anthracnose (*Glomerella cingulata* var. *minor* = *Colletotrichum* sp.) causes ***field*** and ***postharvest*** fruit rots. See Fruit F 5, Pome fruits F 108.

Black spot, scab (*Venturia* spp.) affect fruit on the ***tree*** in the ***field***. See Pome fruits F 108.

Brown rot (*Monilinia fructicola*) is mainly a disease of stone fruits but may be a ***postharvest*** disease of pome fruits, eg apple, quince and may occur on trees near diseased stone fruits. See Stone fruits F 125.

Brown rot, European brown rot (*Monilinia fructigena*), if introduced to Australia, is likely to cause serious losses to apple and pear production in the ***field*** and ***postharvest*** and aggravate brown rot problems on stone fruits. Importation of pome and stone fruits from countries where *M. fructigena* is present is prohibited (Com. of Aust. 1991).

Grey mould (*Botrytis cinerea*) is an important ***postharvest*** disease of apples, pears and other fruit, although infection of fruit on the tree may occur if cool wet weather occurs around harvesting. Infection occurs mainly through wounds and skin injuries. Decaying fruit during storage provides additional inoculum. A soft brown rot develops on ***fruit***. In humid conditions patches of ***grey powdery spores*** develop on the surface of affected areas. Black hard sclerotia may develop. The fungus can spread to other fruit in a container, causing ***nests*** of rotted fruit. See Fruit F 5, Greenhouses N 22.

Mucor rot (*Mucor piriformis, Mucor* spp.) is ***important*** on pome fruits. It initially causes a light brown soft watery ***postharvest*** rot, later a white whiskery fungal growth develops which is soon covered with ***black spores***. A similar disease to *Rhizopus* but may develop at 0^oC while *Rhizopus* cannot develop at $< 4^oC$. It is a soilborne fungus, infecting fallen fruit ***during and after harvest.***

Penicillium moulds (*Penicillium expansum*, *P. rucosum*) is the ***most serious postharvest disease*** of apples and pears. ***Fruit*** at first show soft pale brown watery spots, which enlarge rapidly and may completely envelop the fruit. Under warm moist conditions ***blue-green spores*** develop on affected areas. Fruit has a musty smell. See Fruit F 6.

Rhizopus soft rot, rhizopus transit rot (*Rhizopus stolonifer*) may affect fruit ***postharvest*** (see Mucor rot above). See Fruit F 6.

Ripe fruit spot (*Pezicula alba*) is a minor disease in well maintained orchards. Tiny brown-black sunken spots develop on ***fruit*** with ***whitish spore masses*** in wet weather. Often confused with bitter rot.

Target spot (*Phlyctaena vagabunda* = *Gloeosporium album*) has a wide host range. It ***overwinters*** on mummified apples, twigs, and dead fruiting spurs. It infects ***fruit in the field*** but seldom causes spotting on fruit until the fruit has been stored for some time. ***Postharvest*** dips control it.

Others: ***Core rots:*** *Alternaria alternata, Cladosporium, Epicoccum, Fusarium*) may cause ***postharvest*** dry and wet core rots. Also *Aschochyta mali, Aureobasidium pullulans.*

See Fruit F 5.

Powdery mildew

(*Podosphaeria leucotricha*) affects apple, and occasionally pear and quince. Small white powdery patches of spores first appear on leaf undersurfaces, soon both surfaces are covered. Severely affected ***leaves*** are narrow, inrolled, brittle, and may die and fall.

Buds have a small pinched appearance and usually open later than healthy ones. When buds start growing the fungus grows out along the new shoot infecting each new leaf as it appears. ***Flowers*** produced from infected buds die and rarely set fruit. ***Current year shoots*** (1-year old twigs) may be coated with white fungal mycelium and have completely infected leaves. These shoots may be stunted and may dieback, producing a witches' broom effect of stunted and infected shoots the following season. ***Fruit*** may be infected soon after petal fall. Affected areas may be ***russetted***, growth is retarded, and fruit is misshapen and downgraded. Do not confuse russetting with spray or frost damage. If powdery mildew is not controlled, tree vigour and yield are reduced. Moist conditions ***favour*** spread. Surface mycelium can withstand very dry hot weather and subsequently produce more spores when favourable conditions return. ***Pruning*** all infected shoots in winter is essential for satisfactory control of the disease in susceptible varieties. In ***very susceptible varieties***, terminal buds are likely to be infected, so all laterals should be shortened in the spring. During the growing season, remove all mildewed shoots from the trees and burn them starting in spring. ***Very susceptible varieties*** include Jonathan, Rome Beauty, Gravenstein. Varieties with some resistance include Granny Smith, Delicious. ***Pesticides:*** Protect new growth in spring to prevent losses in the current season and infection of developing buds. ***Field sprays*** (for established trees) and ***dips*** (for transplants) of systemic fungicides combined with a wetting agent almost completely eradicate overwintering powdery mildew ***from shoots and buds***. See Annuals A 6, Fruit F 7.

Root and collar rots

Mature leaves of affected trees turn yellow or reddish, wilt and eventually become brown and papery.

Armillaria root rot (*Armillaria luteobubalina*) may be a problem in orchards established in newly cleared bushland. See Trees K 4.

Phytophthora collar and crown rot (*Phytophthora* spp., *P. cactorum*,) can be an ***important disease*** of apple trees. See Trees K 6.

Sclerotium stem rot (*Sclerotium rolfsii*) causes rotting of ***bark and wood*** at or just below ground level. White wefts of fungal growth cover affected areas when the soil is moist. It is often more serious ***on apple trees planted in sites previously used for vegetables***. When planting apple trees in old vegetable or replant land drench the base of the tree with a recommended ***fungicide***. Repeat in midsummer. Regularly ***inspect*** young trees and if any show signs of infection remove soil from the crown, cut away the diseased wood and treat with any recommended wound treatment. Drench the crown area with fungicide. Leave areas exposed for at least 10 weeks. This treatment is only effective if the disease is detected early. See Vegetables M 7.

Rosellinia root rot, rosellinia root rot (*Rosellinia necatrix = Dermatophora necatrix*) affects some ***ornamental trees***, eg holly, walnut, poplar, ***fruit trees*** and ***vines***. ***Trees*** become unthrifty with leaf yellowing, cessation of growth, premature leaf fall and small shrivelled fruit. The ***bark*** of the crown and base of the trunk is a dark, wet rot, and a sharp margin between healthy and diseased bark occurs. A thin layer of ***white fungal growth*** occurs under the ***bark***. ***Roots*** develop a dark, wet surface rot and are often covered with white strands of fungal growth which may grow into soil and litter. Sometimes all trees may be killed. The fungus ***overwinters*** in soil, on old rotted roots and root debris left in the ground and on the roots of various native trees and weeds such as fleabane (*Conyza* spp.) and stinking Roger (*Tagetes minuta*). Young apple trees planted into infested soil become infected when their roots contact infected material. The disease may cause ***serious losses*** in orchards established in land cleared of native vegetation susceptible to the fungus and in new orchards replanted in old apple orchard land. Remove diseased trees with as many roots as possible and treat site before replanting. Rosellinia root rot can be ***confused*** with ***armillaria root rot*** (except there are no rhizomorphs or fruiting bodies formed), ***nematodes*** and ***other soil problems*** (Horst 1990).

Others: Pythium root rot (*Pythium vexans*).

See Fruit F 7.

Sooty blotch and flyspeck

Scientific name: Flyspeck and sooty blotch are associated with each other and are caused by:
Sooty blotch (*Gloeodes pomigena*)
Australian sooty blotch (*Leptothyrium fulginosum*)
Flyspeck (*Schizothyrium pomi*)

Host range: Apple, pear, peach, citrus, etc. Also many native plants, particularly wattle.

Symptoms: ***Sooty blotch*** grows externally over the surface of ***mature fruit***, producing dark, filmy smudges. Colonies are circular at first, but may join together later to completely cover the fruit. Smudges are superficial and can easily be rubbed off. A heavy attack of sooty blotch is rather similar to ***sooty mould***, which develops on the honeydew secreted by soft scales, aphids and other insects. But unlike sooty mould, ***it is a true parasite***, living on the surface tissue of the host. Although sooty blotch (and flyspeck) are parasitic on the surface cells of fruit, there appears to be no damage. However, fruit is rendered unsightly and is downgraded. Growth of sooty blotch also continues in storage. Sooty blotch sometimes attacks ***young twigs*** (particularly peaches, wattle) and forms a conspicuous black surface growth on the current season's wood, causing alarm during pruning. The disease known as ***flyspeck*** is commonly associated with sooty blotch. Small black dots or specks (fruiting bodies), develop on the surface of the ***fruit***. They grow on a very fine almost invisible film of fungal threads. Dots are superficial and can be easily rubbed off.

Overwintering: As fungal threads or fruiting bodies on the twigs of host plants.

Spread: Spores are spread by rain splash and water dripping through the tree and over the fruit.

Conditions favouring: ***Sooty blotch:*** Warm wet conditions favour the growth of this fungus. A late summer disease of minor importance which affects ripening fruit, especially Granny Smith during humid weather, causing a downgrading of fruit quality. ***Flyspeck:*** High rainfall during autumn and winter, and shade. Fruit hanging inside the tree canopy or on the southern side is more likely to be affected than exposed fruit. Spores are released during cool, humid weather. It is generally a late summer disease of minor importance in well managed orchards, but can be problem on ripening fruit during cool wet weather.

Control:

Cultural methods: Ensure ***fruit*** are ***thinned***, as clusters of small fruit provide ideal conditions for disease development.

Pesticides: Usually sooty blotch is kept in check by spray programs used to control other problems, eg scab. Fruit discoloured by sooty blotch may be bleached clean after harvest. However, the treatment tends to leave a minor brown discolouration and should not be regarded as an alternative to preventative sprays.

Wood rots

Pink limb blight (*Corticium salmonicolor*) causes a ***pink encrustation*** on bark of loquat and other trees.

Red wood rot (*Trametes cinnabarina*) fruiting bodies are ***orange***, up to 700 mm across, with a honeycomb of pores underneath. Also *Pycnoporus coccineus.*

Silver leaf (*Stereum* spp.) may occur on pear and many other plants. See Stone fruits F 128.

Yellow heart rot (*Schizophyllum commune*) fruiting bodies are ***soft whitish*** with ragged edges and gills underneath.

Yellowish wood rot (*Polyporus versicolor*) are up to 30 mm across with various ***coloured bands*** and a smooth upper surface and a honeycomb of pores underneath. causes a white, spongy rot.

Others: ***Spongy wood rot*** (*Heterosphorus biennis*), ***wood and root rot*** (*Ganoderma applanatum*), ***wood rot*** (*Coriolus* spp.).

Prune trees carefully to avoid major pruning cuts. If recommended, treat with wound dressing to promote rapid healing. ***Maintain*** a ***balanced fertiliser*** and ***irrigation program***. See Trees K 8.

Others: ***Leaf blight*** (*Entomosporium mespili*) on loquat, ***pink rot, limb blight*** (*Trichothecium roseum*), ***quince leaf and fruit rot*** (*Entomosporium mespili*) on loquat and quince, ***dieback*** (*Diaporthe perniciosa Valsa* spp.), ***elsinoe spot*** (*Elsinoe piri*) possibly on pear.

NEMATODE DISEASES

Root lesion nematodes (*Pratylenchus* spp.), sometimes called ***apple replant disease (ARD),*** is thought to be caused by a complex of soil microorganisms including parasitic nematodes. ***Replant problems*** associated with these nematodes can be ***serious*** especially where apples are replanted in areas where old apple trees have recently been removed or where crops that are hosts of root lesion nematodes have been grown recently. ***Young replanted trees*** are stunted and unproductive. Established trees show reduced growth and yield. ***Root systems*** of affected trees are small and discoloured and often grow in tufts and lack well-developed feeder roots. When orchard trees are removed, high numbers of nematodes remain in the roots or in the soil. In weed-free fallow soils, nematode numbers tend to decline with time, but they will increase if old apple roots, weeds or host crops are present. ***Roots*** of ***nursery trees*** may be infested with nematodes from the rootstock stool beds or the nursery soils. ***In replant sites*** pull out old trees and then thoroughly rip and plough the soil to remove tree roots. Delay replanting for 12 months or as long as possible. During spring and summer grow recommended ***cover crops***. Incorporate a cover crop in late summer to encourage the debris to breakdown and to achieve ammonia concentrations which are toxic to nematodes. In situations where apples must be replanted soon after removing old trees maintain the area free from weeds, and fumigate soil. After replanting maintain a mulch of sawdust or other organic material 1-2 m wide along the tree row. Do not plant cover crops, eg pea, rye, lupins which are susceptible to root lesion nematodes. ***Pear and quince*** may also be attacked. See Vegetables M 11.

Others: Other nematodes have been recorded on ***apple,*** eg ***root knot nematode*** (*Meloidogyne*) and *Aphelenchoides, Aphelenchus, Basiria, Cephalenchus, Coslenchus, Criconemoides, Ditylenchus, Filenchus, Helicotylenchus, Hemicycliophora, Longidorus, Macroposthonia and Merlinius, Morulaimus, Neopsilenchus, Paratrichodorus, Paratylenchus, Paurodontus, Rotylenchus, Sakia, Tylenchorhynchus, Tylenchus, Xiphinema;* on ***pear***, eg *Aphelenchus, Coslenchus, Criconemoides, Filenchus, Helicotylenchus, Hoplaimus, Longidorus, Paratrichodorus, Rotylenchus, Tylenchorhynus, Xiphinema;* on ***loquat***, eg ***root knot nematode*** (*Meloidogyne* sp.) (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Apple dimpling bug (*Campylomma liebknechti,* Miridae, Hemiptera) infests ***fruit***, eg apple, nashi, pear, ***ornamentals***, eg *Photinia glabra*, *Pyrus calleryana*, wattle, tree lucerne (*Chamaecytisus proliferus*), ***vegetables***, eg potato, lucerne. ***Adults*** are small, pale green, oval insects about ***2.5 mm*** long which fly readily and crawl very actively on flowers. Strong, paired spines on the hind legs are readily seen when the bug is examined under a hand lens. Bugs can be collected by jarring flowers sharply 3-4 times over a wide-mouthed container. Inspection must be prompt as the bugs usually fly off after a few seconds. ***Nymphs*** appear to prey on other insects and possibly mites. Only the adult stage damages plants. ***Flowers and fruitlets:*** Adults suck sap from flower parts which later develop into the fruit and later the fruitlets themselves (up to 7-10 days after petal fall). This injury causes raised, scabby areas of dead tissue which are prominent early in the growth of the fruit. As fruit develops, cells around scabbed areas fail to grow normally and fruit become ***dimpled*** (Fig. 149). Fruits only slightly damaged often grow out of this condition, but severely damaged fruit remain badly deformed and are unsaleable. ***Do not confuse*** damage to fruits by the apple dimpling bug with boron deficiency or hail injury. There is a ***gradual metamorphosis*** (egg, nymph, adult) with probably many generations each year. Bugs invade apple orchards as winged adults from late pink stage to about petal fall. They feed among the flowers and remain on the tree until about ***2 weeks after petal fall***. Eggs are laid around the floral parts. They hatch in about 1 week, giving rise to wingless, yellow-green, inactive nymphs which develop through several stages on trees to become adults in about 4 weeks. These adult bugs fly off to other hosts and are not seen on apple trees again during that season. ***Overwinters*** in some areas on wattles and wild radish. ***Spread*** by bugs flying and by hot dry winds. Damage to apples ***varies from season to season***, being heaviest when bugs are numerous and blossom is sparse. Granny Smith and Delicious are ***very susceptible*** and regularly affected. If conditions are favourable, early varieties of Gravenstein, Early McIntosh and Twenty Ounce may be damaged in some districts. No damage has been recorded on Jonathan. ***Pesticides:*** In commercial orchards, nymph development is prevented on flowers and fruitlets by the pesticides to control codling moth. Usually routine applications are made only to Granny Smith and Delicious. ***Monitor*** bug populations at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). Only use chemicals which do not harm bees. ***Other bugs may also infest apples***, eg ***green vegetable bug*** (*Nezara viridula*) and ***metallic shield bug*** (*Scutiphora pedicellata*).

Apple leafhopper, canary fly, canary jassid

(*Edwardsiana australis = E. crataegi, E. froggatti*), Cicadellidae, Hemiptera) is common in ***young non-bearing trees*** where sprays for codling moth are not applied, neglected apple trees, ornamental crab apples, hawthorn and prunes. ***Adults*** are about ***4-5 mm*** long, greenish-yellow with conspicuous red eyes. They resemble a minute cicada in general shape but their hind legs are formed for jumping. ***Nymphs*** resemble adults except that they are smaller, paler and have no wings. Adults and nymphs live almost exclusively on ***leaf undersurfaces,*** sucking sap and causing them to become grey and mottled (Fig. 150). Leaves may turn yellow and fall prematurely. Leafhoppers may also settle on ***apple fruit,*** depositing an ***unsightly brown excrement*** which reduces market value. It is difficult to remove and is more noticeable on light-skinned varieties. Market value of ***prunes*** can also be lowered, as extensive damage reduces sugar content There is a ***gradual metamorphosis*** (egg, nymph, adult) with 2 generations each year. Sometimes there is a 3rd generation. ***Overwinters*** as eggs in twigs of host plants. ***On bearing apples insecticides*** used for codling moth will control apple leafhoppers. ***On non-bearing apples monitor*** leaves for leafhoppers from October onwards before applying an insecticide (good coverage of leaf undersurfaces is essential). One application may be sufficient, repeat applications may be necessary. See Vegetables M 15.

Borers include:

Auger beetles (Bostrichidae, Coleoptera)
Common splendid ghost moth (*Aenetus ligniveren*)
Fruit-tree borer (*Maroga melanostigma*)
See Trees K 11, K 12.

Caterpillars (Lepidoptera)

Noctuids (Noctuidae): ***Budworms*** (*Helicoverpa* spp.) and ***looper caterpillars*** (*Chrysodeixis* spp.) chew ***fruit*** in spring before sprays for codling moth or lightbrown apple moth are applied. Raised or sunken round ***callused areas*** usually 6-13 mm in diameter appear on the fruit. ***Cluster caterpillar*** (*Spodoptera litura*) may damage pear. See Fruit F 8.

Leafroller moths (Tortricidae): ***Codling moth*** (*Cydia pomonella*) caterpillars feed inside the fruit and is the ***most important pest of pome fruits*** in Australia. See Pome fruits F 113. ***Lightbrown apple moth (LBAM)*** (*Epiphyas postvittana*) is an ***important leafroller moth*** affecting a wide range of plants, eg ***ornamental*** exotic and native trees, shrubs and climbers, eg protea, wattle, ***fruit***, eg apple, grape, ***vegetables***, eg carrot, ***field crops***, eg legumes, ***weeds***, eg blackberry, capeweed, dock. ***Female moths*** are small, bell-shaped brown or yellow moths with darker markings. They are about ***10 mm*** long when at rest with their wings folded. Males are slightly smaller, and have a variable colour pattern. During the day they shelter amongst foliage, when disturbed they make short, quick erratic flights. They are active at dusk, flying amongst trees and other plants. ***Newly hatched caterpillars*** are pale yellow and wander over the plant, usually on ***leaf undersurfaces***. ***When fully fed*** they are ***slender, pale green*** with a brown head, and about ***18 mm*** long (Fig. 152). The body tapers slightly from the middle towards each end. Caterpillars ***roll and web leaves*** or ***leaves and fruit*** together with silk secreted from their mouths to form a shelter from which they feed on the leaf and fruit tissue at these sites. When disturbed they ***wriggle violently*** and retreat into their shelter or fall to the ground hanging suspended by a thread. ***Leaves*** and ***growing points*** of lateral growth of fruit trees and other plants are also favoured. ***Flowers and fruit clusters*** in plants such as grapes where caterpillars have been feeding on the skin are woven together and large, irregular blemishes occur. These may callus over and the fruit may remain on the tree. In wet weather decay organisms may enter; fruit rot and fall. Pears especially William's Bon Chretien, are often severely damaged. There are ***2-3 overlapping generations*** each year. All stages may be found almost throughout the year. Female moths lay flat egg masses (of 20-30 eggs) on the smooth surfaces of leaves, stem or fruit. Caterpillars pupate in a loose cocoon, usually in a rolled leaf where they were feeding or in flower debris. ***Overwinters*** in inland areas as caterpillars sheltering and feeding on hosts, eg citrus. Large numbers shelter in weeds and cover crops. On the coast other stages are more common in winter. ***Favoured*** by cool, moist weather. Hot dry weather is unfavourable. It tolerates low temperatures. Heavy fruit damage may be caused close to harvest in autumn, also sometimes in ***packing sheds and cool stores***. Spray programs may kill natural enemies and contribute to the damaging infestations. ***Sanitation:*** Removal of weeds before bud burst in spring would reduce subsequent infestation of fruit and other crops. If weed growth cannot be removed before budburst consideration should be given to applying a protective spray to fruit and other susceptible crops. ***Biological control: Parasitic insects*** include a wasp (*Trichogramma funiculatum*) and flies (Diptera). Predators include spiders and earwigs. ***LBAM*** virus has been tested in Australia with varying degrees of success. These agents do not prevent economic damage. ***Pesticides:*** Crops attacked by this moth are usually attacked by other pests which require the use of pesticides, eg on pears and apples sprays used to control codling moth will also control ***LBAM***. ***Monitor*** fruit for caterpillars before applying an insecticide (Brough et al. 1994). ***Lucerne leafroller*** (*Merophyas divulsana*) has a similar life history, habits and damage as ***LBAM***. ***Moths*** are yellowish with dark markings, bell-shaped but differ from ***LBAM*** in size with the lucerne leafroller being 13 mm across the outspread wings and ***LBAM*** 18 mm. Eggs are laid in flat clusters on leaves, like groups of tiny fish scales. ***Caterpillars*** are slender, green and up to about ***10 mm*** long. Damage may occur in both spring and autumn crops and in some seasons is extensive. ***Others:*** Also *Epiphyas liadelpha* and ***orange fruitborer*** (*Isotenes miserana*).

Loopers (Geometridae): ***Apple looper*** (*Phrissogonus laticostata*), ***cherry looper*** (*Chloroclystis. approximata*), ***pome looper*** (*C. testulata*). See Avocado F 19.

Painted apple moth, painted wattle moth (*Teia anartoides,* Lymantriidae) is a tussock moth and a ***sporadic, destructive pest***. Plants attacked one year may be free from attack in later seasons. ***Ornamentals***, eg bottlebrush, fern, geranium, gladiolus, grevillea, hardenbergia, melaleuca, rose, wattle, ***fruits***, eg apple, cherry, apricot, ***vegetables*** and ***weeds***. ***Female moths*** are wingless and thickly covered with short brown hairs, legs and antennae are rudimentary. Male moths measure about 25 mm across the outspread wings. The front pair of wings are dark brown, marked with black, and the hindwings are orange with a broad, black, outer band. ***Caterpillars*** are about ***30 mm*** long when fully-grown, densely covered with brown hairs, and bear ***4 tufts*** or brushes of white hairs on their back (Fig. 151). A pair of black, horn-like tufts project from their head. Caterpillars may eat whole ***leaves*** (fine-leaved plants) or ***skeletonise leaves*** by eating the upper surface layer (broadleaved plants such as *Acacia pycnantha*). Because of the large numbers of caterpillars, damage may be severe. Small trees and plants may be totally defoliated. ***Green fruits*** may be grazed. There are ***several generations*** each year. The female, on emergence, usually remains on the outside of the cocoon and deposits up to 500 glossy, white, almost spherical eggs. Caterpillars spin flimsy, silken cocoons on or near their food plant to pupate in. ***Overwinters*** in cool climates probably as cocoons. ***Favoured*** by cool winter weather but may occur all through the year. Populations tend to build up in one season on a particular plant or group of adjacent plants. Hand-picking of the caterpillars is an ***unattractive proposition*** because of their large numbers and the hairs on their body. There is no record of people being affected by the hair. A ***similar pest*** (*Orgyia athlophora*) occurs in south-western WA.

Others: ***Darkspotted tiger moth*** (*Spilisoma canescens*), ***leaf case moth*** (*Hyalarctca huebneri*), also *Pholodes sinistraria*. In China, ***fruit moth*** (*Carposina nipponensis*) caterpillars feed inside apple fruit and threatens 70% of China's expanding apple industry. Spraying with ***nematodes*** (*Steinernema* or *Heterorhabditis*) is recommended. Immature nematodes penetrate the caterpillars and release a bacteria (*Xenorhabditis*) which multiply inside the caterpillars killing them (septicaemia).

See Annuals A 8, Fruit F 8. Trees K 13.

Codling moth

*Codling moth is the **key pest of pome fruits** in eastern Australia. Unless effective control measures are applied regularly, all the fruit on trees may be infested.*

Scientific name: Tortricidae, Lepidoptera:
Codling moth ***(CM)*** (*Cydia pomonella*)

Host range: ***Pome fruits***, eg apple, crab apple, pear, quince. Uncommonly chestnut, damson, hawthorn, kiwi fruit, persimmon, pomegranate, stone fruits, walnut.

Description and damage: ***Moths*** are brown-grey and about 12 mm long when at rest with wings folded. ***Caterpillars*** are up to ***20 mm*** long, cream to pinkish with a brown head. Young caterpillars enter ***fruit*** mainly at the calyx end. Their excreta is pushed outside. Caterpillars tunnel to the core to feed on ***seeds*** (Fig. 153). When fully grown, they tunnel to the surface and emerge through ***round exit holes.*** 'Stings' may occur on fruit surfaces where caterpillars have died after entering, or failed to enter successfully, but fruit is downgraded. Infested fruit may ***ripen early***.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with ***2-3 overlapping generations*** each year (in some overseas countries there is only 1 generation each year making its control easier). The 1st (spring) generation moths begin to emerge ***early in October***, reaching a peak about mid-November. Eggs are laid on leaves and fruit and hatch in 5-10 days. Young caterpillars eat into fruit to feed around the ***core***. When fully fed (in about 4 weeks) they crawl down at night from fruit to spin cocoons under loose bark, in crevices on trunks and main limbs, and on stable litter. The 1st pupation occurs during December-January. Moths emerge in about 15 days and reach peak numbers in ***late January***. Fullyfed larvae from this generation overwinter in cocoons and pupate in mid-September. However, a partial 3rd generation may occur, infesting late varieties in ***April***.

Overwintering: Because moths are not very mobile, the main source of infestation each season in an orchard or on a tree is the overwintering cocoons on tree trunks and limbs and stable litter on the ground, eg fruit cases, ***in that orchard***. A few 'strays' may fly in from surrounding orchards or trees, but their numbers are negligible.

Spread: By moths flying (female moths will fly over not more than ***5-10 trees*** in most orchards (males will fly as far as 180 meters), by transfer of infested fruit and cocoons on packing containers or anything that can carry cocoons.

Conditions favouring: Hot dry weather during late spring and early summer. Moths are only active if temperatures ***> 15^{o}C.***

Control: Where codling moth occurs, control measures are ***compulsory*** under various plant disease acts which require a grower of apples, pears and quinces, to carry out ***prescribed sanitation treatments*** and to apply a minimum number of ***pesticide applications*** to trees of fruiting age. ***Local regulations*** usually include sanitation measures:

Sanitation: ***Comply with local regulations***. You may also be required by law to:

- Collect all fallen fruit and remove all infested fruit from trees at intervals not exceeding 7 days. These fruit must be destroyed immediately either by boiling, burning or placing in a special insect-proof pit. Keep ground beneath and around trees free from long grass and weeds. See Fruit F 9.
- Treat any infested fruit or other ***CM***-infested item on the premises in such a way to destroy the infestation.
- Brush loose bark and cocoons from the trunk and limbs of the tree during December and again at the end of February and during winter (older trees).
- Remove and destroy litter and unwanted plant debris.
- Remove unwanted trees.

Biological control: ***Nematodes*** will attack overwintering caterpillars but are not available commercially. ***Granulosis virus*** may be present in orchards but will not control infestations. A ***fungus*** (*Beauvaria* sp.), which occurs naturally, can reduce populations overwintering on trees during wet winters. None of these seem to reduce moth populations significantly. Moths in apple and pear orchards may be ***monitored*** with ***synthetic female pheromone traps*** which attract the male moths. Depending on numbers caught, tiers containing a ***pheromone*** ***(Isomate®C)*** are tied on shoots and release large quantities of female pheromone which confuse male moths so that normal mating cannot take place. This system may be used as the sole treatment where ***CM*** populations are low. Where populations are high, ***supplementary insecticide applications*** may be needed. In the home garden, wine and molasses traps can be used.

Resistant varieties: All varieties of apples and pears appear to be equally susceptible.

Plant quarantine: Codling moth only occurs in eastern Australia. The ***movement*** of infested fruit and packing cases is strictly controlled by interstate and regional plant quarantine regulations within Australia. As moths do not fly far, apples and pears can be grown in remote areas of the eastern states where codling moth has not reached.

Physical and mechanical methods: Several layers of ***hessian or corrugated cardboard*** tied securely with wire round the trunk of the tree to provide pupating places should be put on no later than mid-November. Remove, burn and replace every month until late May. Kill overwintering caterpillars in ***bulk bins*** by steam cleaning.

Pesticides: Only ***spray fruiting trees*** in infested orchards. As 1 mated female can produce about 1,000 second-brood caterpillars, thorough spraying will produce a clean crop and reduce overwintering populations. After eggs hatch caterpillars almost immediately burrow into the fruit out of reach of pesticides so that sprays must be directed at killing the moths, eggs or very young caterpillars before they burrow into the fruit. ***Insecticides*** and ***insect growth regulators*** ***(Insegar®)*** are registered for codling moth control. ***Select chemical insecticides*** which do not affect natural controls and any biological control agents being used to control ***CM*** or other pests. ***State Fruit Growers' Schemes*** recommend when to spray based on ***CM*** populations and daily temperatures recorded by the grower. Besides the direct savings associated with the cost of chemicals, long-term benefits of reducing the numbers of sprays include slowing down the development of insect resistance to chemicals and overcoming the problem of killing beneficial organisms unnecessarily. ***Monitoring moth activity*** in orchards (see Biological control above) may reduce number of sprays necessary for effective control. In some areas, eg NSW, it appears that the codling moth flight activity pattern may be so irregular and extends virtually over the whole season, that little may be gained by using traps to monitor the activity of moths with the intention of reducing the number of sprays necessary for control. ***Caterpillars*** may be ***monitored*** during thinning. Codling moth may develop ***resistance*** so it is essential to develop and use ***various resistance strategies***, eg sanitation, correct equipment and calibration, spray warning services, etc.

Fruit flies (Tephritidae, Diptera):

Mediterranean fruit fly (*Ceratitis capitata*) and ***Queensland fruit fly*** (*Bactrocera tryoni*) attack pome fruits. Unless fruit fly is controlled in ***loquats***, it multiplies and attacks other later-maturing fruit. Planting ***early maturing variety*** will minimise problems with fruit flies. Spraying can be difficult as a mature tree could be 7-8 m tall. ***Quince*** is a late maturing fruit and in areas where fruit flies occur a rigorous spraying program is usually necessary. See Fruit F 9.

Mealybugs (Pseudococcidae, Hemiptera)

Longtailed mealybug (*Pseudococcus longispinus*) may be responsible for up to ***70% loss*** of ***pears*** at harvest. Mealybugs feed on ***leaves and fruit***, and overwinter under the bark. Prune trees to be open.

Tuber mealybug (*Pseudococcus affinis*) infests ***calyx and stalk ends of fruit***, downgrading it due to their presence, and sticky honeydew and sooty mould which cannot be washed off. The feeding does not directly harm the fruit or tree.

Prune to keep trees open to minimise sheltering places for mealybugs and allow sprays to penetrate. ***Natural enemies***, eg ***green lacewing larvae*** (*Chrysopa* sp.), ***hoverfly maggots*** (Syrphidae, Diptera) and ***mealybug ladybird*** (*Cryptolaemus montrouzieri*) assist in reducing populations but do not provide economic control. ***Monitor*** mealybug populations at regular intervals before applying an ***insecticide*** (Brough et al. 1994). See Greenhouses N 25.

Mites (Acarina)

Eriophyid mites (Eriophyidae): ***Pearleaf blister mite*** (*Eriophyes pyri*) affects pears, nashi, overseas also apples and some related trees. ***Adults*** are microscopic (about 0.2 mm long) and have white bodies. Initially, small pink swellings develop on the undersides of young ***leaves***. These blisters darken as the leaf grows and ages and enlarge to about 3-4 mm in diameter and are visible from ***leaf uppersurfaces*** as well (Fig. 154). On the leaf undersurfaces there is a small hole in each swelling through which the young mites move in and out. They feed entirely on the plant tissue within the blister and are almost completely protected. In severe infestations, ***stems and fruitlets*** may be infested. The young fruitlets may develop reddish blisters on the skin. In warmer climates the ***fruit buds*** may turn brown and flare open during winter or produce ***weak flowers*** and ***misshapen fruits*** due to the feeding of the mites under the bud scale. There is a ***gradual metamorphosis*** (egg, nymph, adult) with many generations each year. As soon as foliage unfolds in spring, mites become active and start feeding on leaf undersurfaces, causing blisters where eggs are laid. In cold regions mites ***overwinter*** as eggs under bud scales. In warmer regions, the eggs deposited within buds hatch and develop during winter, destroying bud tissues. ***Spread*** by mites crawling from tree to tree, movement of infested trees, nursery stock, etc. ***Favoured*** by spring and autumn weather. Activity decreases during the hot summer months. ***Control: Monitor*** mite populations at regular intervals before applying an insecticide (Brough et al. 1994). If mite damage was prevalent the previous season spray at green tip with oil. See Grapevine F 62. ***Other eriophyid mites: Apple rust mite*** (*Aculus schlechtendali*).

Spider mites (Tetranychidae): ***Bryobia mite*** (*Bryobia rubrioculus*) is about ***1 mm*** long and is purplish brown with 8 legs, the front pair of which is ***extremely long***. Nymphs looks like adults but are smaller. ***Eggs*** are minute, globular and ***red***. Adults and nymphs suck sap from ***leaves*** of apple, pear and almond. Heavily infested leaves become pale and may fall prematurely. A spray of winter oil during dormancy usually controls bryobia mite satisfactorily. See Fruit F 12. ***European red mite*** (*Panonychus ulmi*) ***(ERM)*** may be a ***major and frequent pest of pome fruits***. Females are ***0.3-0.5 mm*** long with 4 rows of long stiff curved ***spines*** on the back. They feeds by sucking from ***leaf uppersurfaces***. Leaves may be stippled, and later bronzed and trees may be defoliated. ***Fruit*** from severely damaged trees fails to colour and size properly. Juice content is reduced and premature defoliation exposes fruit to sunburn. Delicious cultivars are very susceptible. ***Monitor*** overwintering red eggs ***during winter pruning***. ***Monitor*** active stages, eggs and its predator (*Typhlodromus pyri*) ***during spring*** but more extensive monitoring can be carried out (Brough et al. 1994). ***ERM*** can be controlled by the introduced predatory mite (*Typhlodromus pyri*) which is resistant to many pesticides used in orchards. Apply winter oil during dormancy. See Fruit F 12. ***Twospotted mite*** (*Tetranychus urticae*) on apple may cause bronzing of ***leaves***, an uprolling of leaf margins and defoliation. In severe cases, ***fruit*** may be attacked. Mites are ***0.5. mm*** long, pale grey with ***distinctive markings*** on either side of the body. On crops such as apples where pesticides are used extensively to control other pests, the pesticides may kill off or reduce the populations of twospotted mites' natural predators, eg *Stethorus* beetles and predatory mites. damage is favoured by ***moisture stress***. Fruit from trees with damaged foliage fails to size properly and has reduced juice content. ***Premature defoliation*** may result in ***sunburnt fruit***. Most mites ***overwinter*** as females hibernating in leaf litter at base of trees, but some come from other external hosts, eg blackberries. During spring and summer ***monitor*** mite populations. ***Predatory mites*** (*Typhlodromus occidentalis*, *Phytoseiulus persimilis*) can be purchased. Introduce predators when twospotted numbers are low, ie 20-30% leaf infestation. Spray when pest populations are high, ie infest between 65-80% of the leaves. Continue monitoring to determine whether further releases of predators or sprays are required (Brough et al. 1994). See Beans (French) M 29, Fruit F 12.

Others: A ***flat mite*** (*Brevipalpus* spp.) may infest quince.

Pear and cherry slug

Scientific name: Tenthredinidae, Hymenoptera: Pear and cherry slug (*Caliroa cerasi*)

Host range: ***Ornamentals***, eg cotoneaster, hardenbergia, hawthorn, photinia; ***fruit***, eg cherry, medlar, plum, pear, occasionally peach, nectarine, almond.

Description and damage: ***Adults*** are 7 mm long, glossy, black sawflies. The female has a saw-like ovipositor at the end of the abdomen. She uses this to cut slits in leaves to lay her eggs in. ***Larvae*** or slugs are about ***12 mm*** long and covered with a green slime and feed and skeletonise ***leaf upper surfaces*** leaving only the veins and lower epidermis (Fig. 155). Leaves look scorched, shrivel and fall. Continual heavy infestations weaken trees.

Pest cycle: Complete metamorphosis (egg, larvae, pupa and adult) with ***2 generations*** each year (spring and autumn). Eggs are laid in the leaves. Larvae feed for several weeks then either fall or crawl to the ground where they pupate. The 2nd generation is usually more numerous and destructive than the 1st generation.

Overwintering: As larvae in cocoons in the soil.

Spread: As adults flying, movement of infested nursery stock with leaves.

Conditions favouring: Cool, moist weather. Adults can only emerge from the cocoons in the soil when weather is moist. Larvae shrivel up quickly during dry weather. During wet weather they may feed on the leaf undersurface.

Control: If the 1st generation is controlled, the 2nd generation will not be so numerous.

Cultural methods: Avoid overhead irrigation.

Sanitation: If only a few small trees are infested, larvae may be squashed by hand.

Physical and mechanical methods: ***Drying agents***, eg lime or ash, may be dusted on to leaves to dehydrate larvae on small trees.

Pesticides: ***Insecticides*** may be applied when larvae are first seen.

Plague thrips (*Thrips imaginis*) suck sap from apple and other ***flowers***. Economic damage occurs when they feed on the ***developing styles*** in unopened flowers. When the flower opens, fertilisation cannot occur and the ***fruit fails to set***. ***Monitor*** thrips populations during the period from pink stage until full bloom daily before applying an insecticide (Brough et al. 1994). See Fruit F 12, Roses J 6.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Apple mussel scale*** (*Lepidosaphes ulmi*) may infest a wide range of ***ornamentals***, eg ash, cotoneaster, elm, lilac, maple, poplar, viburnum, and ***deciduous fruits***, especially neglected apple and pear trees. Scale tends to build up in large numbers on 1-2 branches and these may die. ***Adults*** are brown, about ***3 mm*** long, mussel-shaped, tapering and often curved. They are usually light grey to dark brown and may be shiny. They are mostly found on the ***bark*** of older wood (Hely et al. 1982). ***San Jose scale*** (*Quadraspidiotus perniciosus*) infests many trees, eg apple, pear and quince. Adults and nymphs suck sap from laterals, foliage and fruit of apple trees. The ***bark*** looks pink or ashy. If limbs are heavily infested the tree may die. Pink or red spots about 1 mm in diameter and surrounded by a white halo occur on ***fruit***. The presence of scales on fruit will result in its ***rejection for export*** (Fig. 156). Aim to eradicate scale from every tree in the orchard. Tag any trees found to have infested fruit during harvest, and infested bark during pruning. Spray infested trees and check 3 months later for live scales. ***Others:*** ***Greedy scale*** (*Hemiberlesia rapax*), ***oystershell scale*** (*Q. ostreaeformis*), ***pear scale*** (*Q. pyri*), ***purple scale*** (*L. beckii*). See Citrus F 39.

Soft scales (Coccidae): ***Black scale*** (*Saissetia oleae*), ***dupla scale*** (*Duplaspidiotus claviger*) on loquat, ***soft brown scale*** (*Coccus hesperidum*). See Citrus F 41.

See Citrus F 39, F 41.

Weevils (Curculionidae, Coleoptera):

Apple root weevils (*Perperus* spp.) attack many plants including apple, grape, pear and peach (Hely et al. 1982). They are grey-brown and about ***10 mm*** long. They feed mainly at night, hiding during the day around the trunks or under debris. They do not fly, but crawl rapidly. Infestations can spread rapidly through a block of trees. ***Weevils*** feed on ***buds and foliage*** and then work back along the twigs. Damage can cause severe setback to young trees but is not important on trees > 5 years old. ***Larvae*** feed on ***roots***, causing reduced vigour and pitted or channelled roots with almost total absence of feeding roots. ***Insecticides*** may be applied 1-2 weeks after adults emerge from soil in warm weather.

Apple weevil, curculio beetle, dark weevil (*Otiorhynchus cribricollis*) attacks ***fruit trees***, eg apple, plum, citrus, grape, pecan, ***ornamentals***, eg rose (Hely et al. 1982). ***Weevils*** are about ***9 mm*** long, shiny and dark brown. They emerge from soil in spring, climb trees at night to feed, and shelter in the soil during the day. They chew ***leaf edges*** giving them a sawtoothed appearance and may strip young trees. ***Insecticides*** may be applied to butts and lower limbs when damage is seen. ***IPM Services Adelaide*** provides management advice.

Fruit-tree root weevil (*Leptopius squalidus*) larvae eat out deep furrows of ***thicker roots***. Deep roots are most frequently attacked. Trees become thin and sickly, generally dieback and have excessive leaf-drop. Heavy infestations will ***kill trees***. See Fruit F 11.

Fuller's rose weevil (*Asynonychus cervinus*) chews usually ***mature leaves*** low down on trees. Leaves have coarsely serrated edges. ***Larvae*** damage to roots is not economic and control is not required as insecticides for other pests provide control. See Fruit F 13, Roses J 6.

Others: Elephant weevil (*Orthorhinus cylindrirostris*), ***vegetable weevil*** (*Listroderes difficilis*).

See Vegetables M 17.

Woolly aphid

This is a serious pest of apple trees.

Scientific name: Aphididae, Hemiptera:
Woolly aphid (*Eriosoma lanigerum*)
Pear root aphid (*E. pyricola*) affects pears, but not a significant pest in NSW, elm is an alternate host.
Apple-grass aphid (*Rhopalosiphum insertum*)
Spiraea aphid, apple aphid (*Aphis spiraecola*)
Overseas also *Aphis pomi, Dysaphis plantaginea.*

Host range: Apple, crab apple, occasionally cotoneaster (*Cotoneaster*), hawthorn (*Pyracantha* spp.) and rarely pear.

Description and damage: ***Adults*** are purplish brown and normally wingless, but winged adults may be produced in summer and autumn. Aphids secrete a protective sticky woolly material which disfigures laterals (Fig. 157). ***Nymphs*** are paler. Aphids can only suck sap wood where bark is still thin, eg lateral growth, broken or injured bark or existing feeding sites. ***Infested wood*** is ***gnarled*** and ***lumpy*** due to aphids feeding. Lateral growth may become cracked and distorted and buds may be destroyed. ***Honeydew*** is produced. ***Sooty mould*** grows on it and the white woolly material sticks to it. This disfigures ***fruit*** and is unpleasant for pickers. Heavy infestations may cause fruit to fall prematurely. or may interfere with colouring of red varieties. Affected fruit is downgraded. Heavy infestations on ***roots*** produce characteristic lumpy swellings, stunting growth, particularly of young trees. Once trees are established, root infestations rarely affect vigour.

Pest cycle: Gradual metamorphosis (eggs, which rarely hatch, ***nymphs usually born alive***, adults) with many generations each year. Most aphids are wingless females that reproduce asexually (without being fertilised) and give birth to between 2-20 female young a day. In autumn, winged females, which seem to have little significance in Australia, appear. Some migration to susceptible rootstocks takes place in early winter with a return to aboveground parts in spring. On roots, ***reproduction continues through winter*** at a reduced rate. Once aphids settle at a feeding site they remain there until autumn. Reproduction on aerial parts is also resumed at this time.

Overwintering: Mainly as young aphids in cracks and crevices on the ***above ground parts*** of apple. There is some migration of aphids to roots of susceptible rootstock in late autumn but they do not appear to be important for overwintering.

Spread: Occasionally young winged adults produced during summer establish colonies on neighbouring trees. Aphids may also be spread by wind, carried by birds and insects and by the movement of nursery stock and plant material.

Conditions favouring: Spring and autumn. Cool and moist conditions, shaded situations, interiors of dense, strongly growing trees. Low humidity and temperatures > 27°C are unfavourable. Low temperatures have little effect, only slowing down their rate of development.

Control:

Biological control: A ***parasitic wasp*** (*Aphelinus mali*) lays its egg in the body of an aphid and the feeding of the larva kills the aphid. ***Parasitised aphids*** lose their woolly covering and become black. A ***small exit hole*** is made in the back of the dead aphid by the wasp when it emerges. The wasp ***overwinters*** as a pupa in the body of the dead parasitised aphid and emerges in September at the same time as the colonies of woolly aphid become active. The wasp is scarce in ***commercial orchards*** because of pesticides used to control other pests, but give useful control in non-bearing orchards where fewer pesticides are used. Wasps may be ***conserved*** by not spraying hawthorn and other hosts near apples, occasional infestations are valuable for maintaining wasp populations. ***Twigs with parasitised aphids*** may be collected before winter and stored in a shed away from birds and placed in infested trees in spring. There are several naturally occurring ***predators*** in Australia (mainly ladybirds, lacewing larvae and syrphid fly larvae) and other parasites which assist in reducing populations. Native species of ***ladybirds*** may also prey on woolly aphids. These natural enemies often do not increase in populations quickly enough to prevent woolly aphid populations reaching damaging levels.

Resistant varieties: ***Resistant rootstock*** include Northern Spy and the Malling-Merton series. Trees on ***susceptible rootstocks*** have a more-or-less permanent infestation on roots and this may continually reinfest aerial parts. The use of resistant rootstocks means that woolly aphid only has to be controlled on aerial parts. Woolly aphids are more able to survive during winter on Granny Smith and Jonathan than on either Rome Beauty or Delicious (Asante 1994).

Pesticides: Severely infested roots or whole plants of nursery stock may be dipped in insecticide and drained prior to planting. A dormant spray of ***winter oil*** may kill some overwintering aphids in cracks on trunks and limbs (not very effectively) but not *Aphelinus*. ***Growing season sprays*** should be applied when infestations are first noticed usually in spring, or autumn when trees are growing vigorously. They may be toxic to *Aphelinus*. Insecticides may be applied as a dormant or spring application. ***Monitor*** populations weekly by inspecting 5 laterals from each of 20 trees per ha (Brough et al. 1994).

Others:

Dried apple beetle (*Araecerus palmaris*, Anthribidae), ***driedfruit beetles*** (*Carpophilus* spp.), ***spring beetle*** (*Colymbomorpha vittata*) may occur on quince. Also ***oriental fruit moth*** (*Grapholita molesta*), various ***grasshoppers and locusts*** (Orthoptera). ***Wasps*** (*Torymus* spp.) develop in seeds of apple, hawthorn and *Sorbus* spp.

VERTEBRATE PESTS

Birds may damage fruit. See Fruit F 13.

Non-parasitic

Environment

Field problems: ***Frost***: Flowers of apple may be damaged by late spring frosts. On ***apples***: Frequently the whole flower is killed but occasionally the pistil is undamaged even though all the petals are shrivelled. When the fertile parts have been killed it is usual for the flower to drop within a few days. ***Young fruit*** are even more sensitive to frost than blossoms, the most susceptible part being the ***seed or seeds***. When the seed has been frozen, growth of the fruit usually stops and the fruit falls within days. When freezing has been severe enough to kill seed and flesh, young fruit become dark green then brown and shrivelled (an uncommon effect). ***Frost rings of russet on fruit*** are a common symptom of frost injury. After a frost that has killed only a percentage of the crop, some fruit develop an ***encircling band of russet***. Sometimes the band forms towards the calyx end, but more usually it occurs about midway between stem and calyx. Growth is restricted below these russetted areas and the fruit may develop a marked 'waist'. Severe cracks are likely to develop in damaged tissue as the fruit grows. ***Loquat*** are particularly prone to frost damage in NSW Tablelands as they flower in autumn/early winter with fruit developing through to spring. ***High temperatures:*** Sunburn, sunscald and delayed sunscald caused by direct solar radiation of exposed skin to sun damages growing tissues. ***Favoured*** by leaf fall due to mites or severe pruning. ***Wind damage:*** Fruit may rub against branches in windy conditions, so some shelter is desirable. Leaves may be tattered. ***Strong light*** may scald fruit. ***Moisture:*** Adequate irrigation is essential for good yields. ***Heavy crops*** cause branches to bend.

Storage disorders are comprehensively described by Beattie et al. (1989). ***Freezing injury*** will occur to fruit of apple and pear stored in cool rooms < -1^{o}C. Low temperature breakdown during storage causes moist brownish areas in the mid-cortex area. ***Watercore*** is associated with internal moisture stress usually caused by high day temperatures followed by cool nights during the final maturation stages of the fruit. Starch is converted to sugar and sap leaks from cells, or sap moves to the fruit which fills the spaces between the cells and produces the glassy appearance. ***Senescent breakdown*** is due to overlong storage leading to death of the cells. Browning of the tissue usually starts just under the skin near the calyx end and may extend well into the flesh. ***Jonathan spot*** causes spots to develop on the skin of Jonathans, also sometimes Rome Beauty, Gravenstein and Golden Delicious. Affected fruit show no symptoms inside but have usually lost much of the flavour. It is caused by ***senescence of tissues*** in susceptible varieties after dry growing conditions and on fruit harvested after optimum maturity. ***Pear blackend*** (cause undetermined) affects pears, including Williams Bon Chretien and Packham's Triumph on Oriental rootstocks, eg Keiffer. Affected fruits become dark brown to black at the calyx end. Some fruits have a complete or partial ***concentric rings of dark tissue*** associated with darkened areas. Rings are often separated by bands of healthy skin. Flesh beneath the blackened skin is hardened. Cracking of fruit occurs. Distribution within the tree can vary greatly. ***Carbon dioxide*** injury (core flush) associated with high levels in storage causes small dark areas near the core. ***Brown heart*** of apples and pears is associated with excess carbon dioxide in the storage atmosphere.

Core flush or core browning in tissue surrounding the core is a ***major disorder of stored apples*** and is associated with low temperatures, long term storage and incorrect maturity at harvest. ***Vascular browning and core breakdown*** of pears is caused by tissue ageing and indicates storage life is coming to an end. ***Flesh spot decay (FSD)*** occurs in ***nashi fruit*** and is caused by irrigation problems, water stress, crop load, thinning and increases with storage (Coombs 1995).

Mechanical injuries may occur due to twigs and hail. ***Bruising*** during harvest, packing and transport, causes regular soft areas on fruit, flesh underneath may be slightly discoloured or dark brown.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for pome fruit crops based on diagnostic and research analyses (Weir and Cresswell 1993). ***Loquats*** require need large amounts of fertiliser. ***Pear*** may suffer from boron, manganese or zinc deficiency. ***Low levels of calcium in the fruit*** of pome fruits, especially ***apples,*** is associated with ***bitter pit***. It may occur in fruit on the tree or in cool storage. Pits develop in the flesh and may not be on the skin. ***Iron deficiency*** commonly affects ***quince*** trees in alkaline soil. ***Boron deficiency (cork)*** may be important in tableland areas in NSW. Boron is required in very small amounts by many plants and when deficient a variety of symptoms occur, eg ***apple and pears*** (apples seem to be more sensitive than pears), ***grapes*** (hen and chickens), ***cabbages and cauliflower*** (hollow stem), ***celery, carrots*** (root scurfing) and ***beetroot*** (centre leaves are distorted and misshapen root), ***swedes and turnips*** (brown heart). ***Symptoms in pome fruits*** are often described as internal cork, superficial cork, cork or corky core depending on where the symptoms are in the fruit. Commonly ***internal cork*** in NSW results in small water soaked areas usually rounded and defined in outline appear throughout the flesh, but not in the skin. ***Fruit, twigs and foliage*** may be affected. Affected twigs dieback and an abnormal number of small branches may develop from below the dead portion. Dieback may also result from causes ***other than boron deficiency***. Dwarfed, thickened and brittle leaves arise from nodes separated by short internodes, and this gives rise to a rosette of leaves having smooth, rather serrated edges. ***Favoured*** by soils derived from rocks poor in boron or have been leached, eg granite soils; excessive applications of lime can convert boron into an insoluble form; waterlogging and fluctuations in soil moisture and heavy crops also favour boron deficiency. ***If a deficiency is suspected*** it must be ***identified accurately***.

Pesticide injury: Pesticides may damage ***buds, blossoms, young fruit***, eg thinning, russetting, foliage, eg scorching and defoliation, twigs and bark of apples. Sprays are more likely to cause injury if applied to ***susceptible varieties***, too frequently, at too high concentrations, prior to, during or just after very low or very high temperatures, or when drying conditions are too slow, eg during cloudy weather. Avoid using mixtures of incompatible pesticides or incorrect sequence of pesticides.

Fungicides: ***Copper*** may russet fruit if applied later than the green tip stage. ***Dodine*** may russet yellow varieties which are prone to apple scab russet anyway, eg Delicious. ***Ziram*** and ***mancozeb*** may cause russetting of fruit during cold or frosty conditions. ***Sulphur: Wettable sulphur and lime sulphur*** may damage fruit and foliage of some varieties, eg Delicious, during hot weather. Lime sulphur strengths of 1:20 should not be used later than the green tip stage. Do not use when predicted temperatures are < 0^{o}C or > 28^{o}C or under slow drying conditions, eg showery or cloudy weather, otherwise bud damage may occur. Overspraying the lower sections of trees may damage to buds and bark. ***Thiram*** has a thinning effect on Granny Smith.

Insecticides: ***Carbaryl*** if applied within 30 days of full bloom thinning may thin the crop. If applied before, during or shortly after ***near-freezing conditions***, fruit of Delicious and William's Favourite may be russetted. Quince leaves will be seriously injured. ***Oil sprays:*** Two full strength oil sprays should not be applied in one season and there should be an interval of at least 4 weeks between any oil sprays. Commercial growers should apply ***vamidothion*** for woolly aphid control with caution on Delicious before late January.

Others: ***Polyborate*** used for boron deficiency may damage Golden Delicious. ***Urea*** may damage spurs and laterals in very dry weather. ***Wax residues*** may occur on fruit due to poor management of waxing equipment. ***Chemicals*** used to prevent and control postharvest disorders may themselves injure stored fruit. ***Ammonia gas*** from leaking refrigeration equipment may cause brown lenticel spotting. ***Diphenylamine*** may cause discolouration in the calyx or stem cavity. Severe injury causes blackening and flavour is affected. ***Low oxygen levels*** in fruit due to storage temperatures, carbon dioxide levels and general condition of fruit, cause extensive brown areas.

Others: Reduced yield of apples may be caused by ***phytotoxins*** produced by some grasses growing under them and by interplanted potatoes (Handreck and Black 1994). Apples and pears show a tendency to ***biennial bearing***.

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NSW Agfacts/Agnotes

Apple and Pear Nutrition
Apple and Pear Scab
Apple Dimpling Bug
Apple Growing
Apple Rootstock Identification
Apples in the Garden
Bitter Pit in Apples
Bitter Rot of Apples
Boron Deficiency (Cork) in Pome Fruits
Codling Moth
Codling Moth Resistance and How to Manage
Fleck of Quince, Pear and Loquat
Integrated Control of Mite Pests of Apples
Loquats in the Garden
Mechanical Hedging and Topping of Apple and Pear Trees
Nashi (Asian Pear) Growing
Orchard & Vineyard Plant Protection Guides
NSW Pome Fruits Improvement Scheme
Painted Apple Moth
Pear and Cherry Slug
Pear Growing
Pears in the Garden
Postharvest Disease Control in Pome Fruits
Powdery Mildew of Apples
Quinces in the Garden
Sooty Blotch and Flyspeck
The NSW Pome Fruits Improvement Scheme
Training and Pruning Apple and Pear Trees
Virus Diseases of Deciduous Fruit Trees
Watercore of Apples
Woolly Aphid

Qld Farmnotes

Botryosphaeria Canker and Dieback Apple and Pear

Tas Farmnotes

Controlled Atmosphere Storage (1): Recommendations for Storing Apples
Pest Management in Apple Orchards : An Alternative Approach
Recommended Postharvest Treatment for Apple
Weed Control in Pome and Stone Fruit Orchards

SA Fact Sheet

Apple Dimpling Bug
Codling Moth
Lightbrown Apple Moth
Oystershell Scale
Woolly Aphid

Vic Agnotes

Alternaria Leaf Spot of Apple
Apple Scab
Apple Spray Schedule
Apple Varieties in Victoria
Autumn Sprays to Control Apple and Pear Scab
Avoiding Problems in Postharvest Dipping Apples & Pears
Better Fruit Set for Packham Pears
Blue mould of Pome fruit
Botryosphaeria Canker or Black Rot of Apples & Pears
Chemical Control of Weeds in Pome and Stone Fruit
Close Planting of Apples
Codling Moth
Control of Pests & Diseases in Pome Fruits in Home Orchards
Crown and Collar Rot of Apple Trees
Deciduous Fruit Crops Kit
Fruit Tree Borer Moth & Small Fruit Tree Borer Moth
Grey Mould of Pome Fruit
Growing Nashi in Victoria
Growing Nashi on the Mini Tatura Trellis
Increasing Productivity of Packhams Triumph Pears
Integrated Control of Orchard Mites
Integrated Control of Twospotted Mite in Orchards
Lightbrown Apple Moth in Orchards
Longtailed Mealybug in Pear Orchards
Long Term Controlled Atmosphere Storage for Apples and Pears
Mosaic Virus Diseases of Fruit Trees
Mouldy Core of Red Delicious Apples
Mucor Rot of Pome fruit
Pear Scab
Postharvest Dips for Apples and Pears
Powdery Mildew of Apple
Pruning and Cropping Pears
Pseudomonas syringae on Pears
Rhizopus Rot and Transit Rot of Fruit and Vegetables
Ripening and Colouring of Apples with Ethephon
Ripening of Pears
Rootstocks for Apple Trees
Rootstocks for Pears
San Jose and Oyster-shell Scale
Scouting for Twospotted Mites and Predatory Mites
Scouting Pear Orchards for Longtailed Mealybug
Silver-leaf Disease of Fruit Crops
Spray Program for Commercial Apple Growers
Spray Program for Pears for the Fresh Market
Target Spot of Apples
The Bryobia Mite and the Pear Blister Mite
The Fruit-tree Root Weevil, Leptopius squalidus
The Pear and Cherry Slug, Caliroa cerasi
Thinning Apples
Training, Management & Production Pear Trees on Tatura Trellis
Using Predatory Mite to Control Twospotted Mite in Pome and Stone Fruit Orchards
Verticillium Wilt of Deciduous Fruit Trees
Wood Rots

WA Farmnotes

Trace Element & Magnesium Treatments for Apple & Pear Trees

Remember, always check for recent references

Associations, Journals etc.
Apple and Pear Growers Assoc. (AAPGA)
Australian Horticultural Corporation (AHC)
Australian Nashi Growers Assoc.
Good Fruit & Vegetables
Horticultural Policy Council
Horticultural Research & Development Corp. (HRDC)
See Fruit and nuts F 15.

MANAGEMENT

Pome fruits are grown for fresh fruit, processing and flowering (Fiala 1994, Symon and Gardner 1991). Ornamental *Malus* spp., eg Columnare and Mop-top selections, are currently being introduced in North America for restricted street tree plantings. Different pome fruits are susceptible to different diseases and pests (Table 1). An overview of the pome fruits industry in Australia has been presented by Coombs (1995). ***Pollination:*** Warm sunny weather and plenty of bee activity at flowering time usually ensure that enough fruit set for a home garden. For optimum production it is necessary either to plant 2 different varieties or to plant a tree with more than one variety grafted on to the rootstock. Apples and pears show a tendency to ***biennial bearing***. ***Management programs*** have been prepared for particular regions of Australia. ***Standards*** are available for pears (Frankcom et al. cur. edn) which include requirements for harvest quality, inspections, chemical residues, export markets, postharvest management, packaging, storage and export regulations. ***Propagated*** by budding and grafting. ***Resistant varieties:*** Select cultivars with some resistance to powdery mildew and possible black spot, and rootstocks with resistance to woolly aphid. The long term aim of the Genetic Manipulation Advisory Committee is to genetically engineer apple trees which are resistant to pests and fungal diseases and so reduce pesticide usage. Plant ***disease-free planting material*** from pome fruit improvement schemes. ***Cultural methods:*** Grow pome fruit varieties in recommended climates and sites. ***Sanitation:*** Appropriate ***pruning*** and other ***hygiene practices*** should be carried out in the field and postharvest. ***Biological control:*** Various ***biological control agents***, eg predatory mites, may be purchased for twospotted mite. ***Pheromone lures*** for codling moth are available but their effectiveness may vary. ***Pesticides:*** ***Forecasting systems*** are available for some diseases and pests, eg apple scab, codling moth. ***AAPGA*** has prepared a code of practice for apple and pear growers to provide for the safe and effective application of horticultural chemicals. The apple and pear industry, the Australian Consumers Association and other environmental groups established a pesticide charter in 1991 with the aim of reducing chemical use on apples and pear orchards by 50% by 1996. ***Insect growth regulators*** are available for codling moth. ***Plant growth regulators*** are registered to advance maturity, aid harvest, induce flowering, improve quality and yield, thin fruit, induce bearing, prevent preharvest fruit drop and for many other processes. Some drop of almost mature fruit is not uncommon with early varieties, eg Jonathan. ***Harvest*** fruit at the ***recommended stage*** which varies depending on the type of pome fruit and the ***intended market***. International standards are available for apples and pears (OECD cur. edn). ***Store and transport*** fruit under recommended conditions.

Fig. 146. Apple mosaic virus causes a yellow mottle on apple leaves.

Fig. 147. Black spot, scab (*Venturia pyrina*) on pear.

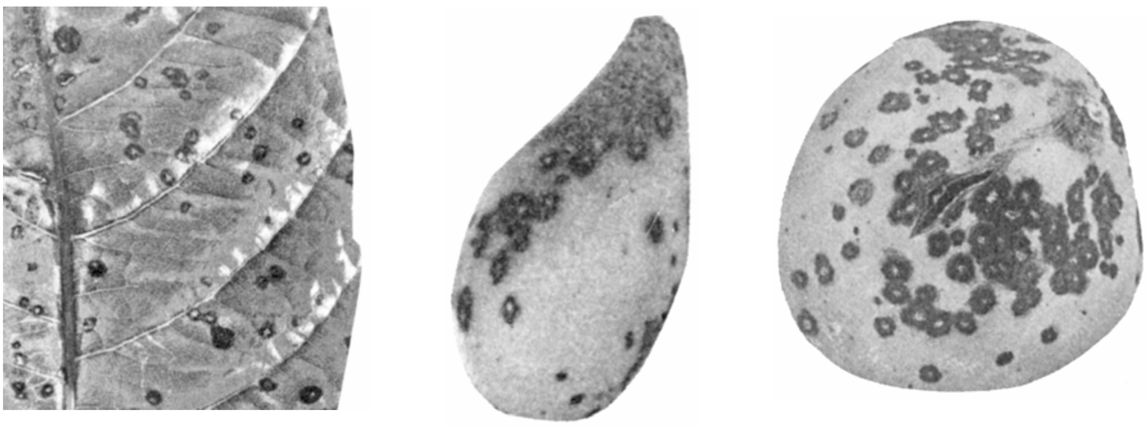

Fig. 148. Fleck (*Diplocarpon mespili*). ***Left :*** Reddish-brown spots with white centres on loquat leaf. ***Centre :*** Fleck lesions on loquat fruit. ***Right :*** Fleck lesions on quince fruit. Dept. of Agric., NSW.

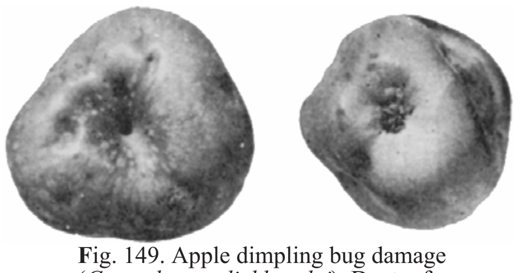

Fig. 149. Apple dimpling bug damage (*Campylomma liebknechti*). Dept. of Agric., NSW.

Fig. 150. Apple leafhoppers (*Edwardsiana australis*). Dept. of Agric., NSW.

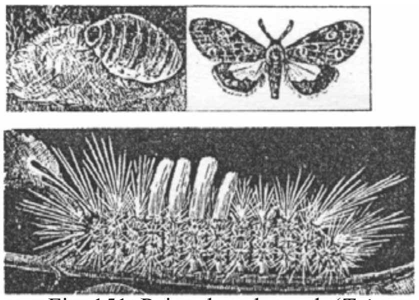

Fig. 151. Painted apple moth (*Teia anartoides*) and caterpillar (30 mm long). Dept. of Agric., NSW.

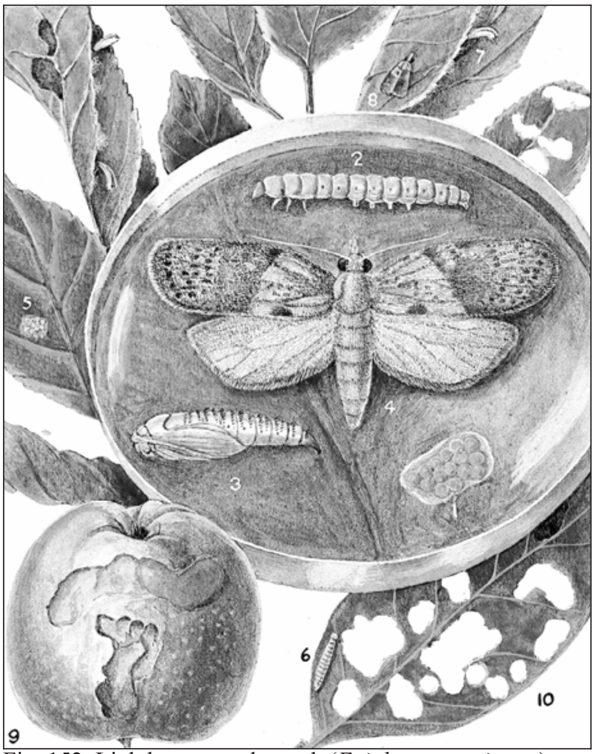

Fig. 152. Lightbrown apple moth (*Epiphyas postvittana*). **1.** Eggs on leaf. **2.** Caterpillar. **3.** Pupa. **4.** Moth (x 4). **5.** Eggs. **6.** Caterpillar. **7.** Empty pupae. **8.** Moth resting on leaf. **9.** Injury by caterpillar to fruit. **10.** Injury to leaf. Dept. of Agric., NSW.

Fig. 153. Codling moth (*Cydia pomonella*). **1.** Eggs (x 4). **2.** Caterpillar. **3.** Cocoon in bark cut open to show pupa. **4.** Moths (x 4). **5.** Eggs on leaf. **6.** Empty cocoon. **7.** Moth resting on leaf. **8.** Caterpillar feeding on seeds and pulp. Dept. of Agric., NSW.

Fig. 154. Pearleaf blister mite (*Eriophyes pyri*) damage.

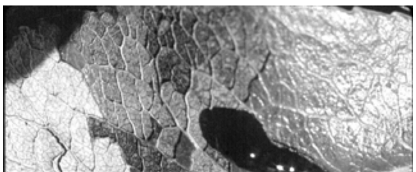

Fig. 155. Pear and cherry slug (*Caliroa cerasi*) (12 mm long) and damage.

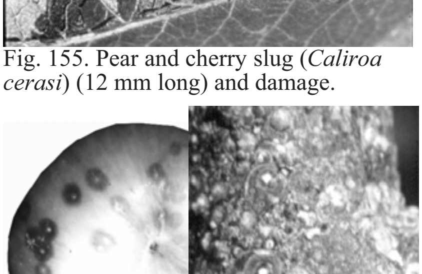

Fig. 156. San Jose scale (*Quadraspidiotus perniciosus*) on apple and cherry.

Fig. 157. Woolly aphid (*Eriosoma lanigerum*).

Table 1. Some diseases and pests of particular pome fruits.

	APPLE	LOQUAT	PEAR	QUINCE
VIRUS AND VIRUS-LIKE DISEASES (few examples only)	Apple mosaic Apple ringspot Green crinkle		Apple chlorotic leaf spot Pear stony pit Quince sooty ringspot	Quince sooty ringspot
BACTERIAL DISEASES				
Bacterial canker			Bacterial canker	
Crown gall	Crown gall			
FUNGAL DISEASES				
Black spot (scab)	**Black spot** (scab)	Black spot (scab)	**Black spot** (scab)	
Bitter rot	Bitter rot			
Cankers	Cankers		Cankers	Cankers
Fleck		Fleck	Fleck	**Fleck** (also medlar)
Fruit rots	Fruit rots	Fruit rots	Fruit rots	Fruit rots
Powdery mildew	**Powdery mildew**			Powdery mildew
Sclerotium stem rot (SSR)	SSR			
Sooty mould & fly speck (SM & FS)	SM & FS		SM & FS	
Wood rot (various species)	Wood rot	Wood rot	Wood rot	Wood rot
NEMATODE DISEASES				
Root lesion	Root lesion		Root lesion	Root lesion
Other species	Many species	Root knot	Many species	
INSECTS AND ALLIED PESTS				
Apple dimpling bug (ADB)	ADB		ADB	
Borers				
Fruit-tree borer (FTB)	FTB	FTB	FTB	FTB
Caterpillars				
Lightbrown apple moth (LBAM)	**LBAM**	LBAM	LBAM	LBAM
Painted apple moth (PAM)	PAM			
Codling moth	**Codling moth**		**Codling moth**	Codling moth
Driedfruit beetles (DB)				
Fruit fly (FF)	**Fruit fly**	**Fruit fly** (worst pest)	**Fruit fly**	**Fruit fly**
Mealybugs				
Longtailed mealybug (LTM)			LTM	
Tuber mealybug	Tuber mealybug		Tuber mealybug	Tuber mealybug
Mites				
European red mite (ERM)	ERM		ERM	
Pearleaf blister mite (PBM)			PBM	
Twospotted mite (TM)	**TM**		TM	TM
Pear and cherry slug (P&CS)			**P&CS**	**P&CS** (also medlar)
Plague thrips	**Plague thrips**		Plague thrips	
Scales				
Dupla scale		Dupla scale		
San Jose scale (SJS)	SJS		SJS	SJS
Weevils				
Apple root weevils (ARW)	ARW		ARW	
Fullers rose weevil (FRW)	FRW			
Woolly aphid	**Woolly aphid**			
VERTEBRATE PESTS				
Birds	Birds	Birds	Birds	Birds (in particular)
Fruit bats				
Possums				
Non-parasitic pests and diseases				
Biennial fruit bearing	**Biennial bearing**		**Biennial bearing**	
Deficiencies *Boron, calcium, iron, manganese*	Boron deficiency Bitter pit (calcium deficiency)	High fertiliser requirements	Boron, manganese and zinc deficiencies	Iron deficiency
Environment		**Frost** (especially loquat). **Strong light** scalds fruit (sunburn can cause loss of >15% of fruit)		

Stone fruits

Almond (*Prunus amygdalus*)
Apricot (*P. armeniaca*)
Cherry (*P. avium*, *P. cerasus*) (sweet, sour)
Nectarine (*P. persica nectarina*)
Peach (*P. persica*)
Plum (*P. domestica*, *P. salicina*) (European, Japanese)
Plumcot (*Prunus hybrida*)
Family Rosaceae

Some stone fruits (and tomatoes) are the most difficult plants on which to diagnose problems.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Several viruses infect stone fruits (Campbell 1994, Persley et al. 1989, Persley 1993).

Cherry rasp leaf virus causes ***leafy outgrowths*** and general decline on *P. avium*, *P. maheleb, Malus sylvestris*; on *P. persica* it also causes stunting and shortened internodes. Symptoms persist. ***Latent*** in *Balsamorhiza sagittata*, dandelion, greater plantain (*Plantago major*). ***Spread*** by vegetative propagation (grafting), by mechanical inoculation, by seed 10-20%, and overseas by a nematode (*Xiphinema americana*).

Plum pox virus (not known to occur in Australia) affects *Prunus* spp. especially almond, apricot, nectarine, plum. In some varieties crop losses can be almost ***100%*** through premature fruit drop, flesh discolouration and pox-like indentations on the fruit skin. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*) and leafcurl plum aphid (*Brachycaudus helichrysi*). ***Quarantine risk:*** Plum pox virus poses a considerable threat to Australian stone fruit industries and all imports of stone fruit must be screened for this and other serious diseases in post-entry quarantine facilities (Com of Aust. 1990). ***Phony peach rickettsia-like organism*** is also not known to occur in Australia.

Prune dwarf virus affects *Prunus* spp., causing stunting, ***leathery strappy leaves***, leaf yellowing and abscission. It is ***spread*** by grafting, by seed to 10% in *P. cerasus,* by pollen to seed, by pollen to the pollinated plant, but not by contact between plants.

Prunus necrotic ringspot virus (Glengarry spot, plum line pattern) may affect cherry, peaches, nectarine, apricot, almond, *Prunus* spp., hops, roses. In spring fine lines appear on leaves outlining narrow interveinal areas which later become yellow, eventually die and fall out. This ***tatter leaf effect*** is a shock reaction seen in the first year of infection by the virus. In later seasons symptoms are less marked and consist of faint yellow ring and ***line patterns*** which persist for the life of a tree. ***Other symptoms*** include: ***almond*** (bright yellow mosaic); ***hops*** (no symptoms); ***peach*** (brown lines and rings, recovery); ***plum*** (creamy white or yellow lines on leaves, rings and bands, oak leaf patterns, no recovery); ***rose*** (yellow lines and rings, oak leaf patterns, no recovery) and ***sour cherry*** (dark dead lines and rings, shot-holes, recovery). The ***apricot*** cultivar Glengarry develop sunken spots or rings on ripening fruit ***(Glengarry spot)***. A brown stain in the flesh beneath affected areas may extend to the stone. Symptoms vary from season to season. ***Fruit quality and yield*** in some varieties may be seriously affected. ***Spread*** by grafting, by seed (over 80% in *P. pensylvanica* but much less in peach), by pollen to seed, by pollen carried by honeybees to the pollinated plant, but not by contact. The seed produced following pollination by the infected pollen may be infected. The virus spreads slowly in the field during insect pollination.

Peach rosette and decline (*Prunus* necrotic ringspot virus + Prune dwarf virus) affects peaches and nectarines. New growth has bunched compact appearance, leaves may be small and rolled, summer growth may be almost normal. ***Yield*** may be reduced by ***66%*** in some cultivars.

Others, eg apple chlorotic leaf spot virus, apple mosaic virus, apricot ringpox, cherry green mottle, green ringspot mottle virus, stem pitting.

To minimise losses: Remove affected trees. Only use proven ***virus-free budwood*** and propagate on proven ***virus-free rootstocks***. To reduce spread via pollen after planting, plant the virus-free trees as a block or some distance from older infected trees. See Fruit F 4.

BACTERIAL DISEASES

Bacterial canker, blast, gummosis

Scientific name: *Pseudomonas syringae* pv. *syringae*. This is a ***serious disease*** of stone fruits.

Host range: ***Ornamentals***, eg poplar, ***fruit***, eg citrus, stone fruit especially apricot, cherry, plum, ***vegetables***, eg bean. The strain infecting citrus may not attack stone fruits and vice versa.

Symptoms: ***Dormant buds*** and ***blossoms*** brown, ***twigs*** may die. ***New shoots*** wilt and die. Cankers may form on ***shoots*** from leaf scar infection. ***Young leaves*** develop brown spots which drop out (shot-hole). Defoliation may occur in spring. On peach and plum, leaves are thin, narrow, often rolled and yellow. ***Two types of canker*** *develop on branches and trunks and these may be > 1 m long before branches are girdled.* ***Gummosis canker:*** *Water soluble gum oozes (Fig. 158) from cankers and wood underneath is brown.* ***Soursap canker:*** *Bark is slightly sunken, brown, moist or gummy, sour smelling and little or no gum oozes out. Symptoms are obvious in spring. Branches and trees may die. Wood underneath is brown.* ***Fruit infection*** of apricot and cherry causes depressed spots with dark centres with underlying gum pockets. ***Roots*** are seldom affected. Trees, especially young trees, may ***die***.

Overwintering: In cankers and infected buds on branches and in other lesions. The bacteria are always present on leaves of all stone fruit, healthy or diseased, and a range of other plants.

Spread: Bacteria are spread by water splash, wind driven rain, irrigation water, insects, and pruning tools. Also by vegetative propagation from infected trees; infected buds used for budding and the introduction of infected nursery stock.

Conditions favouring: Bacteria enter through ***injuries*** (pruning, rain, frost, hail) in wet, cool windy weather in autumn, winter, early spring, and through ***natural leaf scars*** in autumn. Also favoured by trees ***growing poorly***, water stress and deep sandy soil (cherries and plums).

Control: Protect wounds from infection.

Cultural methods: Avoid vigorous growth, ***damage*** by frost, hail and machinery; overhead irrigate or irrigate when leaves dry quickly.

Sanitation: Remove/destroy infected trees<4 years old. ***Disinfect tools*** between cuts. ***Prune*** during active growth just before autumn leaf fall (cuts heal over before infected rain splashes bacteria onto pruning cuts) or not until spring. ***Seek advice for particular species***. During summer prune out diseased wood ***> 150 mm*** below cankers and burn. Seal off cankers by scraping or cauterising with a blow lamp when trees are actively growing (they callus readily).

Resistant varieties: Apricot and some cherry cultivars, eg Florence, Napoleon and St. Margaret, are ***very susceptible***. Merton, Ron's Seedling and Williams Favourite are more tolerant.

Disease-free planting material: Only propagate from ***disease-free nursery stock***. New trees which are 'suspect' should be destroyed.

Pesticides: Apply ***copper sprays*** to nursery stock and trees at risk of infection, at leaf fall, at intervals during winter and at bud burst.

Bacterial spot

Scientific name: *Xanthomonas campestris* pv. *pruni*.

Host range: Most stone fruits, especially plums during wet seasons.

Symptoms: In early spring, ***buds*** may be blighted, often with a dark midrib and petiole and leaves may fail to unfurl. In spring ***angular oily leaf spots*** (partially confined by veins and veinlets) develop and become dark brown to black. As leaves expand, diseased tissue may drop out to give a ***shot-hole effect***. Spots may coalesce, areas become yellow or reddish, leaves become tattered and may fall. Elongated depressed ***cankers*** (10-20 mm long) may develop on ***twigs***. Cankers may crack and exude gum. If cankers are numerous, shoots may be distorted and ***dieback*** causing a gradual loss of leaders and trees become uneconomic. Up to ***50%*** of ***fruit*** may be unsaleable. In late spring, circular greasy spots which become sunken and dark may develop. Centres may crack and ooze gum, edges become corky. ***Peaches and nectarines*** develop many small spots, sometimes with deep cracking and pitting. Plums develop fewer, larger spots.

Overwintering: Bacteria can persist year round on ***surfaces*** of peach and plum trees even in the absence of symptoms. In cankers and leaf scars infected during wet autumns. Bacteria ooze from these active infections in spring to infect young stems and developing leaves. During the growing season bacteria in leaf spots initiate summer cankers and autumn leaf scar infections during wet periods. Bacteria survive on fallen leaves (this is only a minor source of infection).

Spread: By wind-driven rain, especially during leaf fall, propagation from infected trees and the introduction of infected nursery stock.

Conditions favouring: Rain, overhead irrigation, heavy dews, hail, warm temperatures, high winds, exposed situations and leaf fall. In Qld, high summer rainfall and humidity and moderate temperatures favour disease.

Control: Do not market bacteria-infected fruit. Preharvest control measures may be required.

Cultural methods: Avoid planting susceptible cultivars in areas with a ***history of disease***. ***Prune*** susceptible cultivars carefully during winter to remove branches and twigs with summer cankers. Burn/destroy prunings. Provide ***hail protection*** and ***wind breaks*** and ***avoid overhead irrigation*** in susceptible cultivars.

Sanitation: Pruning of visible cankers is of little value in controlling this disease.

Resistant varieties: Some Japanese plums, eg Wilson, Narrabeen and Burbank, are ***resistant***. Plant resistant cultivars of peach and plum in districts where disease is a problem.

Disease-free planting material: Only use ***disease-free*** rootstocks and scion wood nursery stock. Select budwood only from healthy trees which are not grown close to disease sources.

Pesticides: Adopt or modify a bacterial canker spray program to assist control. Spray rootstocks and scion wood and apply preventative sprays.

Crown gall

Scientific name: *Agrobacterium* spp.

Host range: Rosaceae, ***ornamentals***, eg roses, dahlia, ***fruit***, eg pome and stone fruits especially peach, bush fruits, grape, ***vegetables***, eg rhubarb.

Symptoms: Disease is more serious on ***nursery stock*** than on older plants. It occurs sporadically, an area may yield badly infected plants one year and healthy ones the following year. ***Below ground:*** Wart-like ***galls*** ranging in size from a ***pea*** to the size of a ***football*** develop at base of stems or on roots, rarely on stems (Fig. 159). Bacteria multiply inside the host and stimulate cell division and cell size in the host, resulting in galls. Less commonly a proliferation of fine roots on young trees ***(hairy root)*** develops. ***Above ground:*** Young plants which are diseased when planted, or which become infected soon after, grow poorly and may die. Older plants which later become infected may remain vigorous for many years. ***Do not confuse*** crown gall with root knot nematode.

Overwintering: In galls on plants and in soil. Bacteria can survive in soil for years, but in the absence of hosts, ***populations decline rapidly***.

Spread: ***Soil becomes infested*** by introduction of contaminated plants or soil (deliveries, machinery, containers), or by contaminated soil water. ***Plants may become infected*** by planting in contaminated soil or by the use of contaminated tools (pruning and budding knives). Infection also occurs by propagation from infected plants.

Conditions favouring: Older plants in the field suffering from moisture stress may die. Recent wounds made by cultural practices, grafting, insects, etc.

Control: There is no effective treatment for infected plants. To prevent spread and infection of new plantings:

Cultural methods: ***Avoid wounding roots*** of nursery stock during planting and cultivation. Ensure ***graft unions*** are above ground level.

Sanitation: ***Dig up and destroy/burn*** infected young plants, nursery stock and surrounding soil. ***Disinfect*** seed boxes, containers and benches so that treated soil or disease-free seed and cuttings do not become infected. If disease is a problem, ***sterilise secateurs*** between each root trimming.

Biological control: If crown gall is a problem, susceptible seeds, seedlings, cuttings and roots of nursery stock may be treated with *Agrobacterium radiobacter* var. *radiobacter* ***(NoGall®)*** prior to planting in contaminated soil. *Agrobacterium* establishes itself on the ***surface of treated material*** and produces a chemical which inhibits crown gall bacteria. Plants are protected during their early growth stages when they may suffer severe damage if infected. Some fungicides (and other chemicals) are toxic to *Agrobacterium*. Occasionally strains of crown gall are not controlled by Nogall®.

Plant quarantine: Carefully ***inspect*** new stock for galls, burn all infected or doubtful plants.

Disease-free planting material: Propagate only from ***disease-free plants*** and plant in ***disease-free soil***, otherwise plant susceptible plants in contaminated soil after treatment with Nogall®.

Physical and mechanical methods/Pesticides: Pasteurise/treat ***seed and cuttings beds*** prior to planting. Attempts to control crown gall on ***established plants*** by removing galls and applying various 'gall paints' to the raw surface have been unsuccessful.

Others: ***Pseudomonas syringae pv. mors-prunorum*** on cherry (*P. avium*) and *Prunus* spp. ***Pseudomonas viridiflava*** on cherry and apricot.

FUNGAL DISEASES

Brown rot

Scientific name: Ascomycetes:
Brown rot (*Monilinia fructicola*, *M. laxa*). These two species cause ***serious losses*** to stone fruits in Australia. ***European brown rot*** (*M. fructigena*) is not known to occur in Australia, but if introduced could cause serious losses to apple and pear production and aggravate ***brown rot on stone fruits***, eg on ***plums*** (Com. of Aust. 1991).

Host range: Mainly stone fruits, apricot, cherry, peach, nectarine, plum, occasionally apple, pear, quince.

Symptoms: Occurs in the ***field*** and ***postharvest***. ***Blossoms*** turn brown and die. In humid weather tufts of spores develop on infected blossoms. ***Fruits*** rot and are soon covered with brown tufts of spores (Fig. 160). Infected fruit left either on the tree or on the ground shrivel into hard ***mummies***. The fungus grows into ***twigs*** from infested blossoms or fruit, causing cankers. If the canker girdles the twig, twigs die and the canker may ***gum***. ***Leaves*** may appear shot-holed.

Overwintering: As mycelium on infected peduncles, cankers on shoots of up to 1-year-old wood and in mummies on or off the tree.

Spread: Spores are spread by wind and water splash, also by ***driedfruit beetles*** (*Carpophilus* spp.) and ***oriental fruit moth*** (*Grapholita molesta*). In storage, the fungus grows from fruit to fruit.

Conditions favouring: Warm, wet weather, damage by insects, hail, wind or handling.

Control:

Cultural methods: ***Cultivate*** at some stage between harvest and blossoming to cover any infected fruit or mummies on the soil, to help decomposition and reduce production of conidia in spring. ***Prune and shape trees*** to simplify spraying. Handle fruit carefully to reduce injury.

Sanitation: ***Remove/bury*** all infected fruit from the orchard as harvesting progresses to prevent spore buildup during harvest and to restrict growth of the fungus into the stalks, which produces spore the following season. During normal winter pruning, ***prune out*** all cankered and dead shoots and remaining mummies. ***Bury/burn*** all diseased material with prunings. ***Maintain hygiene*** in packing sheds by cleaning equipment regularly with disinfectant and removing waste fruit daily.

Resistant varieties: Early ripening, thick skinned varieties of stone fruits may have ***some resistance***.

Plant quarantine: Stone fruits (apricot, cherry, nectarine, peach and plum) and almond and quince sent from other states to Qld must be accompanied by a ***certification of inspection*** stating that the fruit is from areas free from *M. laxa*, that *M. laxa* has not been recorded with 10 km, or that the fruit has been given an effective postharvest treatment with an approved fungicide. There is a similar requirement for sending ***nursery trees*** to Qld.

Pesticides: It is necessary to follow a ***strategic spray program*** for ***susceptible varieties*** during blossoming and before harvest. This will reduce the development of brown rot resistance to fungicides. There are ***brown rot forecasting services*** during peach harvest in some areas of NSW, eg Young, Murrumbidgee Irrigation Area. Fruit may be dipped in fungicide ***postharvest***.

Cankers

Cankers: ***Canker*** (*Botryosphaeria* spp. = *Dothiorella* spp.) infects limbs through pruning cuts, causing dieback of limbs and tree decline. Small black fruiting bodies develop in bark of affected limbs. ***Canker***, dieback (*Valsa leucostoma*) may also affect stone fruits. See Trees K 5.

Eutypa dieback

Eutypa dieback (*Eutypa lata = E. armeniacea*) may be an important pruning wound disease of ***apricots*** in warm (21-24^{o}C) wet weather in spring, eg in South Australia, also almond, plum and grape. Excessive ***gumming, wilting and dieback*** or brittleness of branches can indicate *Eutypa* dieback. As the disease may be ***confused*** with bacterial canker and other diseases, have the diseased ***confirmed*** by a pathologist. ***Do not prune*** during wet weather and treat all cuts with fungicide. See Grapevine F 59.

Freckle, scab

Scientific name: *Venturia carpophila,* Ascomycetes (= *Fusicladium carpophilum*).

Host range: Stone fruits, especially apricot, peach, nectarine, occasionally plum, cherry.

Symptoms: Small, poorly defined spots may develop mostly on the ***leaf undersurfaces***. These later darken, and a pale yellow patch may develop on the ***uppersurface*** above the infected spot, particularly on apricot leaves. Spots may also occur on the ***leaf petiole and midrib***. Spots on ***twigs*** may cover the entire surface of a shoot for several centimetres, but dieback is rare ***(compare with shot-hole, brown rot, bacterial canker),*** and may persist for several seasons. Flat, definite superficial dark spots (freckles) about 3 mm across develop on ***apricot fruit*** (Fig. 161) and may coalesce forming large brown scabby areas which are more numerous on exposed parts of fruit. Fruit may be distorted and cracked. ***On apricots do not confuse with shot-hole scabs which are raised!*** On ***peaches, spots*** are black, on ***nectarines*** freckle spots are pale green or cream with a dark centre.

Overwintering: As mycelium in twig lesions on the host. Possibly also as fruiting bodies (perithecia) on fallen leaves. These fruiting bodies may produce spores in spring.

Spread: Spores are released in wet conditions and are washed down the tree or blown in drops of water to other trees.

Conditions favouring: By moist weather, rain throughout summer and during harvest.

Control:

Sanitation: In theory, infected twigs on heavily infected trees should be ***pruned*** in spring to reduce initial infections. However, lesions are ***hard-to-see*** and rarely cause dieback, so pruning out infected twigs is impractical.

Resistant varieties: Varieties vary in ***resistance***.

Pesticides: On ***susceptible varieties***, several fungicide applications may be necessary during budswell and flowering, and after rainy weather.

Fruit rots

Fruit moulds: Many fungi grow on fruit in the field and/or postharvest. The colour of the mould is usually due to the ***collective colour of the spore masses***. The ***high sugar content*** of some fruit, eg ***prunes*** such as D'Agen and Robe de Sargeant, prevents rotting at maturity.

Alternaria rot (*Alternaria alternata*)
Aspergillus (*Aspergillus* sp.)
Blue and green moulds (*Penicillium* spp.)
Brown rot (*Monilinia fructicola, M. laxa*) (see above)
Cladosporium rot (*Cladosporium* sp.)
Grey mould (*Botrytis cinerea*)
Mucor rot (*Mucor* spp.)
Rhizopus soft rot (*Rhizopus stolonifer*)
Occasionally others affect fruit, eg ***anthracnose*** (*Colletotrichum acutatum*), ***sclerotinia rot***, green rot (*Sclerotinia sclerotiorum*), ***internal breakdown*** (*Auriobasidium pullulans*), ***pink rot*** (*Cephalothecium roseum*).

Other fruit rots, disfigurations: Some fungal diseases, eg ***freckle***, scab (*Venturia carpophila*), ***peach leaf curl*** (*Taphrina deformans*), ***prune rust*** (*Tranzschelia discolor*, *Puccinia pruni*), ***shot-hole*** (*Stigmina carpophila*) which mainly affect ***leaves and twigs*** may also cause markings on ***fruit in the field***.

See Fruit F 5.

Fungal leaf spots

Some fungi which are important as fruit rots of stone fruits, also cause leaf spotting, eg brown rot, freckle, shot-hole. Some ***bacterial diseases***, eg bacterial canker, bacterial spot also cause leaf spots. Many other fungi cause minor leaf spotting (*Ascochyta, Phoma, Phyllosticta, Septoria*). See Annuals A 5.

Peach leaf curl, curly leaf

Scientific name: Ascomycetes:
Peach leaf curl (*Taphrina deformans*) is a ***serious disease*** of stone fruits. ***Bladder plum*** (*T. pruni*) uncommonly affects plums, has leaf symptoms similar to peach leaf curl but fruit is swollen and distorted (Aitkinson 1971).

Host range: Stone fruits, especially peaches and nectarines, also almonds, apricots, ornamentals.

Symptoms: In spring infected parts of peach and nectarine ***leaves*** thicken (Fig. 162) and become pale (the fungus inside stimulates tissues to make abnormal growth). Infected leaf parts become covered with a whitish bloom, leaves brown and may fall. ***New healthy leaves appear***. Defoliation in consecutive seasons weakens tree growth. Severely defoliated nursery stock rarely develops satisfactorily. ***Do not confuse*** peach leaf curl symptoms with those caused by green peach aphid infestation. ***Infected peach shoots*** are less obvious. They become swollen, stunted, pale green to yellow and gum may ooze from them. In ***apricot trees*** a witches' broom develops (densely bunched growth). It is rare to find an isolated infected leaf. Infected shoots usually die. ***Infected flowers*** usually fall from the tree. Defoliation results in heavy ***shedding of developing fruit.*** Infected ***peach fruits*** show raised, irregular areas which may develop a pinkish or reddish colour long before normal fruit show any colour change. Infected fruits generally die and fall from the tree.

Overwintering: Spores on bud scales.

Spread: Spores are spread by wind and water.

Conditions favouring: Cold, wet weather followed by warm, humid weather during early blossoming in spring. Tissue is only susceptible when young, becoming ***resistant with age***.

Control of leaf curl is achieved more efficiently and easily than any other major stone fruit disease.

Cultural methods: If leaf fall is heavy, an application of ***quick-acting fertiliser***, eg sulphate of ammonia, helps trees produce new foliage.

Sanitation: ***Prune out*** infected shoots to reduce infection sources.

Resistant varieties: Some peaches and nectarines, eg Elberta and Blackburn. are ***very susceptible***.

Pesticides: As initial infection occurs during a short period when leaves emerge from buds, apply 1 application of a ***copper fungicide*** (or lime sulphur) when buds start to swell or ***immediately before bud burst*** in spring. Only ***one spray*** is required to give complete control. Sometimes 2 sprays are applied, one at the 1st sign of bud movement and a 2nd, one week later, to ensure that timing is right and full coverage is obtained. Where peach leaf curl has been serious in previous seasons, a spray at leaf fall in autumn is also recommended. The whole tree must be sprayed thoroughly, especially the extremities of small limbs and twigs. ***Failure to control peach leaf curl*** with 1-2 copper sprays is usually due to ***incorrect timing*** (difficulty in recognising the 1st sign of budswell) or ***wet weather*** (spraying impossible). An occasional curly leaf on an otherwise healthy tree is not important.

Powdery mildew

Powdery mildew (*Sphaerotheca pannosa*) may affect ***apricot*** and ***peach nursery stock*** during spring and summer but is uncommon on stone fruit trees in orchards. ***New shoots*** are covered with a white growth and may become distorted and fall. ***Overwinters*** on the surface of shoots or inside dormant buds. Separate potted plants in nurseries to provide adequate ventilation. Apply ***fungicides*** as required. See Annuals A 6.

Root and trunk rots, wilts

Phytophthora trunk canker, root rot, summer canker (*Phytophthora* spp., *P. cinnamomi*) is mainly a problem on ***peach and apricot***, but also plum. ***Leaves*** yellow, wilt and fall prematurely. Long wide sunken areas extend from just below ground level to the first branches and involve up to half the circumference of the ***trunk***. Beneath the sunken bark, wood is discoloured. ***Orange-red gum*** may exude from the edge of active cankers. It is introduced into clean soil with diseased nursery stock and with water and soil movement. ***Favoured*** by stone fruits on peach rootstock in wet soils. Plant ***disease-free nursery stock***. Grow in well drained soils. When a canker appears cut away all discoloured wood and apply a slurry of a copper fungicide. See Fruit F 7, Trees K 6.

Others: ***Armillaria root rot*** (*Armillaria luteobubalina*) may occur on orchards planted in newly cleared bushland. See Trees K 4. ***Verticillium wilt, black heart*** (*Verticillium dahliae*) is uncommon but may be a serious soilborne disease of stone fruits, especially if apricots are planted into soils previously cropped with infected crops, eg tomato, potato, strawberries or interplanted with these crops. It survives in the soil for years and invades the ***water-conducting tissues*** of trunks and branches. Woody tissue in infected stems is discoloured. It is an economic problem only in young trees 3-6 years old. ***Leaves*** yellow, look dull and leathery and may fall. Affected trees gradually decline. Plant ***disease-free nursery stock***, avoid growing susceptible crops before planting stone fruit or intercropping with susceptible crops. Control weed hosts between trees. See Vegetables M 9.

Rust

Rust (*Tranzschelia discolor*, *Puccinia pruni*) affects *Prunus* spp., especially peach, nectarine, plum, prune, apricot, in late summer and autumn. Rust is a ***major disease*** of ***French prunes.*** ***Leaf uppersurfaces*** are speckled with small yellow patches which may run together. On ***leaf undersurfaces*** there are corresponding orange-red or rusty-brown powdery spore masses. If infection is heavy, premature leaf fall occurs. Trees ***defoliated prematurely*** before harvest do not mature their fruit satisfactorily. ***Yield is reduced***, bud development is weak and crop yield in the following season may be below normal. Defoliated trees often shoot and come into flower in autumn, so that there is no crop the following season. ***Limbs*** may be sunburnt and later invaded by wood-rotting fungi. ***Twigs*** (1-2-year old shoots) may develop small dead patches, bark develops lengthwise and splits crosswise. ***Peach and nectarine fruit*** may develop small, circular, depressed spots with reddish centres and pale green border, late in the season. Where rust infection occurs over several consecutive seasons, tree life may be considerably shortened. ***Favoured*** by warm, wet weather. ***Remove diseased wood*** during pruning, apply recommended ***fungicides***. Remove and bury diseased leaves as they provide a source of rust spores early in the next season. A ***Prune Rust Infection Prediction Service (PRIPS)*** is available for prune growers. ***PRIPS*** is based on computer programs which incorporate local day-to-day crop and climatic conditions and automatically calculate the risk of rust infection. See Annuals A 7.

Shot-hole

Scientific name: Imperfect Fungi:
Shot-hole (*Stigmina carpophila*)

Host range: Commonly apricot, almond and cherry. Also peach, plum and nectarine. A ***common and serious disease***.

Symptoms: Small brown spots with reddish margins develop on ***leaves***. These spots enlarge a little, but soon become dry, brittle and fall away, so that leaves have a shot-holed appearance (Fig. 161). Shot-holing of leaves can also be caused by:

Prunus necrotic ringspot virus: Leaves develop a severe shot-holing and tattering of the leaves.
Bacterial diseases: Bacterial canker (*Pseudomonas syringae* pv. *syringae*), ***bacterial spot*** (*Xanthomonas campestris* pv. *pruni*), *P. syringae* pv. *mors-prunorum*.
Fungal leaf spot (*Cercospora circumscissa*): On cherry, ***large reddish brown circular spots*** develop and are usually larger than those caused by shot-hole. They do not fall out as readily.

Infected ***buds*** darken when killed, but are not conspicuous until bud movement. They may be surrounded by ***exuded gum***. ***Twig infection*** results in depressed spots with a raised margin, or round to oval raised brown spots. They ***exude gum***. On ***young shoots*** irregular cankers may develop and girdle shoots, causing ***dieback and gumming***. Cankers are found on ***wood*** up to 2-3 years of age on peach and nectarine. ***Fruit*** symptoms vary according to type of stone fruit attacked, almond and apricot most seriously affected:

Almond: ***Raised brown scabs*** on the surface accompanied by strings and blobs of ***gum*** projecting from surface. Rain spreads the gum, so that severely diseased fruit may be almost covered by clear gum.
Apricot: ***Raised brown scabs*** similar to almonds but little, if any, gumming. The fruit surface may crack.
Peach and nectarine: Infection is less common. Spots are brown, depressed and larger than on apricot. Some cracking and gumming can occur.
Plum and cherry: Fruit are seldom attacked.

Overwintering: On the buds and twigs of hosts.

Spread: Spores (conidia) are spread in water droplets to various parts of the host.

Conditions favouring: Cool, wet weather in spring and early autumn (surface must remain wet for several hours for infection to occur).

Control:
Cultural methods: Design the orchard to allow ***ventilation*** around trees, and avoid excessive shading which may prolong leaf wetness after irrigation or rainfall.
Sanitation: Prune infected twigs and dead shoots during winter pruning, treat if recommended.
Resistant varieties: Within each type of stone fruit there is some ***variation in susceptibility***.
Pesticides: 1st spray in autumn at leaf fall. 2nd spray in spring at late budswell (this spray is too late for peach leaf curl but is similar to the one for freckle and brown rot). The autumn spray is not necessary if shot-hole is not serious.

Wood rots:
Dieback of limbs, cankers and eventual death of trees can result from the invasion of various fungi including ***wood rotting bracket fungi***. ***Fruiting bodies*** produce spores which are spread by wind to other trees. They gain entry through pruning and natural wounds. Once established the fungi grow through the heartwood. Limb dieback is more common in mature trees which have suffered ***stress*** due to drought, hail, sunscald, mechanical root damage, overcropping, poor nutrition and severe winter pruning.

Red wood rot (*Trametes cinnabarina*) is a weak pathogen. It causes a ***white wood rot*** and forms ***orange-red*** leathery brackets (700 mm across, 5-10 mm thick) with pores underneath. Also ***Pycnoporus coccineus*** which is more common.
Silver leaf (*Stereum strigoso-zonatum*, *S. purpureum*) may be a ***serious disease*** of stone fruits. *S. strigoso-zonatum* occurs on plums and nectarines. *S purpureum* rarely on apricots. ***S. strigoso-zonatrum*** brackets are small, ***leathery, grey to brown***, with a polished black inside. Spores are produced on infected branches or old stumps and prunings. They can be blown by wind, and enter trees though wounds. Important in some temperate production areas. ***Leaf silvering*** is usually the first indication that infection has occurred. Affected leaves have a pale-grey, metallic sheen in contrast to the deep green of healthy leaves. ***Silvering*** can also be caused by twospotted mite or by peach silver mite usually in late summer and autumn. ***Silvering caused by silver leaf*** is due the breakdown of leaf structure, the epidermis can lift away from the tissue below, the epidermis peels away readily when rubbed or scraped. Silvering usually appears first in a few small shoots and then rapidly expands to all leaves of an infected branch. Affected plants slowly decline over several seasons. Remove and burn infected trees. See Trees K 8.
Yellowish wood rot (*Polyporus versicolor*) may be a ***serious disease*** of stone fruits. ***Fruiting bodies*** are smooth, greyish with various ***brownish bands*** and up to 30 mm across There are cream pores underneath.
Others: Several weak pathogens may attack declining trees, eg ***tinder punk*** (*Phellinus setulosa*), ***coral spot*** (*Nectria cinnabarina*); ***white wood rot*** (*Pycnoporus coccineus*) has ***bright orange*** fruiting bodies up to 700 mm across, with a honeycomb of pores underneath; ***yellow heart rot*** (*Schizophyllum commune*) has ***soft whitish*** fruiting bodies with ragged edges, gills underneath.

See Trees K 8.

NEMATODE DISEASES

Many nematodes associated with stone fruits have a wide host range and occur in sandy soils low in organic matter. ***Roots*** of nursery stock may become ***infested*** from infested rootstock or nursery soils. Nematodes reduce growth, especially of peach and nectarine grown in replant land. ***Control in established orchards*** includes adequate irrigation and fertiliser management and maintaining a thick organic mulch under trees. In ***replant situations*** do not replant for at least 1 year after removing old trees. During this time grow green manure cover crops, eg oats, to increase soil organic matter. Choose ***nematode-resistant rootstocks***, eg for almonds. Where nematodes are a problem, prepare soil by ploughing, deeply, ripping and discing to remove old roots. ***Pre-plant*** treat/fumigate soil. Nematodes associated with stone fruits include ***root knot nematode*** (*Meloidogyne* spp.), also *Aglenchus, Belonolaimus, Coslenchus, Criconema, Criconemoides, Ditylenchus, Filenchus, Helicotylenchus, Hemicycliophora, Hoplotylus, Longidorus, Macroposthonia, Merlinus, Neopsilenchus, Paratrichodorus., Paratylenchus, Pratylenchus, Pseudohalenchus, Rotylenchus, Scutellonema, Tylenchorhynchus, Tylenchus, Xiphinema*. ***Bacteria-nematode complexes*** may occur. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) are ***important pests*** of stone fruits. They suck plant sap. There is 1 pair of cornicles on the abdomen. Aphids attacking stone fruits excrete copious amounts of ***honeydew*** on which sooty mould grows, attracting ants. ***Foliage and fruit*** may be disfigured. Large amounts of sooty mould on the ***limbs*** can result in a bark-bound condition.

Black peach aphid (*Brachycaudus persicae*) mainly infests peach, nectarine, Japanese plum, cherry; also apricot and almond growing on peach stock. ***Adult aphids*** may be winged or wingless, glossy black and about ***1.5 mm*** long. Wingless forms are more common and have a bloated appearance. ***Nymphs*** are similar to adults except they are smaller, wingless and brown. ***Dormant buds*** are stimulated to develop by aphids sucking. Infested branches carry open blossoms while those on the rest of the tree are still tightly folded. Aphids may migrate to ***flowers and young fruit*** which may fall. Occasionally late infestation causes slightly raised reddish roughened areas on the skin of fruits. Aphids swarm on to ***new spring leaves*** causing them to shrivel and finally drop. Slight leaf curling, similar to that found in green peach aphid infestations, occurs. Aphids feeding on ***lateral shoots*** and tree tops cause dieback (Fig. 163). Throughout the year, wingless aphids occur on ***roots*** at the junction of trunk and main roots and on the feeder roots, at a depth of about 300 mm, 300-450 mm from the butt. ***General:*** On young trees, heavy infestation can harm the framework. ***Pest cycle:*** Gradual metamorphosis (nymphs-live birth, adult female) with many generations each year on stone fruits. ***In spring*** aphids move from cracks and crevices on larger limbs and from roots to blossoms and buds, reproducing rapidly. Winged forms develop and fly off to other hosts. With the onset of ***hot summer weather***, aphids move to roots. ***In autumn***, aphids again infest above ground parts, this time mainly the lateral shoots. With the ***onset of winter***, wingless aphids shelter in crevices on the bark of larger limbs or on the roots of the tree and especially suckers. ***Spread:*** During spring as winged female aphids and movement of infested nursery stock. ***Favoured*** by mild moist weather in spring and autumn, hot dry weather can kill large numbers on the tree. Aphids on roots are protected from heat. ***Sanitation: If replanting***, roots of old peaches should be removed, new trees should not be planted in old holes unless soil is treated. ***Biological control:*** Wasp parasites and predators, eg hover fly larvae and ladybird beetles, do not seem to provide economic control. ***Disease-free planting material:*** Inspect roots of new trees before planting, treat if aphids are present. ***Mechanical methods:*** Grease bands may be placed on the main trunk of infested trees to trap aphids migrating to blossoms and buds. ***Winter sprays*** of petroleum oil may kill aphids on main trunks but not those on roots. ***Monitor aphids*** on blossoms at regular intervals before applying an insecticide at first sign of attack in spring or autumn (Brough et al. 1994).

Cherry aphid (*Myzus cerasi*) is an ***important pest*** of cherries. ***Adult females*** may be winged or wingless. Wingless females are glossy ***black*** while the winged forms are dark brown or black and about ***2 mm*** long. ***Adult males*** are winged and resemble winged females. ***Nymphs*** are usually brown. Aphids infest ***foliage*** of young shoots in spring, terminal shoots become a dense, sticky mass of twisted leaves, which may wither and die (Fig. 163). ***Fruit*** below twisted masses also become gummed with honeydew and are unmarketable. ***Buds:*** During winter many wingless aphids, together with nymphs may occur on trees that were heavily infested the previous year. Their feeding causes a premature swelling and pinking of the buds. Unchecked heavy infestations, can kill cherry trees in a few years. ***Pest cycle:*** Gradual metamorphosis (egg, nymphs, adult) with many generations each year. Only wingless females are present in spring on cherry but later in spring, winged females develop and fly to uninfested trees. As the growth hardens in December, infestation almost ceases, and few aphids are present. Usually only ***sucker growth*** around the margins of an orchard is infested ***during summer months***. Late ***in autumn***, winged males and wingless egg-laying females develop and mate. Females lay the ***overwintering*** eggs around the bases of the fruit and leaf buds and also as small colonies on some trees. The winter eggs hatch in spring. ***Spread*** by adults flying, movement of infested plants. ***Favoured*** by wet springs. The main peak is usually during November. ***Sanitation:*** Remove sucker and seedling cherry growth around margins of orchards, as these provide an important source of reinfestation. ***Biological control: Predators*** include common spotted ladybird (*Harmonia conformis*), transverse ladybird (*Coccinella repanda*), lace wing and syrphid fly larvae. In some seasons ladybirds are numerous and bring an infestation under control before much damage is done. ***In wet seasons***, which appear to favour the aphids and not the ladybirds, they have little if any effect and aphid infestations are usually severe. ***Pesticides: Monitor*** aphids and eggs in winter, before applying an insecticide at budswell. Examine trees again when in leaf in spring and spray at first sign of infestation (Brough et al. 1994).

Green peach aphid (*Myzus persicae*): ***Primary food plants*** are peach and nectarine, also apricots and plums (rarely almond). ***Secondary food plants*** include ***ornamentals***, eg rose, ***vegetables***, eg cabbage, potato, ***fruit***, eg strawberry, ***weeds***. ***Adults*** are globular with dark green markings and about ***2.5 mm*** long. ***Nymphs*** are like adults except that they are smaller and wingless. Their colour varies from green to pale yellow and pale pink. Aphids feed on ***swelling buds***, often causing premature opening of flowers. A single petal emerging from the bud indicates its presence. Later generations feed on ***flower parts*** before petals unfold fully. Opening buds and flowers are distorted and fall readily, reducing fruit setting. ***Young fruit*** may also be attacked and much of it falls. Aphids infest ***young leaves and laterals*** of fruit trees, causing leaves to curl and shrivel (Fig. 163). The tree may become unproductive and take several years to recover from repeated severe attacks. Green peach aphid causes distortion and shrivelling of young leaves in a wide range of ornamental plants. ***On stone fruits do not confuse green peach aphid*** damage to leaves with the fungal disease peach leaf curl. ***Over 100 virus diseases*** of a range of plants are transmitted by the green peach aphid during feeding, eg cucumber mosaic virus and turnip mosaic virus. It does not transmit virus diseases of stone fruits. ***Pest cycle:*** Gradual metamorphosis (egg, nymphs, adult) with many generations each year. ***In spring*** aphids multiply rapidly on peach and nectarine trees, producing wingless young-bearing females and causing serious damage. ***In early summer*** winged forms migrate to their secondary food-plants (ornamental plants, vegetables and weeds), where they spend the summer. ***In late autumn***, some females and males migrate back to peaches and nectarines and lay eggs about the bases of the buds from May-July. Eggs may also be laid on cherry trees but they fail to survive. Eggs hatch in late July-August, but aphids remain in the buds until bud burst when they multiply rapidly as the trees come into leaf. ***In warmer districts*** (coastal areas) the autumn migration to peach trees does not occur, eggs are rarely seen. ***Overwintering:*** In cool areas as eggs about the bases of buds on peach and nectarine trees. In milder climates there is no egg stage and aphids ***breed throughout the year on secondary hosts***, occasionally producing winged forms which fly to other secondary hosts. ***Spread*** by winged forms flying, movement of infested plants, young nursery trees which may carry overwintering eggs, and seedlings and container plants which may carry wingless forms. ***Favoured*** by abundant growth of herbaceous weeds in the previous summer and autumn, late leaf-fall from the peach trees and a cool, wet spring. Cold, damp, spring weather slows down the hardening of early peach growth and delays the appearance of natural enemies. ***Biological control:*** Aphid populations can be reduced by heavy rain and early leaf fall in autumn. If weather prevents the returning winged males from reaching peach trees, females lay infertile eggs. Field populations are regulated by ***predatory ladybirds***, ***parasitic wasps***, eg *Diaeretiella* sp. and a ***fungus*** (*Entomophthora*). A strain of another ***fungus*** (*Verticillium lecanii*) is being investigated as a biological control agent for green peach aphid and also scale, thrips and whiteflies (Bates 1996). ***Pesticides:*** Green peach aphid has developed ***resistance*** to many insecticides. ***Monitor*** aphids during winter pruning for shiny black overwintering eggs. Label infested trees and spray all infested trees with ***winter oil*** either when trees are dormant or at budswell. Check results at flowering by monitoring aphids on flower clusters before applying an insecticide (Brough et al. 1994).

Others: ***Leafcurl plum aphid*** (*Brachycaudus helichrysi*), ***mealyplum aphid*** (*Hyalopterus pruni*), ***rusty plum aphid*** (*Hysteroneura setariae*).

See Roses J 4.

Borers

Fruit-tree borer (*Cryptophasa melanostigma*) caterpillars tunnel into branches at the base of twigs or ***forks of branches***. Their entrance is covered with frass and webbing. Caterpillars chew the bark under the webbing. The attack weakens and may kill branches. See Fruit F 10.

Others: ***Auger beetles*** (Bostrichidae), ***elephant weevil*** (*Orthorhinus cylindrirostris*), ***fruit tree pinhole borer*** (*Xyleborus saxeseni*).

See Trees K 11, K 12.

Bugs (Hemiptera)

Apple dimpling bug (*Campylomma liebknechti*) feeds on ***fruits*** 15-20 mm diameter until fruit reach full size. Numerous dark spots, 5-10 mm in diameter, pepper the fruit, mainly near the stem end, gum may exude. Some nectarine varieties are not damaged, eg Maygrand and Nectared. Bugs may be ***monitored*** using disposable white sticky traps or collecting bugs in an insect net before making a decision to apply an insecticide (Brough et al. 1994). See Pome fruits F 111.

Brokenbacked bug (*Taylorilygus pallidulus*) sucks juice from ***young fruitlets*** resulting in distortion, dimpling and scarring. Fresh feeding punctures may gum. ***Monitor*** bugs by inspecting fruit. Tap fruit clusters and collect bugs or use white sticky traps before making a decision to apply an insecticide (Brough et al. 1994).

Coon bug (*Oxycarenus arctatus,* Lygaeidae) are winged, ***black and white***, about ***3 mm*** long, and may swarm on ***flowers*** causing them to fall. They breed on weeds and attack fruit trees when weed growth matures and dries off. Nymphs are red and may cluster on weeds, fence posts and stumps (Hely 1982).

Fruitspotting bug (*Amblypelta nitida*) attacks ***green stone fruits***. Adults and nymphs feed on ***fruit*** causing sunken spots in fruit, juices may exude from punctures and bug-damaged fruit is unmarketable. Inspect the terminals for bugs before making a decision to apply an insecticide (Brough et al. 1994). See Fruit F 10.

Green mirid bug (*Creontiades dilutus*) sucks sap from ***young fruitlets*** causing distortion, dimpling, scarring and obvious feeding punctures. Spiders and predatory damsel bugs (*Nabis kinbergii*) feed on mirids but do not give adequate control. ***Monitor*** bug populations at regular intervals before making a decision to apply an insecticide (Brough et al. 1994). See Vegetables M 12.

Metallic shield bug (*Scutiphora pedicellata*) occasionally attack ***almond fruits*** late in the season, causing the kernels to ***wither and gum***. They migrate in dry weather from other hosts on which they have been breeding. See Vegetables M 12.

Rutherglen bug (*Nysius vinitor*) attacks stone fruits, peach, apricot, cherry, etc. ***Younger growth*** of terminal shoots is first attacked and the effect of great numbers of these small bugs sucking the sap causes drooping and wilting of the foliage and in some cases, ***total destruction***. When peaches, apricots, cherries and other ***fruits*** are infested, they become so pitted and disfigured with exudations of gum that they are spoiled both as fresh and canning fruit. As the bugs breed amongst various ***weeds***, early turning in of cover crops or rubbish, usually not later than mid-October (in inland areas), may prevent damage to fruit crops. If later, then bugs migrate to fruit crops. They are a ***major pest of all stone fruits*** except plums and feed from green and maturing fruit, causing young fruit to shrivel and fall. Ripening areas around feeding sites become tough, remain green and strands of gum may exude from punctures. Control weeds. ***Monitor*** bugs on fruit before applying an insecticide (Brough et al. 1994). See Vegetables M 12.

Others: ***Green stink bug*** (*Plautia affinis*), ***green vegetable bug*** (*Nezara viridula*), ***pale cotton stainer*** (*Dysdercus sidae*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa*, *Heliothis*): **Native budworm** (*Helicoverpa punctigera*) moths migrate into orchards in spring and lay eggs during flowering. Caterpillars tunnel into **fruitlets** leaving round holes, as they grow they eat the seed. **Monitor** caterpillars in fruit before deciding to apply an insecticide (Brough et al. 1994). See Sweetcorn M 89.

Leafroller moths (Tortricidae): **Lightbrown apple moth** (*Epiphyas postvittana*) infest plums, apricots, peaches and nectarines. Caterpillars **web** adjacent **leaves and/or fruit** together to form a silken tunnel in which they feed. They graze on fruit. Control weeds which are alternative hosts. Hand thinning fruit reduces the incidence of infestation. **Monitor** caterpillars and damage to fruit before applying an insecticide (Brough et al. 1994). See Pome fruits F 112. **Orange fruitborer** (*Isotenes miserana*) caterpillars bore into tips of **young shoots** of peaches and nectarines in coastal areas, causing leaf webbing, wilting and gumming. They also infest fruit around the stem end. **Monitor** caterpillars, webbed leaf shelters, wilted tips, stem end boring, and leaf and fruit damage at regular intervals before applying an insecticide (Brough et al. 1994). See Citrus F 37. **Oriental fruit moth** (*Grapholita molesta*) caterpillars bore into **tips of young shoots** causing them to wilt and die (Fig. 164). They cause severe damage to framework of young trees. Tunnelling often causes exudation of gum, the formation of callus and multiple shooting. **Fruit** are attacked later in the season by caterpillars entering the stem end or where a leaf or small branch is touching the fruit (Fig. 164). Several caterpillar and pupal parasites can help reduce numbers. See Stone fruits F 131.

Pyralid moths (Pyralidae): **Carob moth** (*Ectomyelois ceratoniae*) may infest stone fruits in areas of WA. Also **yellow peach moth** (*Conogethes punctiferalis*). See Stone fruits F 133, F 137 (Fig. 166).

Others: Cherry looper (*Chloroclystis approximata*, Geometridae), **cup moths** (*Doratifera* spp.), **leaf case moth** (*Hyalarcta* huebneri), **tussock moths** (Lymantriidae), eg painted apple moth (*Teia anartoides*) and *Porthesia paradoxa.*

Driedfruit beetles (*Carpophilus* spp.) may cause **crop losses** as great as **25%** to ripening peaches by their **feeding** and carrying **spores of the brown rot fungus**. Fruit loss is caused primarily by the beetles burrowing into **ripening fruit**, commonly through cracks in the skin or open stem ends. Rarely do beetles penetrate the exposed surface of fruit. Female beetles lay eggs in the fruit and larvae tunnel in the fruit. **Decay organisms** develop within the tunnels causing them to rot. An efficient program to control fruit fly, oriental fruit moth and lightbrown apple moth reduces the volume of damaged and fermented fruit available to the beetles. Cultivars that are prone to produce split stones are more **susceptible**, eg Southland. Destroy or bury in an insect proof pit, all fallen fruit and damaged fruit from trees and ground. ***It is not practical to monitor*** driedfruit beetles (Brough et al. 1994). See Fruit F 8.

Fruit flies (Tephritidae, Diptera) are an **important pest** of stone fruits **on the tree** and **postharvest**. Stings are not very noticeable in peaches and nectarines. See Fruit F 2 (Fig. 101) F 9.

Leafhoppers, treehoppers

Apple leafhopper (*Typhlocyba froggatti*, Cicadellidae)
Green treehopper (*Sextius virescens*, Membracidae)
See Pome fruits F 112, Trees K 15, Vegetables M 15.

Mites (Acarina)

Eriophyid mites (Eriophyidae): **Peach silver mite** (*Aculus cornutus*) infests peach. Adult mites are narrow, tiny mites about 0.2 mm long. They taper towards the rear end and have 2 pairs of legs near the head. The silvering first becomes noticeable about December or January and by late autumn all **leaves** are a leaden or a dull silvery colour. This does not seem to cause significant damage as the leaves do not fall prematurely, at least not on irrigated trees. The mites have long been suspected of causing **bud shatter** or bud shedding, which may reduce the yield of fruit, for which no other cause has been established. **Overwinter** under the scales enclosing the scales. **In spring** the mites move out from the buds to feed on the upper surfaces of new leaves. Control is not usually warranted. If necessary, dormant sprays should provide adequate control. **Plum leaf mite** (*Phyllocoptes abaenus*) may be found living on **leaf undersurfaces** of plums and ornamentals. It frequents basal hairs along leaf midribs. See Grapevine F 62.

Spider mites (Tetranychidae): **Bryobia mite, brown almond mite** (*Bryobia rubrioculus*): By midsummer **foliage** develops a grey green appearance. As autumn approaches the colour becomes more bleached and defoliation may be heavy and trees may look scraggy. Leaf size is affected and trees infested year after year have narrow thin leaves. The crop is reduced by the fall of half-developed **nuts** and those remaining on the tree are undersized and often empty. **Favoured** by inadequate irrigation. Peerless is **very susceptible**. Control by spraying in winter with **winter oil**. **Predatory mite** (*Typhlodromus doreeniae*) may be a biological control agent for bryobia mite but may be reduced by winter oil sprays. It may be necessary to spray during the growing season. See Fruit F 12. **European red mite** (*Panonychus ulmi*) is an **important pest**. See Fruit F 12, Pome fruits F 115. **Twospotted mite** (*Tetranychus urticae*) affects peaches and nectarines, plums and prunes, almonds. Infestation is usually mild and occurs when trees have been sprayed for certain other pests (natural enemies of twospotted mite are killed). **Leaves** are stippled, grey looking or almost white, such damaged leaves fall and **fruit size** is reduced and sunburnt and fail to colour. **Monitor** mite and predators at regular intervals before applying an insecticide (Brough et al. 1994). Various outlets, eg IPM Services in Adelaide, provide management information for twospotted mite, apple weevil and European earwig. See Beans (French) M 29, Fruit F 12.

Oriental fruit moth, peach tip moth

Scientific name: Tortricidae, Lepidoptera: Oriental fruit moth (*Grapholita molesta*)

Host range: Mainly ***stone fruits***, especially peach and nectarine but also almond, apricot, plum and cherry. Occasionally quince, apple and pear. Also the ornamental varieties of these species.

Description and damage: ***Moths*** are a mottled grey-brown colour and are about 6 mm long when at rest with wings folded. They are rarely seen during the day. ***Caterpillars*** are up to ***12 mm*** long, are whitish or pale pink with a light brown head. They have a special appendage, the anal comb, a toothed horny plate on the last segment. Caterpillars usually enter ***twigs*** near the tip (and often near the petiole) and tunnel downward for 7-10 cm causing the twig to wilt, collapse, produce gum and die. One caterpillar may attack as many as ***3 shoots*** during feeding. When older caterpillars move from one twig to another, the point of entry into the shoots may be at the axil of a leaf below the tip. Later broods of caterpillars may enter ***fruit*** either through the stem of the fruit or where a leaf or small branch touches the fruit, so that fruit can appear perfect on the outside but when cut open numerous feeding burrows can be seen. These tunnels may be filled with brown particles of excreta, similar to ***codling moth*** damage to apples (Fig. 164). Shoot growth can be severely damaged and the ***framework*** of young trees is affected. Fruit attacks by caterpillars can increase the amount of ***brown rot infection***, especially in wet weather.

Pest cycle: Complete metamorphosis (egg, caterpillar, pupa, adult) with several generations each year (probably 5-6).

Overwintering: As caterpillars in cocoons under bark on trees, and on mummified fruit and litter on the ground, also in crevices in the soil.

Spread: By moths flying, they are not strong fliers, the transfer of infested fruit, nursery stock and possibly in picking boxes.

Conditions favouring: Succulent shoot growth due to warm, moist conditions, overwatering, overfertilising or severe pruning encourage populations to build up quickly. As warm moist conditions also favour the brown rot fungus, the total damage may be greatly increased. Hot dry windy weather is unfavourable to the moth. Even if heavy infestation is threatened in spring, hot winds in summer can reduce infestations significantly. Very cold winters are unfavourable.

Control: Control infestations on both ***bearing and non-bearing trees*** as the framework of developing trees may be seriously damaged and moths may spread to adjoining mature trees.

Sanitation: Damage to individual home garden trees may be reduced by ***pruning off*** and burning/destroying infested tips in spring. This reduces the number of 1st generation moths. Fallen and infested ***fruit*** on the tree should be destroyed every few days by burning or placing in an insect-proof pit. Remove loose or ***rough bark*** under which larvae may pupate from the tree.

Biological control: Various ***wasp parasites*** attack larvae and pupae and may reduce moth numbers considerably. Female pheromones are released from tiers ***(Isomate®M)*** on trees, this confuses male moths preventing mating; they are used ***commercially*** to control oriental fruit moth.

Pesticides: If tiers are not being used and if there is no warning service, ***insecticides*** should be applied when moth activity is first observed (usually within 14 days of petal fall, October onwards) and at intervals of 3 weeks thereafter (observe withholding periods). The aim is to kill the moths as they alight on the treated plant and the caterpillars as they crawl on the surface of the plant. If a warning service based on ***trap catches*** is available, intervals between applications can be extended beyond 3 weeks. For all sprays use a coarse spray and good pressure and enough spray to wet the leaves thoroughly. A fully grown tree will need several litres of spray to cover it thoroughly. The ***use of pesticides*** to control oriental fruit moth may reduce the natural enemies of ***twospotted mites*** resulting in an increase in damage by this pest.

Pear and cherry slug (*Caliroa cerasi*)

are ***slug-like***, green-black and about 12 mm long. They ***skeletonise leaves*** of stone fruits (Fig. 165), especially cherry, but also plum, causing them to brown and trees to look scorched. Regular severe infestation year after year reduces the ***vigour of trees***. Cultivars vary in ***susceptibility***. ***Insecticides*** may be applied when slugs are seen on the tree. See Pome fruits F 115.

Scales (Hemiptera)

Armoured scales (Diaspididae)
- Oystershell scale (*Quadraspidiotus ostreaeformis*)
- Peach white scale (*Pseudaulacaspis pentagona*)
- San Jose scale (*Q. perniciosus*)
- Red scale (*Aonidiella aurantii*)
- Yellow scale (*A. citrina*)
- See Citrus F 39.

Soft scales (Coccidae): ***Frosted scale,*** prune scale (*Eulecanium pruinosum*) infests deciduous fruit and ornamental trees, especially apricot, peach, plum, prune and nectarine. ***Adult*** scales are about 5 mm long, oval-convex, soft-bodied with a white powdery wax (frosted) and a few fine white hairs. See Fruit F 3 (Fig. 107). ***Nymphs*** are active, light brown crawlers. ***Leaves*** are usually infested with nymphs during summer. Undersurfaces of ***twigs, spurs or laterals*** are infested with half-grown scales and adults. This scale produces large quantities of ***honeydew*** with associated sooty mould. ***Overwinters*** as developing scale insects on the undersurfaces of twigs and branches. During winter, half-grown scales lie along the undersurfaces of spurs or lower laterals. These scales become adult in spring. ***Egg laying commences*** shortly afterwards, large numbers of white eggs accumulate under old scales. ***Eggs commence hatching*** about November. Nymphs crawl to leaf undersurfaces where they settle without much further development until autumn, when they ***migrate*** back to twigs. ***Spread*** by movement of infested nursery stock, scales crawling or carried by ants, and by humans to other adjacent trees. ***Predatory ladybirds*** can keep infestations in check, both the adults and larvae feed on this scale. One spray of ***winter oil*** during winter will usually keep this scale in check and is not detrimental to predatory ladybirds. ***Grapevine scale*** (*Parthenolecanium persicae*) is usually controlled by the mealybug ladybird (*Cryptolaemus montrouzieri*) and wasp parasites. Inspect bark of trees during pruning, label and spot spray any infested trees. Also ***black scale*** (*Saissetia oleae*), ***soft brown scale*** (*Coccus hesperidum*). See Citrus F 41

Others: Cottonycushion scale (*Icerya purchasi*).

Dormant petroleum sprays are usually applied, ensure undersides of laterals are thoroughly covered. See Citrus F 39, F 41, Trees K 16.

Thrips (Thripidae, Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause ***leaf silvering***. See Greenhouses N 24.

Plague thrips (*Thrips imaginis*) attack peach and nectarine at ***flowering***, causing skin blemishes and slight fruit malformation resulting in rejection of fruit from the fresh fruit market. ***Monitor*** thrips by inspecting 5 blossoms or by shaking flowers over a hand or into an ice cream container from each of 20 trees/ha at weekly intervals from early flowering to shuck fall. Thrips may be found in flowers and under the shuck. Spray if thrips numbers average > 6/flower (Brough et al. 1994). See Roses J 6.

Weevils Curculionidae, Coleoptera)

Apple root weevils (*Perperus* spp.)
Apple weevil (*Otiorhynchus cribricollis*)
Fruit tree root weevil (*Leptopius squalidus*)
Fuller's rose weevil (*Asynonchus cervinus*)
Vine weevil (*Orthorhinus klugi*)
See Pome fruits F 116, Trees K 17, Vegetables M 17.

Yellow peach moth

Scientific name: Pyralidae, Lepidoptera:
Yellow peach moth (*Conogethes punctiferalis*)

Host range: ***Ornamentals***, eg seed capsules and leaves of flame tree (*Brachychiton acerifolium*), fruits of *Planchonia careya,* palm (*Livistona humilis*), ***fruit***, eg custard apple, citrus, pawpaw, macadamia, mango, peach, ***vegetables***, eg eggfruit, ***field crops***, eg cotton, maize, sorghum.

Description and damage: ***Moths*** are bright yellow or orange with a wing span of about 25 mm. Wings and body have conspicuous black spots. ***Caterpillars*** are about ***20 mm*** long, grey-white, often tinged with pink. They have a dark head, a dark shield on the upper surface of the 1st body segment. ***Fruit injury*** occurs when fruit is nearly ripe. Caterpillars bore in where 2 fruits hang together or at the stem end. They usually feed around the stone and fill the cavity formed with dark brown frass pellets (Fig. 166). If the fruit is green, there is often an exudation of clear gum.

Pest cycle: Complete metamorphosis (egg, larvae, pupa, adult) with several generations each year. Eggs are laid on developing fruit. Caterpillars feed in the fruit and pupate on the outside of fruit on the host in shelters of webbed larval droppings.

Overwintering: As cocoons on the host plant.

Spread: By moths flying, and by the movement of infested fruit.

Conditions favouring: Yellow peach moth is a subtropical species of Far North Coast and is not found in the commercially important peach-growing areas of NSW.

Control:
Sanitation: Remove and destroy infested fruit.
Pesticides: If insecticides are necessary, those for oriental fruit moth will probably be effective. Ensure coverage of fruit. Spray within 2 weeks of petal fall and repeat every 2-3 weeks.

Others: ***Grasshoppers, katydids, locusts*** (Orthoptera), eg ***inland katydid*** (*Caedicia simplex*), chew the skin of ripening fruits making them unmarketable. ***Scarab beetles*** (Scarabaeidae), eg African black beetle (*Heteronychus arator*), Christmas beetles (*Anoplognathus* spp.). ***Cicadas*** (Cicadidae, Hemiptera) damage twigs and branches when they lay eggs into them during spring and summer. Females make rows of slits along the branches as they lay their eggs. Each slit about 6 mm long is marked by a tuft of wood splinters. Some small branches can be severely damaged but damage is not economic. Eggs can be seen in slits when fresh. Cicada nymphs develop in the soil where they feed on roots but do not cause economic damage. Chemical control is not recommended. Avoid planting near native areas (Brough et al. 1994). Also ***cherrynose*** (*Macrotristria angularis,* Cicadidae). ***Very occasional pests*** include whiteflies (Aleyrodidae), ***pumpkin beetle*** (*Aulacophora hilaris*), ***codling moth*** (*Cydia pomonella*), ***European earwig*** (*Forficula auricularia*), ***mealybugs*** (Pseudococcidae), ***redshouldered leaf beetle*** (*Monolepta australis*), ***soldier beetle*** (*Chauliognathus* sp.), ***woolly aphid*** (*Eriosoma lanigerum*).

VERTEBRATE PESTS

Birds, fruit bats, rabbits, hares may damage stone fruits. See Fruit F 13.

Non-parasitic

Environment: Beattie et al. (1989) describes ***postharvest diseases***. Adequate and appropriate ***irrigation*** is essential when fruit and nuts are maturing. ***Crinkle of plum:*** If water lost from leaves during hot dry periods is not replaced quickly, water is removed from fruit to the leaves and fruits shrivel. ***Skin cracking*** or rain-induced split in apricots and cherries may be due to excess uptake of water by fruit shortly before harvest. Cracks may be invaded by ***secondary rots***. Select cultivars with ***some resistance***. ***Pit burn:*** ***Apricots*** may be damaged by very hot weather and low humidity between early ripening and harvesting, causing internal softening. ***Late spring frosts*** may damage ***early flowering cultivars*** of ***almond, apricot and plum***. After a severe frost, petals may brown and collapse. The whole flower may be killed, but occasionally the pistil is still undamaged. If the fertile parts are damaged the flower usually drops within a few days. ***Apricots*** prefer hot dry summers and cold winters, by careful choice of variety it is possible to produce crops in a range of climates. Most varieties blossom early so choose site to avoid frosts. ***Cherries*** need cold winters and do not tolerate shallow, waterlogged or saline soils. Choose a site sheltered from strong winds, frost-free in spring and provide protection from drying winds. Frost damage on ***plum*** is unusual. A light frost after fruit set may cause irregular patches of rough scaly russet on any part of the fruit. See Fruit F 3 (Fig. 109). Growth under patches of this russet is only slightly restricted. ***Fruit handled postharvest without temperature control***, eg cooling, may lose quality quickly. ***Cool storage breakdown*** is usually due to holding fruit for an excessive time in storage and/or by storing at incorrect low temperatures. Damage includes internal discolouration of flesh and/or shrivelling of the whole fruit which only develops after removal from cool storage. ***Freezing injury*** during cool storage may occur to fruit. ***Condensation*** on the skin of peaches and nectarines occurs when fruit is cooled, removed from cool storage for packing then cooled again for transportation.

Genetic: Some stone fruits, eg apricots, readily ***gum***. Do not confuse this gumming with damage caused by bacterial canker, bacterial spot, brown rot, shot-hole, fruit-tree borer, waterlogging, water deficiency, heavy pruning, intense heat. Some *Prunus* spp. develop ***burr knots*** or galls at the base of the trunk. Burr knots can produce adventitious shoots if necessary, for example, if the top of the tree was lopped off. ***Autumn leaf roll*** causes an upward rolling of leaves of some of peaches, eg the newer peach cultivars, eg Maygold, and may cause stunting and loss of yield (Persley 1993).

Mechanical injury: ***Physical damage*** to skin of fruit postharvest may occur during rough handling, eg dipping, fingernails, twigs. ***Rubbing*** of skin may cause browning of the skin and of the flesh underneath and is due to packing and grading equipment ***Pressure and bruising injury*** is due to rough handling and overfilling containers. Surface pitting may occur on cherries. ***Limbs*** of some stone fruits, eg apricot, gum readily when injured. Plums, particularly some Japanese plums, may ***overcrop*** and ***split limbs***.

Nutrient deficiencies, toxicities: ***Standards*** based on diagnostic leaf analyses are available for stone fruits (Weir and Cresswell 1993). ***Apricots*** may be susceptible to ***salt toxicity***.

Pesticide and chemical injury: ***Pesticides:*** Only apply ***dormant sprays of copper*** on stone fruits otherwise foliage damage will occur. Copper persists in the soil. ***Bordeaux mixture*** if applied after flowering to apricot may, under certain weather conditions, ***russet fruit***. In Europe where copper sprays have been used for decades ***vegetables*** grown in stone fruit orchards may suffer from ***copper toxicity***. ***Dimethoate*** may damage early peaches. ***Chemical injury:*** During storage ***ammonia gas*** leaking from refrigeration systems may enter fruit through the skin causing surface blotches on skin. ***Sulphur dioxide*** used to control grey mould in grapes and injury may occur when they are transported with stone fruit.

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NSW Agfacts/NSW Agnotes/NSW Agric
Almonds in Garden
Apricots in the Garden
Bacterial Canker of Stone Fruit
Bacterial Spot of Stone Fruit
Black Heart of Apricots
Brown Rot of Stone Fruits
Cherries in the Garden
Cherry Growing
Diseases of Cherries (NSW Bull. 1972)
Frosted scale
Major Pests & Diseases of Deciduous Fruits (poster)
Orchard & Vineyard Plant Protection Guide for Inland NSW (Current Season)
Orchard Spray Calendar for the MIA and Young
Palmette Training of Dessert Stone Fruit
Peach and Nectarine Growing
Peach and Nectarine Varieties for New South Wales
Peach Leaf Curl
Plums in the Garden
Preparing Produce for Markets (Export Note, NSW Agric)
Prune Growing
Prune Rust : A Practical Guide to its Control

Rust of Stone Fruits
Shot-hole and Freckle of Stone Fruits
Stonefruit Pest & Disease Control (Leaflet NSW Agric.)
Summer Trunk Canker of Peach and Other Stone Fruits

Vic Agnotes

Aphid Pests of Peaches, Cherries and Citrus
Apricot Scab (Shot-hole)
Apricots : Production, Harvesting, Marketing
Bacterial Canker (Gummosis) of Stone Fruits
Brown-rot of Stone Fruit
Chemical Control of Weeds in Pome and Stone Fruit
Chemical Thinning of Cling Peaches
Closer Planting of Peach Trees in Goulburn Valley Orchards
Crop Control of Clingstone Peaches for the Fresh Market
Fresh Marketing of Canning Peaches
Crown Gall of Stonefruit
Deciduous Fruit Crops Kit
Drying Apricots at Home
Drying Stone Fruit
Eutypa Dieback of Apricot
Freckle of Peaches and Apricots
Fruit Tree Borer Moth & Small Fruit Tree Borer Moth
Growing Cherries on Tatura Trellis 1
Growing Sweet Cherries
Integrated Control of Orchard Mites
Mechanical Harvesting of Peaches for Processing
Nectarine Varieties for the Mallee
Oriental Fruit Moth
Peach and Nectarine Spray Schedule
Peach Leaf Curl
Peach Rosette and Decline Virus
Peach Rust
Phytophthora Trunk Rot of Peaches and Apricots
Plum and Prune Spray Program for the Mallee
Plums : Rootstocks and Cultivation
Plum Spray Schedule
Plums : Varieties and Pollination
Plum Varieties for the Mallee
Postharvest Fungicidal Dips for Stone fruit
Propagating Peach Trees from Hard-wood Cuttings
Propagating Peach Trees from Softwood Cuttings
Rhizopus Rot & Transit Rot of Fruit & Vegetables
Silver-leaf Disease of Fruit Crops
Spray Programs for Commercial Apricot & Cherry Growers
Spring-budded Peach Trees
The Pear and Cherry Slug
Thinning Canning Peach Trees
Training Peach & Nectarine Trees on Tatura Trellis
Training Plum Trees on Tatura Trellis
Trickle Irrigation : The Water Needs of Young Peach Trees
The Dried Fruit Beetle (Vic Agnote)
Using Predatory Mite to Control Twospotted Mite in Pome and Stone fruit Orchards
Verticillium Wilt of Deciduous Fruit Trees
White-fleshed Dessert Peach Varieties
Wood Rots
Yellow-fleshed Dessert Peach Varieties
Yellow-fleshed Nectarine Varieties

WA Farmnotes

Almond Growing in Western Australia
Sites, Layout and Irrigation for Nut Orchards

SA Fact Sheets

Commercial Almond Growing (SA Dept of Agric Bull)
Eutypa Dieback in Apricots and Grapevines
Oriental Fruit Moth
Postharvest Control of Rot in Stone Fruits

Qld Farmnotes/DPI Notes

Plums : Selection of Pollinator
Stone Fruit : Propagation, Growing Peach Rootstocks

Tas Farmnotes

Postharvest Disease Control in Stone Fruits
Weed Control in Pome and Stone Fruit Orchards

Associations, Journals etc.

Almondco (formerly the Almond Coop.)
Australian Almond Improvement Society
Australian Nut Industry Council (ANIC)
Canned Fruits Industry Council of Australia
Cherry Growers Assoc.
Good Fruit and Vegetables
International Prune Assoc. (IPA)
NSW Canning Fruitgrowers Assoc. of NSW
Plant Protection Quarterly
SA Canning Fruitgrowers Assoc.
Vic. Canning Fruitgrowers Council

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

Stone fruits are grown for the fresh market, processing and drying. An overview of the industry is presented by Coombs (1995). Many species are grown for their flowers, but some are high maintenance trees requiring yearly spraying for peach leaf curl and in some seasons for aphids (Sutton 1976); they may also require pruning and summer irrigation. Each type of stone fruit has its own list of diseases and pests (Table 2) so it is difficult to generalise. ***Select*** cultivars suited to the area, determine tree spacing, soil, slope, equipment width and rootstock. ***Check pollinating requirements*** for your particular area, eg cross pollination may be essential for economic fruit or nut production. Cross-pollination is necessary for production of ***almonds*** and these can only mature satisfactorily (without constant disease problems), in areas of long, hot dry summers; ***pollinators*** are required for ***sweet cherry***, but not for ***sour cherry***. Areas where cool, showery weather prevails during flowering (July/August) are unsuitable because pollination is affected. ***Biennial bearing*** occurs in some ***stone fruit*** varieties which can be modified by management practices, eg selection of budwood, appropriate thinning techniques. Choose rootstock with some ***resistance*** to local problems, eg waterlogging. Purchase ***virus-tested planting material*** and inspect rootstock and nursery stock for crown gall, black peach aphids, scales and other diseases and pests. Stone fruits are traditionally ***propagated*** by budding and grafting onto rootstocks grown from seed but also by cuttings, eg peaches. ***Diagnostic, monitoring and pest management systems*** are available and should be followed (Campbell 1994). Overseas expert systems are available for peach and nectarines. Regional plant protection guides and computerised decision support systems have been developed, eg for prune rust. ***Cultural methods:*** ***Replant problems*** can occur, eg poor growth and death of young peach trees planted into old peach orchards, these are caused by ***toxins*** released during the ***decomposition of old peach roots*** (Handreck and Black 1994). Some stone fruits, eg Japanese plums, need regular hard ***pruning***, European plums need less pruning. Appropriately ***thin*** stone fruits, eg by growth regulators, hand thinning or tree shakers. ***Sanitation:*** Prune at the appropriate time and prune off diseased parts, eg brown rot mummies. ***Biological control:*** Pre-plant treat ***crown gall*** susceptible nursery stock with *Agrobacterium*, and use other biological control agents, if available. ***Pesticides:*** ***Copper,*** which is commonly and widely used on stone fruits, is non-systemic so only protects tissue from infection. ***Growth regulators*** are used for thinning, increasing size and uniformity, controlling vegetative growth and other processes. ***Regional spray schedules*** are available for brown rot, peach leaf curl and shot-hole and insect pests on ***susceptible varieties***. ***Winter oil*** is used for scales during ***dormancy***. ***Storage:*** ***Fruit diseases and pests*** must be controlled both in the ***field*** and ***postharvest***, eg brown rot, rhizopus soft rot and fruit fly. See Fruit F 5, F 17, Postharvest N 62. ***Organic standards*** are available for stone fruits (Madge 1995, Pascoe 1995).

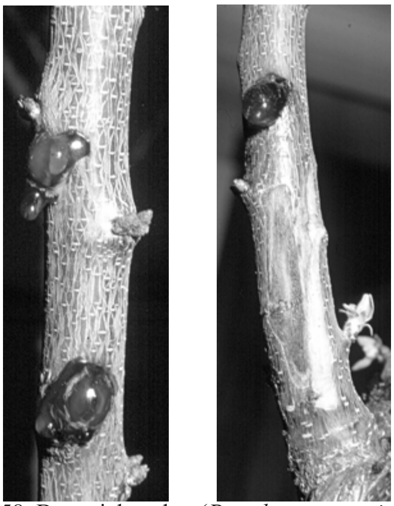

Fig. 158. Bacterial canker (*Pseudomonas syringae* pv. *syringae*). ***Left :*** Gumming. ***Right :*** Bark removed to show brown tissue underneath.

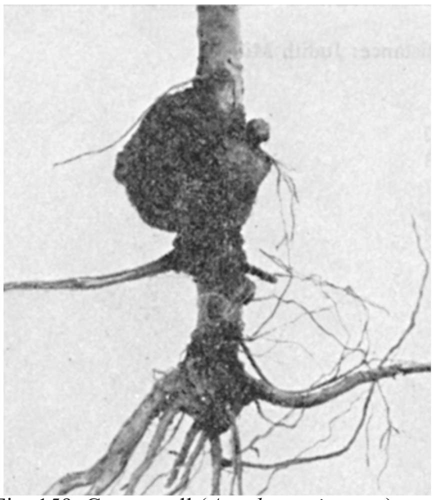

Fig. 159. Crown gall (*Agrobacterium* sp.) on peach nursery stock. Dept. of Agric., NSW.

Fig. 160. Brown rot (*Sclerotinia fructicola*) of peach fruit. Dept. of Agric., NSW.

Fig. 161. ***Left :*** Apricot fruit and leaves infected with shot-hole (*Stigmina carpophila*). ***Right :*** Nectarine fruit infected with freckle (*Venturia carpophila*). Dept. of Agric., NSW.

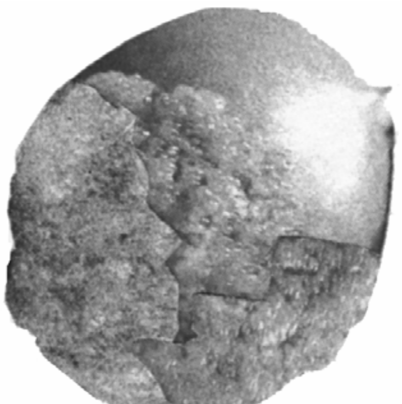

Fig. 162. Peach leaf curl (*Taphrina deformans*).
Left : Curly leaves. Dept. of Agric., NSW.
Right : Damage to nectarine fruit.

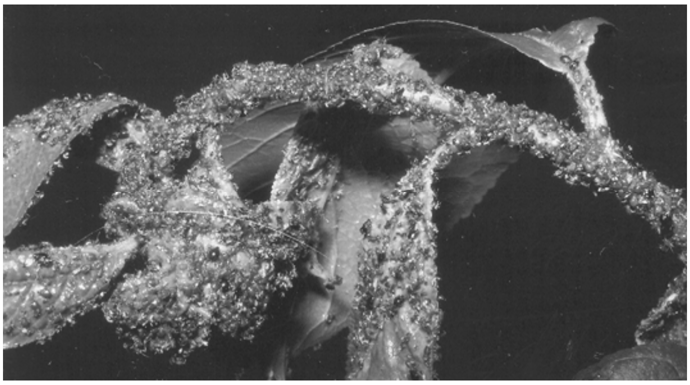

Fig. 163. Aphids. ***Top left :*** Black peach aphids (*Brachycaudus persicae*). ***Top right :*** Cherry aphid (*Myzus cerasi*) damage. ***Lower left :*** Green peach aphid (*Myzus persicae*) damage.

Fig. 165. Pear and cherry slug (*Caliroa cerasi*), up to 12 mm long, skeletonising a cherry leaf.

Fig. 164. Oriental fruit moth (*Grapholita molesta*). ***Left :*** Caterpillar damage in peach fruit. ***Right :*** Shoot tips die due to caterpillars tunnelling in them.

Fig. 166. Yellow peach moth (*Conogethes punctiferalis*). ***Left :*** Damage to custard apple**.** *Right :* Caterpillar (20 mm long).

Table 2. Some diseases and pests of particular stone fruits.

	ALMOND	APRICOT	CHERRY	PEACH NECTARINE	PLUM
VIRUS & VIRUS-LIKE DISEASES					
Prunus necrotic ringspot virus (PNRV)	PNRV	PNRV	PNRV	PNRV	PNRV
BACTERIAL DISEASES					
Bacterial canker (BC)		BC	BC		BC
Bacterial spot (BS)			BS	BS	BS
Crown gall	Crown gall	Crown gall	Crown gall	Crown gall	Crown gall
FUNGAL DISEASES					
Armillaria root rot (ARR) (sporadic in contaminated areas)	ARR	ARR	ARR	ARR	ARR
Brown rot		**Brown rot**	**Brown rot**	**Brown rot**	**Brown rot**
Eutypa		Eutypa			
Freckle		Freckle	Freckle	Freckle	Freckle
Fruit rots (various species)	Nut rots	Fruit rots	Fruit rots	Fruit rots	Fruit rots
Peach leaf curl (PLC)	PLC	PLC		**PLC**	PLC
Powdery mildew (PM)		PM		PM	
Rust	Rust	Rust	Rust	Rust	**Rust**
Shot-hole	**Shot-hole**	**Shot-hole**	**Shot-hole**	**Shot-hole**	Shot-hole
Phytophthora root rot (PRR)		PRR		PRR	PRR
Verticillium wilt (VW)		VW			
Wood rot (WR) (various species)	WR	WR	WR	WR	WR
NEMATODE DISEASES	Many	Many	Many	Many	Many
INSECTS & ALLIED PESTS					
Aphids					
Black peach aphid (**BPA**)	**BPA**	**BPA**	BPA	**BPA**	**BPA**
Cherry aphid **(CA)**			**CA**		
Green peach aphid (**GPA**)	GPA	GPA		**GPA**	GPA
Borers					
Fruit-tree borer **(FTB)**	FTB	FTB	FTB	FTB	FTB
Bugs					
Fruitspotting bug **(FSB)**		FSB	FSB	FSB	FSB
Rutherglen bug **(RB)**	RB	RB	RB	**RB**	RB
Caterpillars					
Budworms **(B)** (*Helicoverpa*)		Budworms	Budworms	Budworms	Budworms
Lightbrown apple moth **(LBAM)**		LBAM	LBAM	LBAM	LBAM
Oriental fruit moth **(OFM)**	**OFM**	**OFM**	**OFM**	**OFM**	**OFM**
Yellow peach moth **(YPM)**				YPM	
Driedfruit beetles (DFB)	**DFB**	**DFB**	**DFB**	**DFB**	**DFB**
Fruit fly		**Fruit fly**	**Fruit fly**	**Fruit fly**	**Fruit fly**
Pear & cherry slug (P&CS)	P&CS	P&CS	P&CS	P&CS	**P&CS**
Mites					
Bryobia mite **(BM)**	BM	BM	BM	BM	BM
European red mite **(ERM)**	ERM	ERM		ERM	ERM
Peach silver mite (**PSM**)				PSM	
Twospotted mite **(TM)**	TM	TM	TM	TM	TM
Scale					
Frosted scale **(FS)**		FS		FS	FS
Grapevine scale **(GS)**		GS			GS
San Jose scale **(SJS)**	SJS	SJS	SJS	SJS	SJS
Soft brown scale **(SBS)**		SBS			
Thrips					
Plague thrips **(PT)**			PT	PT	PT
VERTEBRATE PESTS					
Birds	Birds	Birds	Birds	Birds	Birds
Fruit bats		Fruit bats	Fruit bats	Fruit bats	Fruit bats
Possums		Possums	Possums	Possums	Possums
Non-parasitic pests and diseases					
Late frosts in spring (early flowering cultivars)	Late frosts	Late frosts			Late frosts
Overcropping (split limbs and smaller fruit)					Overcropping
Rain split			Rain split		Rain split

Strawberry

Fragaria spp.
Family Rosaceae

PESTS AND DISEASES

Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Fruit rots
  - Fungal leaf spots
  - Powdery mildew
  - Root and crown rots
  - Wilts
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Crickets, grasshoppers, locusts
  - Mites
  - Scarab beetles
  - Slaters
  - Thrips
  - Weevils
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic
  - Environment
  - Mechanical injury
  - Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Crinkle-yellow edge complex: Several viruses affect cultivated strawberries including strawberry crinkle virus, strawberry mild yellow edge virus, strawberry veinbanding virus. In most commercial strawberry varieties ***none of the viruses alone produce any noticeable symptoms*** although some decline in yield occurs with strawberry crinkle virus in some varieties. In general, viruses are a problem only if 2 or more combine in one plant. Symptoms depend on which viruses are present and the cultivar. As the number of viruses and virus strains increases there is an increase in severity of symptoms, particularly in autumn. Symptoms are more distinct in cooler months of the year. The most common symptoms classified as ***crinkle*** include stunting of plants, reduced and uneven leaf size, leaf crinkling, small and often misshapen fruit. Leaves may be flecked with yellow, particularly along veins, which may become dead and discoloured. Leaf margins when held up to light appear yellow. Virus-infected plants may yield ***60% less fruit*** and a smaller proportion of large and marketable fruit. Even mild virus infection can result in a ***25% reduction*** in yield. ***Overwinters*** in infected strawberry plants. ***Spread*** by vegetative propagation (runners, grafting) from virus-infected plants, by aphids especially the strawberry aphid (*Chaetosiphon fragaefolii*), not by mechanical inoculation, not by contact between plants, not by seed, not by pollen. Virus-infected plants cannot be cured. ***To minimise losses:*** Remove and destroy infected plants when observed. Only plant ***virus-free runners*** obtained from a certified supplier and replant every 2-3 years. New crops must be at least 400 m from existing infected ones to avoid aphids spreading viruses from old crops to new virus-free crops. Control ***aphid vectors*** which build up in numbers during spring and autumn. As an aphid on a sprayed plant can inoculate it with virus during a few minutes of feeding before the aphid dies, it is unlikely that viruses can be kept out of crops as long as virus-infected strawberries are grown. See Fruit F 4, Vegetables M 4.

Others: Strawberry lethal yellows, little leaf/green petal mycoplasma causes runner plants from infected parent plants to be stunted. Young leaves yellow and die. Probably spread in nature by ***leafhoppers***. See Tomato M 97.

BACTERIAL DISEASES

Strawberry angular leaf spot (*Xanthomonas fragariae*), if established in Australia, could seriously affect Australia's strawberry industry. Two outbreaks so far have been recorded in Australia. It is ***spread*** by infected planting material. Enzyme-liked immunosorbent assay (ELISA) diagnostic tests have been developed overseas (Rowhani et al. 1994).

FUNGAL DISEASES

Fruit rots are common on strawberries.

Anthracnose, black spot, ripe rot (*Colletotrichum* sp.) causes a firm slow-spreading rot of ripe or near-ripe fruit. ***Fruit*** develop ***circular black spots*** about 2-8 mm across; these become sunken and covered with masses of wet glistening ***pink to green spores***. ***Overwinters*** in infected dead leaves and berries on the plant. Spores are ***spread*** by rain splash and overhead irrigation. ***Favoured*** by warm, humid conditions and ***2nd-year fruit beds.*** See Fruit F 5.

Rhizopus soft rot, leak (*Rhizopus stolonifer*) attacks ripe fruit causing mushy ***berries*** which become covered with ***white mycelium*** and later masses of ***black spores***. This is mainly a ***postharvest*** disease. See Fruit F 6.

Gnomonia fruit and leaf blotch (*Gnomonia fructicola*) during wet springs and summers commonly attacks fruit at its base. In ***flowers and immature fruit***, the calyx is rapidly killed and fruit shrivel. In ripe or near-ripe fruit the calyx is killed and a ***firm brown rot*** slowly spreads from the calyx to the whole fruit. Leaf blotch attacks ***older leaves***, causing large brown circular spots. ***Overwinters*** in debris from infected and current strawberry crops. Spores are ***spread*** from infected debris and strawberry plants by wind and water splash (rain or overhead irrigation).

Grey mould (*Botrytis cinerea*) is the most important ***field*** and ***postharvest*** disease of strawberry. It attacks ***flowers and fruit stalks*** during flowering causing them to die rapidly. ***Green and ripe fruit*** develop a brown rot that spreads to the whole fruit and becomes covered with masses of ***dry greyish spores*** (Fig. 167). See Fruit F 5, Greenhouses N 22.

Tan rot (*Hainesia lythri*) causes a firm slowly spreading rot (Persley 1993).

Others: ***Black plug*** (*Phoma* sp.), ***blue mould*** (*Penicillium* sp.), ***cladosporium rot*** (*Cladosporium* sp.), ***leather rot*** (*Rhizoctonia solani*), ***sclerotinia rot*** (*Sclerotinia sclerotiorum*)

Fruit rots are ***favoured*** by warm wet conditions. Some fungi require wounding to initiate fruit infection (anthracnose, rhizopus soft rot, tan rot). ***Avoid overhead irrigation***. ***Remove/destroy*** dead leaves, diseased berries and debris from infected crops. Plant ***disease-free runners***. Apply ***fungicides*** if needed in spring and summer. Cool fruit after harvest and during transport. See Fruit F 5.

Fungal leaf spots

Alternaria leaf spot (*Alternaria alternata* f.sp. *fragariae*) causes ***circular spots 3-6 mm across with reddish margins and brown centres*** which may run together. Leaves and plants may die. Red Gauntlet is ***very susceptible***.

Black spot, eye spot, leaf spot (*Mycosphaerella fragariae*) causes small spots usually ***3-6 mm across with purple margins, greyish-white centres*** (Fig. 168). If spots are numerous, leaves die rapidly and fall. Similar symptoms develop on ***petioles, fruit stalks, stolons and calyxes***.

Leaf blight (*Phomopsis obscurans*) causes large circular, elongated or V-shaped spots, ***5-15 mm across with reddish margins and brown centres***, they often cover large areas of leaves. Small black specks (fruiting bodies) occur in the leaf spots. During wet weather spots may be numerous, leaves may die. In some varieties, ***petioles, fruit stalks and stolons*** may be attacked.

Leaf scorch, red spot (*Diplocarpon earliana*) causes small, ***irregularly-shaped reddish brown spots***, ***rarely > 2 mm across***. Small raised glistening dots (fruiting bodies) appear within the leaf spot. Spots may combine to produce large purplish, reddish or dead patches. Leaves may yellow and die, giving a scorched appearance. ***Petioles, fruit stalks, sepals and calyces*** may be similarly attacked.

Some fruit rots may cause minor leaf spotting. ***Gnomonia fruit and leaf blotch*** (*Gnomonia fructicola*) causes large irregular spots on older leaves.

Destroy diseased crop residues, do not plant in damp or shady areas. Only plant ***disease-free runners***. Crops should be replaced at regular intervals. ***Fungicides*** are registered for leaf spot control on strawberries. See Annuals A 5.

Powdery mildew (*Sphaerotheca macularis*)

is a ***serious disease***. During warm humid conditions ***leaf margins*** curl up. Irregular purple blotches often develop along the major veins. Leaves feel brittle. Typical white spore masses are not produced. ***Infected flowers*** do not set and eventually die. Infected ***immature fruit*** remain hard and do not ripen. ***Infected ripe or near-ripe fruit*** looks dull with prominent seeds. Varieties differ in ***susceptibility***, none are resistant. Potential exists for developing new resistant cultivars to reduce reliance on fungicides (Nelson et al. 1996). See Annuals A 6.

Root and crown rots

Most have a wide host range including ornamentals, fruit, vegetables, field crops, weeds and cause decline and death of plants in ***patches***.

Black root rot (undetermined). Soil fungi and nematodes have been implicated. Symptoms occur during fruiting when older leaves die rapidly and new leaves are not produced fast enough to replace them. ***Leaf uppersurfaces*** are dull and bronzed, margins curl downwards. ***New leaves*** become progressively smaller, fruit is small and hard. ***Roots*** have a high proportion of dead roots and many have dead patches. More and more roots die. ***Favoured*** by replant crops without a fallow between crops.

Phytophthora diseases: Leathery rot *Phytophthora cactorum*), ***red stele***, red core (*P. fragariae*). See Trees K 6.

Others: Armillaria root rot (*Armillaria* spp.), ***pythium root rot*** (*Pythium* spp.), ***fusarium*** (*Fusarium* spp.), ***rhizoctonia wilt*** (*Rhizoctonia solani*), ***sclerotinia crown rot*** (*Sclerotinia sclerotiorum*), ***sclerotium stem rot*** (*Sclerotium rolfsii*).

See Vegetables M 7.

Wilts

Fusarium wilt (*Fusarium oxysporum* f.sp. *fragariae*).

Verticillium wilt (*Verticillium dahliae*)***:*** Plants with a large crop of fruit suddenly wilt, usually in hot weather in late spring or early summer. ***Some plants die within a week***, others survive for longer. Plants may die when cut back in late summer. If weather is hot and dry during autumn, a 2nd period of plant collapse may occur. ***Very susceptible varieties*** include Torrey and Tioga. Varieties with some resistance include Red Gauntlet and Naratoga.

See Vegetables M 9.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) causes lack of vigour and low yields. ***Roots*** are covered with small ***galls*** about 1 mm across and usually branch above the swellings and appear as a ***tangled mass***. See Vegetables M 10.

Foliar nematodes, strawberry bud nematode, strawberry crimp (*Aphelenchoides* spp.). See Ferns E 2.

Others: Dagger nematode (*Xiphinema*), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematode*** (*Helicotylenchus, Rotylenchus*), ***sheath nematode*** *(Hemicycliophora*), ***stem and bulb nematode*** (*Ditylenchus*), ***also*** *Filenchus, Paratrichodorus*, *Pseudhalenchus, Scutellonema*, *Tylenchorhynchus*, *Tylenchus*.

Only plant certified ***disease-free runners*** in ***nematode-free soil***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Strawberry aphid (*Chaetisiphon fragaefolii*) is small, white and sucks sap from ***leaf undersurfaces*** and ***stalks*** of new leaves. Plants may die. Strawberry aphid ***transmits*** some virus diseases of strawberry. Aphids excrete ***honeydew*** which is sticky and drips onto leaves and other parts of strawberry plants and is unsightly.

Others: **Cotton aphid** (*Aphis gossypii*), **green peach aphid** (*Myzus persicae*), **potato aphid** (*Macrosiphum euphorbiae*).

Natural enemies do not provide economic control or ***prevent transmission of virus diseases***. Insecticides may be necessary. See Roses J 4.

Bugs (Hemiptera)

Mirid bugs (Miridae): ***Grey cluster bug*** (*Nysius clevelandensis*) and ***Rutherglen bug*** (*N. vinitor*) are very similar in appearance. ***Adults*** are greyish, narrow-bodied, rectangular-shaped, and up to ***5 mm*** long. In dry seasons nymphs and adults sporadically migrate in spring into crops from drying weeds, eg sowthistle and capeweed. Clusters of bugs feeding on ***flower buds, flowers and young fruit*** can cause flower losses, poor fruit setting and ***fruit malformation***. Feeding on fruit makes it look dehydrated and ***seedy***. Fruit may be tainted and unfit for market. Large numbers of bugs at house lights indicate that invasion of crops is imminent. Flowers or fruit should be ***examined*** for presence of bugs and sprayed when critical numbers are reached (Brough et al. 1994). See Vegetables M 12.

Others: ***Strawberry bug*** (*Euander lacertosus,* Lygaeidae).

See Vegetables M 12.

Caterpillars (Lepidoptera) may be serious pests of strawberries.

Cluster caterpillar (*Spodoptera litura*) is a ***serious pest***, skeletonising ***leaf undersurfaces***. Mature caterpillars are solitary and damage ***flowers and fruit*** in spring and autumn. See Vegetables M 13.

Corn earworm (*Helicoverpa armigera*) is an ***important pest***. Caterpillars are up to ***40 mm*** long, pale green or cream initially, later yellow, green or red-brown with longitudinal stripes. They feed on ***young shoots and flowers*** and bore into ***young fruit*** (Fig. 169). ***Favoured*** by warm dry weather during spring and summer. See Sweetcorn M 89.

Cutworms (*Agrotis* spp.) are ***serious pests*** of ***strawberry runners***, severing stems of young heart leaves near ground level and eating holes in ***leaves and ripening fruits***. See Seedlings N 68.

Leafroller moths (Tortricidae) ***Ivy leafroller*** (*Cryptoptila immersana*) and ***lightbrown apple*** moth (*Epiphyas postvittana*) caterpillars are green and may damage ***young foliage*** in autumn. They feed from between ***webbed leaves, flowers and fruits***, wriggle furiously when touched or disturbed, often dropping off the leaf or plant on a silken thread. See Pome fruits F 112.

Looper caterpillars (*Chrysodeixis* spp.) feed on ***leaf undersurfaces*** chewing irregular holes. They are difficult to see as their colour resembles that of their food plant. Plants may be able to tolerate moderate defoliation without harm. See Vegetables M 13.

Caterpillars can be squashed if found during picking in a home garden situation ***Monitor*** plants for presence of caterpillars and damage. Only apply insecticide if numbers are likely to lead to economic loss (Brough et al. 1994). Ensure good coverage of whole plant especially ***flowers and fruit***. See Annuals A 8, Fruit F 8, Vegetables M 13.

Crickets, grasshoppers, locusts (Orthoptera)

Black field crickets (*Teleogryllus commodus*) are about ***25 mm*** long and dark brown or black. Adults are winged and have hind legs modified for ***jumping***. In dry spring weather they nibble ***green and ripening strawberries***. If numerous, removal of plastic mulching will reveal a network of runways used by the crickets. In the evening, the stridulation of the crickets can be heard. ***Monitor*** in autumn by listening for crickets singing at dusk before deciding to apply insecticide bait (Brough et al. 1994). See Turfgrasses L 9.

Mole crickets (*Gryllotalpa* sp.) are soft, light brown and up to ***30 mm*** long. Their front legs are broadly flattened to aid ***digging***. Only adults are winged. Unlike field crickets, mole crickets shelter by day and feed at night on young ***heart leaves***, cutting leaf stems near ground level. Plants can be severely set back early in the growth season. When weeds and grasses in inter-row spaces are killed in preparation for ratooning, crickets may feed on strawberry plants. Monitoring is impossible. Bait as for black field cricket. See Turfgrasses L 10.

Wingless grasshopper (*Phaulacridium vittatum*) are small, brownish grey grasshoppers about ***18 mm*** long. They chew small shallow holes in ***ripening fruits***. Treat borders around crop up to a distance of 20 m or more to reduce migration. See Vegetables M 14.

Mites (Acarina)

Cyclamen mite, strawberry mite (*Steneotarsonemus pallidus*) feeds on ***unopened leaves*** in crowns causing stunting and dwarfing of leaves, on ***flowers***, and cause ***fruit distortion***. Infestations are usually first detected by the puckered twisted appearance of older leaves. ***Monitor*** plants for mites before deciding to apply an insecticide (Brough et al. 1994). See Cyclamen C 16.

Flat mite (*Brevipalpus* sp., Tenuipalpidae) is a slow-moving, flat and dark red false spider mite which occasionally feeds on ***leaf undersurfaces*** and on leaf stalks in dry weather in summer. They do not spin a web. Eggs are bright red. Leaves are speckled and dried up if there are large numbers of mites. They do not usually cause much harm.

Redlegged earth mite (*Halotydeus destructor*) may be a problem on ***new plantings***. Their feeding causes bleaching of the ***leaves***. See Vegetables M 16.

Twospotted mite (*Tetranychus urticae*) and bean spider mite (*T. ludeni*) are the ***major pests*** of strawberries during winter, spring and early summer. Twospotted mite is numerically dominant. ***Other spider mites,*** eg ***banana spider mite***, strawberry spider mite (*T. lambi*) and ***European red mite*** (*Panonychus ulmi*) (does not occur in WA) may also infest strawberries. ***Leaf uppersurfaces*** become speckled and mottled due to mites sucking plant sap. Mites, their eggs and webbing, may be seen on leaf undersurfaces. Growth and cropping of plants may be retarded. Severely infested plants may die. ***Fruit skin*** may be scarified with seeds becoming prominent. In winter, mites tend to migrate into the strawberry crowns. ***Predatory mites*** (*Amblyseius womersleyi, Phytoseiulus persimilis*) are generally present on strawberry plantings. Twospotted mite is hard to control with ***insecticides*** because it readily develops resistance to them and overwinters in crowns where it is hard to reach with sprays. On strawberry only apply pesticides with a short withholding period. Predatory mites in conjunction with pesticides are used to control twospotted mite on strawberries in ***pest management programs***. *P. persimilis* must be reintroduced regularly. In USA it has proved effective on raspberry and other trellised berries. ***Monitor*** leaves for twospotted mites and predatory mites prior to releasing *Phytoseiulus persimilis* or applying a miticide. Runners may need to be dipped in miticide (Brough et al. 1994). See Beans (French) M 29.

Scarab beetles (Scarabaeidae, Coleoptera)

African black beetles (*Heteronychus arator*) in spring bore into ***ripening fruit*** lying on the ground and hollow them out from underneath. ***Stem bases and root crowns*** of young plants are chewed ragged. Tissues are teased out, causing plants to wilt and die. See Turfgrasses L 7.

Other scarab beetles, white curl grubs: Most commonly, larvae of ***Argentinian scarab*** (*Cyclocephala signaticollis*), ***canegrubs*** (*Lepidiota* spp.), ***Christmas beetle*** (*Anoplognathus porosus*), ***pruinose scarab*** (*Sericesthis geminata*), ***dusky pasture scarab*** (*S. nigrolineata*), ***rhopaea canegrub*** (*Rhopaea magnicornis*) may cause losses in ratooned strawberries. The white C-shaped larvae (up to 20/plant) can be seen in the soil amongst the roots (Fig. 170). Three or more larvae (*Repsimus* sp. and *Lepidiota* spp.) per plant will cause plants to be unthrifty (Brough et al. 1994). ***Larvae*** are white, plump, C-shaped grubs about 50 mm long with hard, brown heads and strong jaws. They eat off ***roots*** up to the crown. Plants stop growing and in dry weather wilt and die and are easily pulled from the soil. Larvae feed along the beds and generally a few adjacent plants are affected. ***Adults emerge from the soil*** during November and December and lay eggs in areas being prepared for planting. Young larvae begin feeding on the roots late in the next spring after the crop has been harvested. ***Favoured*** by crops close to eucalypt trees that beetles have fed on, or if the crop is planted in land that was recently under pasture, or strawberry beds which have been heavily mulched with bush litter (eggs or larvae appear to be introduced with the litter). There is no effective control for established infestations. ***Prevent infestation by careful land preparation.*** Long crop rotations with non-host plants assist control. Thorough pre-plant cultivation will expose larvae to birds and mechanically injure them so they die. Pre-plant incorporation of an insecticide on to plantings intended for ratooning may protect plants. If damage is obvious before the end of April remove damaged plants, manually kill any white grubs found in root zone and replant with fresh runners. If beetles are moving in from nearby pasture land, ***baits*** may be scattered in deep steep-sided furrows ploughed around the crop. ***Insecticides*** gives some protection of young plants but it is difficult to achieve satisfactory control in beds mulched with plastic. Losses of fruit can be reduced by scattering baits lightly through the crop, ***taking care not to contaminate fruiting plants***. Fungal diseases may exert some control.

See Eucalypt K 61, Trees K 16, Turfgrasses L 11, Vegetables M 16.

Slaters, woodlice (Crustacean) may damage ***ripe strawberries*** or further damage those attacked by other pests. Slaters only attack fruit in contact with the ground. Reducing contact with ground will normally prevent damage. Pesticides are generally not necessary. See Greenhouses N 27.

Thrips (Thripidae, Thysanoptera)

Plague thrips (*Thrips imaginis*) feeding on ***flowers***, may result in no fruit or malformed ***fruit***. In dry years thrips invade crops from other drying hosts. ***Monitor*** flowers for thrips prior to applying an insecticide. Apply spray late in afternoon when bee activity is low (Brough et al. 1994). See Fruit F 12, Roses J 6.

Strawberry thrips (*Scirtothrips dorsalis*) feed on ***younger leaves*** causing crimping, and on ***fruit*** causing rusting, cracking and reduced size.

Weevils (Curculionidae, Coleoptera)

Black vine weevil, European strawberry weevil (*Otiorhynchus sulcatus*) larvae feed on strawberry ***roots***. See Grapevine F 63.

Fuller's rose weevil (*Asynonychus cervinus*) during late summer/autumn may chew ***leaf edges*** giving them a saw-toothed appearance. See Roses J 6.

Spotted vegetable weevil (*Desiantha diversipes*) feeds on ***stems, leaves and runners*** in spring and autumn. Larvae feed on ***roots***. See Vegetables M 17.

Strawberry weevil (*Rhinaria perdix*) may be a ***serious pest*** of strawberries. ***Weevils*** are about ***8 mm*** long, have a short snout above which are two flattened horn-like processes between the black eyes. They are a variegated red-brown and white, are active and run about the foliage; when disturbed they drop to the ground or hide under leaves. They fly readily. Eggs are laid in the crown in late spring or early summer and hatch in about 6 weeks. ***Larvae*** hollow out ***crowns*** and tunnel in ***leaf stalks and roots***. ***Leaves, flowers and fruit*** are chewed. Damage leads to invasion by fungi and plants may die. They pupate in a hollowed-out space or in the soil nearby. ***Overwinters*** as pupae. Weevils emerge in spring.

Whitefringed weevil (*Graphognathus leucoloma*) may attack ***foliage***. ***Larvae*** are thick, white, legless with brown heads. They gouge and channel ***roots*** and attack ***runners***. Autumn planted runners may be damaged by larvae feeding in spring. Injured plants turn purple and growth stops. See Vegetables M 17.

Others: Rough strawberry weevil (*Otiorhynchus rugosostriatus*), ***thin strawberry weevil*** (*Rhadinosomus lacordairei*).

Control of weevils is difficult. See Vegetables M 17.

Others: ***Black strawberry beetle*** (*Clivina tasmaniensis*, Carabidae), ***redshouldered leaf beetle*** (*Monolepta australis*) may swarm on to strawberry crops, ***citrus mealybug*** (*Planococcus citri*) is only important in ratooned crops.

SNAILS AND SLUGS

Slugs and snails feed on ***new growth, flowers and fruit***. One slug may damage several berries. Damaged fruit are susceptible to fruit rots. One ***brown slug*** (*Deroceras parnormitanum*) per 50 m row indicates that treatment is required (Brough et al. 1994). See Seedlings N 70.

VERTEBRATE PESTS

Birds and ***native animals***, eg goannas, may feed on strawberry ***fruit***. See Fruit F 13.

Non-parasitic

Environment: Plants must be protected from ***frost*** which damages flowers, and hot drying winds. During hot weather plants wilt but generally recover at night. Although strawberries need a sunny position, the fruit of summer crops may be ***sunburnt***, so that shade or evaporative cooling in the form of a fine mist of water may need to be provided. Extreme temperatures ***postharvest*** is the most common cause of loss of product quality and is due to failing to remove heat from berries immediately after picking. Strawberry plants have ***shallow roots*** so adequate water must be provided during summer. However, plants will not tolerate ***waterlogging.*** When roots are few and brown, do not overwater, particularly on heavy or poorly drained soils; waterlogging from natural rainfall can be reduced by building beds 150-200 mm high.

Mechanical injury to berries can occur ***postharvest*** during picking, packing, transport and marketing, eg crushing during handling.

Nutrient deficiencies, toxicities: ***Fertiliser burn*** is caused by over-use of ***soil-applied*** organic and mineral fertilisers, particularly ***nitrogenous*** fertilisers. It usually occurs within 2 months after planting. Fertiliser burn may cause marginal or complete burning of ***leaves***, plant collapse and ***root death***. ***Foliar fertilisers*** may kill flowers, burn fruit and scorch young leaves. Nitrogenous fertilisers should be applied sparingly and not at all if soil is fumigated. Avoid mixing foliar fertilisers with other sprays or using wetting agents. ***Leaf analysis standards*** are available for strawberry crops based on diagnostic and research analyses (Weir and Cresswell 1993).

Others: ***Phyllody:*** Green leafy outgrowths from ***seeds*** are extensions of the seed coat occurs on the first flush of fruit in spring. Affected fruit either does not ripen or ripens unevenly. Later fruit is normal. Cambridge Vigour is very susceptible, Torrey very rarely. ***Slime moulds*** (*Diachea leucopoda*) cover leaves and petioles forming ***black spores*** 0.5-1 mm across on white stalks 1-2 mm long. It commences as a jelly-like material which lives on dead organic matter on the ground and flows up any suitable object to produce spores. Favoured by wet weather in late spring and autumn. No control is needed. ***Springtails*** are found in strawberries in holes made by slugs or snails.

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Biological Control of Spider Mites in Strawberries (Video Qld DPI)
Fungal Leaf spots of Strawberries (NSW Agfact)
Growing Strawberries in Southern Victoria (Vic Agnote)
Insect Pests of Berry Fruits (NSW Agfact)
Pesticide Usage on Strawberries (Vic DARA)
Pests and Diseases of Strawberries (WA Farmnote)
Pests of Strawberries (NSW Agfact)
Strawberry Disease Control Guide (NSW Agfact)
Strawberry Fertiliser Guide (NSW Agfact)
Strawberry Growing (NSW Agfact)
Strawberry Management Calendar (Qld Farmnote)
Strawberries : Pest and Disease Control (NSW Agnote, Vic Agnote)
Strawberries : Weed Control (NSW Agfact)
The Victorian Strawberry Runner Certification Scheme (Vic Agnote)
See District Spray Calendars.

Association, Journals etc.

Australian Berryfruit Growers Federation.,
Farmers Information Centre, Qld DPI, Nambour
Good Fruit and Vegetables
Hydroponic Conferences
National Berryfruit Seminars
Qld Approved Strawberry Runner Scheme
Strawberry Growers Assoc. of NSW
Strawberry Growers Assoc. of WA
Toolangi Strawberry Growers Co-op.
Vic Strawberry Growers Assoc.
Vic. Strawberry Industry Development Committee

See Fruit and nuts F 15

Remember, always check for recent references

MANAGEMENT

An overview of the industry is presented by Coombs (1995). There are many different cultivars. Strawberries are subject to a wide range of diseases and pests affecting the fruit, leaves and roots and their correct ***identification*** is essential. ***Integrated pest management (IPM)*** is available for strawberries for before planting, during crop growth and for all postharvest stages (Broadley (ed.) 1992, Vock 1991). Some diseases and pests require specific treatments but their control has to be considered as part of the pest management program. For example, aphid control should be integrated with control of twospotted mite as many insecticides also kill its predators, resulting in a rapid buildup of twospotted mite. Because strawberries are attacked by a large number of diseases and pests, there is high pesticide usage and ***IPM*** is difficult (Cooley et al. 1996). ***Select cultivars*** of ***proven performance*** and ***suited to the area*** in which they are to be grown and for the ***intended market***. Some varieties have some ***resistance*** to anthracnose, leaf blight (*Phomopsis*), tan rot, various crown rots, powdery mildew, foliar nematodes and rain damage. Commercial growers should only plant ***disease and pest-free strawberry runners*** obtained from a certified runner grower. Runners may be fresh or cool stored. Do not plant diseased runners. Home gardeners should replant every 2-3 years. Strawberries are often grown ***hydroponically*** in Australia. Choose a system that has a proven commercial record (Donnan 1993). ***Propagated*** by runners, some of the newer varieties are covered by ***patents***. ***Pre-plant soil treatments***, eg fumigation, are a principle method of controlling root and crown diseases and pests together with persistent weeds. ***Cultural methods:*** Do not plant too deeply as crowns may rot. Water supply must be regular for good berry production. Good drainage is essential. Avoid overhead watering or if this is unavoidable, water at the time of day that allows quick drying of leaves and fruit. ***Sanitation:*** Remove and destroy new runners formed as plants grow, allowing them to remain decreases fruit production. ***Biological control agents*** are available for twospotted mites. Routine ***pesticide*** applications for insect pests, grey mould, leaf spots and other problems may be required. Apply additional sprays after cutting back and in autumn to help control *Gnomonia* fruit rot and leaf spots. Avoid spraying when bees are active. ***Control weeds*** in pathways by using mulch, eg sawdust, wood shavings or straw. See Fruit F 14. Mulching with black polythene sheeting is widely used in beds, so weeds are not a serious problem. ***Pre- and post-emergence herbicides*** must only be applied at the correct growth stage of the strawberry crop (avoid spray drift onto strawberry plants and runners). Strawberries are one of the ***most fragile and perishable*** of all fruits and must be ***harvested,*** handled, stored and marketed with great care. This includes attention to ***refrigeration, packaging and grading*** according to various regulations and standards, eg at least 3/4 of the surface of each fruit must be red. ***Labelling, transport, and observance of quarantine regulations*** is essential, eg fruit entering WA is subject to restrictions for European red mite and entry to Tasmania is prohibited.

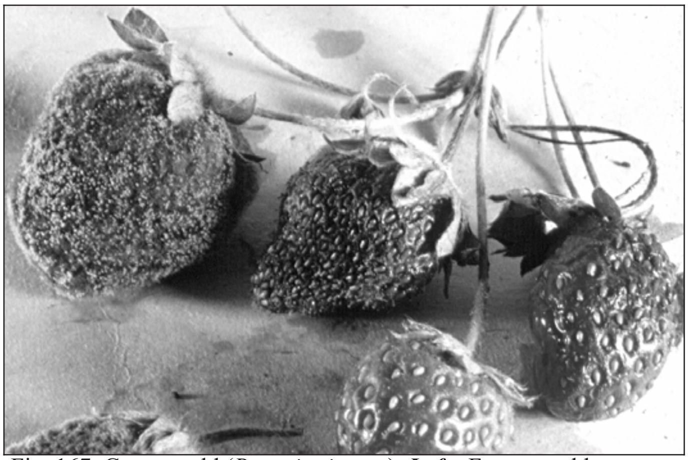

Fig. 167. Grey mould (*Botrytis cinerea*). ***Left :*** Furry mould on infected fruit. ***Right :*** Healthy fruit.

Fig. 168. Black spot (*Mycosphaerella fragariae*) on leaves.

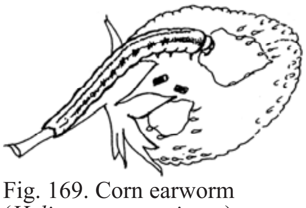

Fig. 169. Corn earworm (*Helicoverpa armigera*) up to 40 mm long, feed on fruit.

Fig. 170. Larvae (up to 50 mm long) of scarab beetles (Scarabaeidae) eat roots of plants up to the crown.

Trailing berries

Rubus spp.
Blackberry (*R. fructicosa*)
Boysenberry, loganberry, youngberry (*R. occidentalis*)
Raspberry (*R. idaeus*)
Family Rosaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Anthracnose, bitter rot, cane spot
  - Downy mildew, dryberry
  - Fruit rots
  - Fungal leaf spots
  - Grey mould (*Botrytis*)
  - Root and stem rots, wilts
  - Rusts
  - Spur blight
- **Nematode diseases**
- **Insects and allied pests**
  - Bugs
  - Caterpillars
  - Sawflies
  - Scales
  - Thrips
  - Twospotted mite
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases may ***seriously reduce yield***.

Raspberry bushy dwarf virus infects raspberry causing ***leaf*** mosaic, veinbanding and yellow, crumbly ***unsaleable fruit*** in some cultivars. Symptoms are most obvious in early spring (latent in Lloyd George). Plants infected with mixtures of bushy dwarf and other viruses may produce a few stunted canes and reduced fruit quality. Fruit may be late. ***Spread*** by cuttings, by pollen and by seed. ***Susceptible varieties*** include those originating from Lloyd George. Willamette seems ***resistant*** to Australian isolates.

Tobacco streak virus affects loganberry, youngberry, dahlia, *Melilotus*, *Phaseolus vulgaris*, *Soya max*, *Trifolium pratense*, *Rosa steigera,* tobacco, asparagus. ***Yield*** is affected only in combination with other viruses. ***Spread*** by grafting, by seed (of some plants to a variable degree), by pollen to the pollinated plant, not by contact between plants. ***Onion thrips*** (*Thrips tabaci*) and ***western flower thrips*** (*Frankliniella occidentalis*) aid its spread by carrying pollen.

Others: Possibly apple chlorotic mottle. Australia is free of the aphid vectors of the major virus diseases. Boysenberry decline mycoplasma is spread by the boysenberry leafhopper in NZ.

Select ***resistant varieties*** and plant ***virus-tested planting material*** from a raspberry certification scheme. See Fruit F 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) occurs on raspberry and loganberry. Large galls develop on ***stems*** just below ground level. Only serious on young plants. See Soil N 84 (Fig. 448), Stone fruits F 125.

FUNGAL DISEASES

Anthracnose, bitter rot, cane spot, spot anthracnose (*Elsinoe veneta*) is the ***most serious disease*** of trailing berries, especially loganberries, also raspberries. Grey sunken spots 1-3 mm in diameter with purple margins appear on ***canes***. Spots may join together killing large areas of bark. Spots may occur on ***leaves***. ***Yield*** may be reduced. Anthracnose ***overwinters*** on fruiting canes, old fruited canes and fallen leaves. Spores are ***spread*** by wind. ***Remove and burn*** old fruiting canes and severely infected young canes. Raspberry variety Lloyd George is ***very susceptible***. ***Fungicides*** may be applied at green-tip and white-bud stages. See Fruit F 5.

Downy mildew, dryberry, splitberry (*Peronospora sparsa*) affects brambles (blackberry, boysenberry, loganberry, youngberry), raspberry, rose. Red blotching occurs on ***leaf uppersurfaces*** along midrib and lateral veins. On the ***lower surface*** beneath the blotches, ***white downy spores*** develop in moist weather. Infected new leaves are distorted. Loganberries do not redden, but just yellow and dieback. Unless spores are present it is difficult to identify the disease. ***Suckers*** may be weak and have red staining that can be traced to infected leaves. ***Berries*** become dull (oily), shrivelled and hard (dryberry); they redden prematurely, and may split into 2 parts, one or both being shrivelled (splitberry). ***Overwinters*** as mycelium inside roots, crown and canes. In spring when sucker growth starts it keeps pace with apical shoot growth, infecting stems and unfolding leaves. ***Spread*** by vegetative propagation, by spores (from first infected leaves by wind to other leaves, flowers and fruit) and by internal fungal growth within plants. ***Favoured*** by overhead irrigation and wet weather at 18^{o}C. Remove or chemically control suckers regularly; control weeds to reduce humidity. Trailing berries are ***very susceptible***, some raspberry varieties have ***some resistance***. Only propagate from ***disease-free plants*** protected from systemic infections by spraying. A ***fungicide*** program is usually necessary. See Annuals A 5.

Fruit rots: ***Brown rot*** (*Sclerotinia fructicola*), ***grey mould*** (*Botrytis cinerea*), ***mucor soft rot*** (*Mucor* sp.), ***rhizopus soft rot*** (*Rhizopus* sp.) (Beattie et al. 1989). See Fruit F 5.

Fungal leaf spots (*Ascochyta, Cercospora*, *Cylindrosporium, Phoma*, *Schiffnerula, Septoria*). ***Anthracnose*** (see above) may also cause leaf spotting. See Annuals A 5.

Grey mould (*Botrytis cinerea*) is a ***major disease*** of trailing berries. It rots ***buds*** and ***berries*** of loganberries and raspberries, especially in the ***field*** and ***postharvest*** during moist weather. See Fruit F 5, Greenhouses N 22.

Root and stem rots, wilts

White root rot (*Vararia* sp.) is a ***serious disease*** of raspberry (less seriously loganberry, wild blackberry). Its white mycelium spreads over ***rootstock***. Plants yellow, canes dieback. ***Spread*** by infected planting material. ***Favoured*** by dry soils. Water canes during late summer/early autumn. Before replanting treat soil.
Others: ***Armillaria root rot*** (*Armillaria* spp.), ***sclerotium stem rot*** (*Sclerotium rolfsii*), ***verticillium wilt*** (*Verticillium* sp.)

See Vegetables M 7.

Rusts (Uredinales, Basidiomycetes)

Blackberry leaf rust (*Phragmidium violaceum*) affects some ***cultivated trailing berries,*** eg Thornless Evergreen, and wild blackberry (*R. fructicosus*). ***Leaf undersurfaces*** develop ***yellow spore masses*** which turn ***dark brown*** with age and with cooler weather. Uppersurfaces have large purple blotches. Leaves may fall prematurely, cane growth weakened and fruit yield reduced. Many cultivars of cultivated trailing berries have some ***resistance***. It has been researched as a possible biological control agent for wild blackberry.
Cane and leaf rust (*Kuehneola uredinis*) affects some ***cultivated trailing berries,*** eg boysenberry, loganberry, youngberry, Thornless Evergreen, some *Rubus* hybrids and wild blackberry (*R. fructicosus*), but not raspberry. ***Symptoms*** similar to blackberry leaf rust except that ***spores masses*** turn ***buff or white*** with age. ***Stems*** are also attacked.
Yellow rust (*Phragmidium rubi-idaei*) only attacks ***raspberry***, some cultivars, eg Glen Clova, Lloyd George, are very susceptible, also native mountain raspberry (*R. gunnianus*) in Tasmania. ***Symptoms*** are similar to those of blackberry leaf rust. ***Leaves*** fall prematurely, yield is reduced and ***young canes*** may die. Use ***resistant cultivars***.
Others: ***Rust*** (*Phragmidium barnardi*) attacks native *R. parvifolius*, introduced cutleaf blackberry (*R. lacinatus*), native Tasmanian mountain raspberry (*R. gunnianus*) and possibly other *Rubus* spp.

See Annuals A 7.

Spur blight (*Didymella applanata*, Ascomycetes) ***commonly*** affects raspberries and loganberries killing ***buds*** and destroying ***spurs or laterals*** on canes. ***Berries*** may be affected. During late summer and autumn red-brown shield-shaped areas spread around the base of leaves and buds on 1st-season canes. Infected areas become silvery-grey with age, tiny black dots (fruiting bodies) appear on their surfaces. Buds that should produce fruiting arms die but the canes normally survive. Spores are ***spread*** by wind. ***Space plants*** to allow plenty of sunlight for quick drying of foliage and canes. ***Remove and burn*** all infected canes after harvest. ***Fungicides*** may be applied at green tip and white bud stages. ***Other fungi may damage canes*** including ***stem scab*** (*Seismatosporium licchenicola*), ***raspberry cane blight*** (*Leptosphaeria coniothyrium*).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) and ***root lesion nematodes*** (*Pratylenchus* spp.) can cause serious damage to raspberry, and *R. ursinus* var. *loganobaccus, R. ursinus.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Bugs (Hemiptera): ***Grey cluster bug*** (*Nysius clevelandensis*) and ***Rutherglen bug*** (*N. vinitor*) suck sap from ***foliage*** and ***developing berries*** leaving them malformed. See Vegetables M 12.

Caterpillars (Lepidoptera)

Leafroller moth (Tortricidae) caterpillars feed on ***foliage and berries*** from under webbed shelters.
Ivy leafroller (*Cryptoptila immersana*)
Lightbrown apple moth (*Epiphyas postvittana*)
Raspberry fruit caterpillar (*Lobesia* sp.)
See Pome fruits F 112.
Loopers (Geometridae): ***Twig looper*** (*Ectropis excursia*) attacks raspberries and brambles.
Raspberry bud moth (*Carposina adreptella*, Carposinidae) caterpillars bore into ***buds, flowers*** and ***berries*** of raspberry. Prune as early in autumn as possible and burn the prunings.
Others: ***Common splendid ghost moth*** (*Aenetus ligniveren*) caterpillars may feed in raspberry canes. ***Fiery jewel*** (*Hypochrysops ignitus ignitus*) caterpillars feed on foliage of blackberry.

See Annuals A 8, Fruit F 8.

Sawflies (Hymenoptera)

Bramble sawfly (*Philomastix macleaii*, Pergidae) larvae ***defoliate*** cultivated and wild loganberry and blackberry. ***Sawflies*** are stout yellow-brown, about ***10-15 mm*** long with yellowish wings with a dark band across each forewing. Females lay eggs in slits in leaf tissue. ***Larvae*** have large heads and 2 long thin structures at the end of the body (Hely et al. 1982).
Raspberry sawfly (*Priophorus morio,* Tenthredinidae) larvae feed on ***leaf undersurfaces*** of raspberry and blackberry. They chew between the main veins and pupate between leaves or in soil. ***Sawflies*** are ***6 mm*** long, black with whitish legs. Eggs are laid in canes or leaf stalks. ***Larvae*** are about ***12 mm*** long, yellow with a brown band along the back.

If there are only a few larvae, hand pick or cut off shoots on which they are feeding. If necessary spray when seen. See Eucalypts K 63, Trees K 16.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Rose scale*** (*Aulacaspis rosaeus*) attacks older and mature ***canes*** and, if infestations are neglected, younger canes. Canes may die. See Roses J 7.
Soft scales (Coccidae): ***Frosted scale*** (*Eulecanium pruinosum*), ***soft brown scale*** (*Coccus hesperidum*). See Citrus F 41.

Thrips (Thysanoptera): ***Plague thrips*** (*Thrips imaginis*) may infest ***flowers*** of boysenberry and raspberry in spring, preventing drupelet development and causing fruit malformation. Control is difficult. See Fruit F 12.

Twospotted mite (*Tetranychus urticae*) may suck sap from ***leaves and fruit*** of raspberry and brambles. See Beans (French) M 29.

Others: ***Aphids*** (Aphididae) may damage new growth, ***driedfruit beetles*** (*Carpophilus* spp.) attack ripe fruit, ***leafhoppers*** (Cicadellidae, Hemiptera) may suck sap from leaves causing them to become speckled (minor damage), **wingless grasshopper** (*Phaulacridium vittatum*) damages lower branches. Also **root weevils**, eg black vine weevil (*Otiorhynchus sulcatus*), **scarab beetles** (Scarabaeidae, Coleoptera).

SNAILS AND SLUGS

Snails may climb up canes and feed in the bushes. ***Leaves*** develop holes. See Seedlings N 70.

VERTEBRATE PESTS

Birds enjoy the fruit, especially of loganberries and raspberries. See Fruit F 13.

Non-parasitic

Environment: Mid-to-late spring ***frosts*** may damage young growth. ***High temperatures and intense solar irradiation*** may result in white drupelets, cultivars vary in susceptibility. Hot dry ***winds*** may snap fruit-bearing side shoots and dry out berries. Trailing berries have shallow roots, protect from ***drought*** by irrigating appropriately.

Nutrient deficiencies, toxicities: ***Iron or manganese deficiency*** may occur. Raspberries are sensitive to a build up of ***salt*** in soil. ***Leaf analysis standards*** are available for raspberry crops based on diagnostic and research analyses (Weir and Cresswell 1993).

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Insect Pests of Berry Fruits
Pruning and Training Cultivated Blackberries
Raspberry Growing in NSW
Trailing Berry and Bush Fruits in the Garden
NZ Aglink Min. Ag. & Fish. leaflets
Brambles : Pests and Diseases
Brambles : Weeds and Disease
Tas Farmnotes
Weed Control During Site Preparation for Berry Fruit Plantations
Weed Control : Raspberries
Vic Agnotes
Commercial Raspberry Growing in Southern Victoria :
Pruning and Training
Site, Selection and Costs
Varieties and Site Preparation
Cultivated Blackberries :
Establishment and Management
Raspberry Growing in Southern Victoria :
Cane Management
Harvesting
Heritage for Autumn Crop
Irrigation and Weed Control
Site Selection and Soil Preparation
Raspberry : Pest and Disease Control
Raspberry Root Rots in Victoria
Raspberry Varieties
Rust Diseases of Rubus Species in Victoria
Trellising Loganberries
WA Farmnotes
Growing Raspberries and Brambleberries
Loganberry : Propagation and Planting
See Fruit and nuts F 15

MANAGEMENT

Raspberries and trailing berries prefer cool winters for uniform bud break, cool summers and rain-free harvest. They need a sunny position protected from hot afternoon sun, a good supply of water in summer and when fruit is filling. Boysenberries, loganberries and youngberries will ***tolerate more heat*** than raspberries. Select raspberry varieties ***resistant*** to raspberry bushy dwarf, *Phytophthora* and white root rot (*Vararia* sp.). Purchase ***virus-tested planting material*** through a Raspberry Certification Scheme. ***Propagated*** by cuttings or burying the tip of new canes in summer and autumn to a depth of about 150 mm. They grow on a variety of soils, but drainage must be good. Eradicate perennial weeds prior to planting. Fruit develop on shoots which develop from 1-year old canes. Canes die after fruiting so should be ***pruned*** out each winter and burnt to eliminate sources of fungal infection. Well-grown trailing berries will bear well for up to 15 years. Spray guides are available for particular regions. ***Harvest:*** When fruit is close to optimum eating quality as it does not ripen further after picking. Trailing berries ***do not transport or store well***. Cool store immediately. An overview of the industry has been presented by Coombs (1995).

Walnut

English, European, Persian walnut (*Juglans regia*)
Family Juglandaceae (walnut family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Cherry leafroll virus, walnut black line is only known to occur on elders (*Sambucus* spp.) in Australia. Overseas it also occurs on cherry and walnut. On walnut, there is an incompatibility between *J. regia* and rootstocks of *J. hindsii* and Paradox, the cause is unknown. See Fruit F 4.

BACTERIAL DISEASES

Bacterial blight, walnut blight, walnut black spot (*Xanthomonas campestris* pv. *juglandis*) is the ***only serious disease*** of walnuts and > 50% of a crop may be lost. Disease first appears as small irregular shaped black spots on ***leaves*** and petioles (Fig. 171). Sunken black cankers develop on ***shoots up to 1 year of age*** and may girdle them causing dieback of twigs. Black sunken areas develop on green ***nuts***, which may shrivel and die. Nuts infected later may have stained and rotted kernels and fall. Nearly ripe nuts may develop large black spots. Bacteria ***overwinter*** in infected buds, twigs and old nuts left on trees, also in fallen leaves (not an important source of infection). Bacteria are ***spread*** by rain splash and possibly by insects, eg walnut blister mite, by the introduction of infected nursery stock. ***Favoured*** by frequent rain, frost or hail damage just before and during blossoming, poor cultural conditions, eg inadequate irrigation. ***Control*** is difficult and on susceptible varieties must be carried out while trees are young, otherwise it is difficult to contain. ***Avoid overhead irrigation*** of young plants in spring. Keep plants in good cultural condition. ***Prune out*** severely infected shoots (at least 100 mm below diseased areas) as soon as they develop during the growing season when they are easy to see. This reduces the amount of inoculum the following spring. During winter prune off and burn dead twigs and old nuts. Plant varieties with some ***resistance***, eg Concord, Eureka, Wybalaena and Franquette (the most widely grown commercial variety). Freshford Gem, and Kelvin are ***very susceptible***. The thin shell of Wilson's Wonder is easily damaged by bacterial blight but may be disease-free in warmer climates. Seedling trees seem to be ***more susceptible*** than grafted ones. It is difficult to detect bacterial blight on ***dormant nursery stock***. Reject plants with dead shoot tips. In Australia, only non-systemic copper ***fungicides*** are registered for use. Overseas, the systemic antibiotic streptomycin is used either on its own or mixed with copper. ***In commercial orchards*** of susceptible varieties or where disease is a problem, apply routine protectant sprays during bud burst especially when trees are young. Spray tops of trees thoroughly to prevent reinfection of lower parts. Home gardeners should not spray trees > 3 m tall. See Stone fruits F 124

Crown gall (*Agrobacterium* spp.) which is only serious on nursery stock causes large galls at or just below ground level on the main root. ***Susceptible species*** include English walnut (*J. regia*) and the hybrid Paradox (*J. hindsii* x *regia*). Northern Californian black walnut (*J. hindsii*) is ***more resistant***. See Stone fruits F 125.

FUNGAL DISEASES

Branch and trunk cankers: Several fungi may cause minor cankers on trunks and branches with resulting ***dieback***, eg *Botryosphaeria ribis*, *Diplodia juglandis*, eutypa canker (*Eutypa armeniacae*). See Trees K 5.

Fungal leaf spots

Yellow leaf blotch, downy spot, white mould (*Microstroma juglandis*, Imperfect Fungi) is a minor disease of walnut, overseas also pecan and hickory. Yellow blotches develop on ***leaf uppersurfaces*** and a snow-white coating of spores occurs on the ***underside***. Leaves may fall prematurely. In orchards where copper sprays are used for bacterial blight in spring, this disease should not occur. Where disease occurs, gather and destroy or bury fallen leaves.

Others: *Gnomonia leptostyla*, *Marssonina juglans.*

See Annuals A 5.

Root and collar rots

Armillaria root rot (*Armillaria* spp.): Walnuts on Californian black walnut (*J. hindsii*) rootstock are ***resistant*** provided trees grow vigorously and root damage is avoided. English walnut (*J. regia*) and hybrid Paradox (*J. hindsii* x *regia*) are ***susceptible***. If *Armillaria* is present in soil, diseased trees should be removed and replaced with trees on Calfornian black walnut (*J. hindsii*) rootstock. See Trees K 4.

Phytophthora collar and root rot (*Phytophthora* spp.) has a white mouldy appearance in the ground and can move up into the centre of the tree causing it to fall over in a few years. California black walnut (*J. hindsii*) rootstock is ***very susceptible***, black walnut rootstock (*J. regia*) and hybrid Paradox (*J. hindsii* x *regia*) are ***more resistant***. See Trees K 6.

Others: ***Anthracnose*** (*Glomerella cingulata*), ***fruit spots*** (*Colletotrichum acutatum*), ***powdery mildew*** (*Phyllactinia guttata*). Various ***wood rotting fungi*** may invade weakened walnuts, eg ***yellow heart rot*** (*Schizophyllum commune)*.

NEMATODE DISEASES

Dagger nematodes (*Xiphinema* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* spp.), *Merlinius* have been recorded on *J. regia* (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Mites (Acarina)

Spider mites (Tetranychidae): ***European red mite*** (*Panonychus ulmi*) damages ***leaves***. Economic loss may occur on nursery stock and it may be necessary to apply a miticide. See Fruit F 12. ***Twospotted mite*** (*Tetranychus urticae*) feeds on ***leaves*** causing a sandy mottle. See Fruit F 12.

Walnut blister mite (*Eriophyes tristriatus,* Eriophyidae) sucks sap from ***leaf undersurfaces*** resulting in ***felty areas on undersurfaces*** and ***corresponding blisters on uppersurfaces*** (Fig. 172). Heavily infested leaves may be distorted and fall, but this is uncommon. Control measures are not generally recommended. See Grapevine F 62.

Walnut pinhole borer (*Diapus pusillimus,* Curculionidae, Coleoptera): Pinhole borers (ambrosia beetles) attack ***moist wood***, usually as logs in the forest and millyard but once the log has been converted to sawn timber their activity ceases and only holes in the wood remain to affect at the worst, its appearance. They do not re-infest timber and no treatment is required. See Trees K 10.

Others: ***Codling moth*** (*Cydia pomonella*) very occasionally attacks developing nuts, also ***fruit flies*** (Tephritidae) and ***twig looper*** (*Ectropis excursiana*). ***Vegetable weevil*** (*Listroderes difficilis*) can severely damage young trees planted in old vegetable areas. Adults climb trees in September-January chewing leaves and young bark which then turns black. Young trees may die.

VERTEBRATES

Rabbits and hares can attack young trees. ***Birds***, particularly cockatoos, and ***possums*** will attack and eat the nuts. See Fruit F 13.

Non-parasitic

Delayed graft union failure may occur in California black walnut (*J. nigra*).

Environment: Late spring ***frosts*** may damage flowers and young shoots. Choose varieties, eg Franquette, that flowers and comes into leaf late. High temperatures in summer can ***burn*** nuts and trunks. Although walnut trees are deep rooting, approximately ***75% of their water requirements*** is taken from the top **2 m** of soil. For maximum growth and production, the top 2 m of soil should not be allowed to ***dry out*** during the 6 weeks following flowering otherwise nut quality will be reduced. ***Hot, strong winds*** may cause leaf scorch and leaf fall, but do not appear to reduce yield. Wind may affect the training of the tree.

Juglone toxicity: Black walnut (*J nigra*) releases a chemical ***(juglone)*** from the roots during the growing season that is toxic to many plants. Plants growing near black walnut trees may suddenly wilt or yellow and die during the growing season. Plants growing near the ***roots*** within the drip line have a ***discoloured vascular system*** and are often killed. ***Susceptible woody plants*** include apple, pear, pine, rhododendron and sour cherry. Juglone does not persist in the soil over winter so sensitive species can be planted in the same site a year after black walnut has been removed.

Nutrient deficiencies, toxicities: ***Boron deficiency*** symptoms include weak, twisted shoots with abnormal, often yellow leaves. English walnut (*J. regia*) rootstocks are thought to be more tolerant to free ***lime*** in the soil. Walnuts have a high demand for nitrogen and phosphate. ***Standards*** based on diagnostic leaf analyses are available for walnuts (Weir and Cresswell 1993).

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Growing Walnuts (Vic Agnote)
Pests and Diseases of Walnuts (Vic Agnote)
Propagation of Walnuts (Vic Agnote)
Sites, Layout and Irrigation for Nut Orchards (WA Farmnote)
Walnut Blight (NSW Agfact)
Walnut Growing (NSW Agfact)
Walnuts in the Garden (NSW Agfact)

Association, Journals etc.
Australian Nutgrower (Jn.)
Australian Nut Industry Council (ANIC)
Australian Walnut Industry Assoc. (AWIA)
International Walnut Research Network
Walnut Council Bulletin (Black walnut) USA
West Australian Nut and Tree Crops Assoc. (WANATCA)

See Fruit and nuts F 14

MANAGEMENT

Remember, always check for recent references

Walnuts have similar chilling requirements to apple so they do not do well in mild coastal climates. Walnuts carry their male and female flowers separately on the same tree. In most varieties male flowers appear before the female flowers and particularly in young trees pollen may be shed before the female stigma is receptive. Fruit set is therefore improved by cross pollination by another variety. High fruit set is essential for good yields, as walnuts, especially the older varieties, have relatively few female flowers. Pollen is distributed by wind. Choose varieties with ***some resistance*** to local problems, eg Franquette to bacterial blight; California black walnut root stock (*J. hindsii*) has some resistance to *Armillaria* root rot but is susceptible to *Phytophthora* root rot. Plant ***bacterial blight-free*** nursery stock. ***Propagate*** by grafting, seed and tissue culture. Grafted varieties will be more reliable croppers than seedling trees. Plant in rich, deep soils with good drainage and apply appropriate fertiliser regimes. ***Harvest*** at the appropriate time by hand or by mechanical harvester, collect and clean, then ***dry*** for 3-4 weeks in a well ventilated room. An overview of the industry is presented by Coombs (1995).

Fig. 171. Bacterial blight (*Xanthomonas campestris* pv. *juglandis*).
Above : Small irregularly-shaped black spots on leaves.
Above right : Black sunken areas on green nuts, whole nuts may blacken and rot.

Fig. 172. Walnut blister mite (*Eriophyes tristriatus*) sucks sap from leaf undersurfaces amongst felty hairs, areas on uppersurface above the hairs are blistered.

Orchids

Fig. 173. Orchid viruses.
Left : Symptoms of odontoglossum ringspot virus.
Right : Symptoms of cymbidium mosaic. Dept. of Agric., NSW

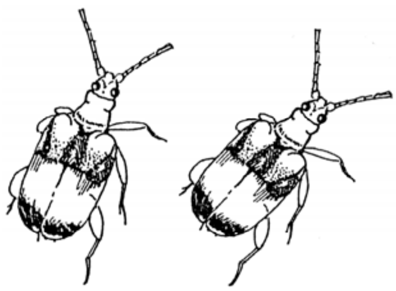

Fig. 174. Orchid beetles (*Stethopachys formosa*) are 12-15 mm long and chew leaf uppersurfaces, buds, flowers and seed pods.

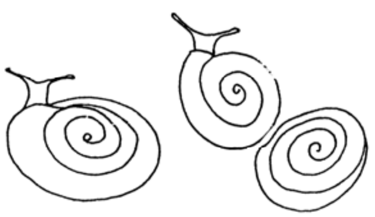

Fig. 175. Tiny orchid snails (Zonitidae) have a shell diameter of about 2 mm. They live in pots of orchid compost and feed on the tips of roots and on young shoots.

Fig. 176. Spots on petals caused by pollution from exhaust fans. Grey mould (*Botrytis cinerea*) also causes small spots on petals, these spots are sometimes bordered by delicate rings of pink, they enlarge and a furry grey mould develops in humid conditions.

Orchids

Family Orchidaceae
Cattleya, *Cymbidium*, *Dendrobium*, *Vanda*, others
Cooktown orchid (*Dendrobium bigibbum*)
(Floral emblem of Queensland)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Orchids, individually and collectively, are the most expensive plants grown. They have ***more virus diseases*** than most crops and these virus diseases are the ***most important problem*** affecting orchids.

Scientific name: The most important are:
Cymbidium mosaic virus ***(CyMV)***
Odontoglossum ringspot virus ***(ORSV)***
= Tobacco mosaic (orchid strain)
= Cymbidium diamond mottle
Orchid fleck 'virus' ***(OFV)***
Others include bean yellow mosaic virus, cucumber mosaic virus, tobacco mosaic virus, tomato spotted wilt virus. At least 25 viruses of orchids have been recorded worldwide.

Host range: ***CyMV*** affects many species of orchids, ***ORSV*** affects many species of orchids especially cymbidiums, ***OFV*** affects many species of orchids, especially cymbidium, cattleya.

Symptoms: Virus infections do not usually kill orchids. Generally, growth and vigour and flowering may be reduced. Leaves and/or flowers may be affected depending on the host. Although some viruses cause typical symptoms on orchids, ***ORSV*** may cause ringspotting on leaves and a colour break in flowers; symptoms caused by one virus, generally are not the same on all orchids. Orchids may be infected with more than one virus (Taylor 1989d). Virus diseases are often detected in imported orchids and symptoms in most plants are a ***mottle pattern of pale green*** patches on the ***leaves***. These mottles are often difficult to detect especially in young leaves. Distortion, twisting or banding of leaves may sometimes accompany the mottling.

Cattleya: ***ORSV*** in cattleya causes clear ringspots on ***leaves***. ***CMV and ORSV*** cause a colour break of ***flowers*** which is especially prominent in lavender-flowered cattleyas, causing sunken white spots in the petals.

Cymbidiums: Symptoms are most clearly seen as a pronounced blotching on ***new leaves***. Infected older leaves develop streaks, diamonds, rings or elongated dark brown markings or sunken areas (Fig. 173). Symptoms vary according to the cultivar, temperature, age of leaf. ***CyMV and ORSV*** are more evident on the leaf uppersurfaces whereas ***OFV*** is equally severe on both leaf surfaces. ***Flowers*** are not commonly affected but a few cultivars show a colour spot with ***ORSV*** infection. Virus infection in some cymbidiums can be symptomless. This can be due to a time lag between infection and symptom expression, or to a particular combination of cultivars and virus that may never show symptoms.

Dendrobium: ***ORSV*** where ringspot symptoms on ***leaves*** are clear. ***Soft-caned dendrobiums:*** Leaves develop white patches quite unlike the apparent pattern in cymbidiums. A colour break of the ***flowers*** may occur. The flowers of soft-caned dendrobiums may be affected too. Sometimes flowers will develop without petals and at other times, the labellums will be deformed.

Odontoglossum: Ringspot patterns may develop on ***leaves*** as a result of ***ORSV***. ***Flower*** symptoms do not develop.

Masked and latent viruses: Many orchids carry ***masked viruses*** which remain undetected provided optimum temperature and nutrition prevail. Others carry ***latent viruses*** which produce no symptoms at all on that particular host. ***Do not confuse*** virus infections with false spider mite infestation, genetic problems, copper toxicity, fungal infections or other problems. Suspect plants of being infected if there is any ***marked mottling of new leaves***. In general, ***sudden changes*** in leaf colour are caused by viruses, whereas ***gradual changes*** are produced by nutritional and other non-parasitic problems.

Diagnosis: While symptoms of virus infection can be severe, reliable diagnosis cannot be based on visual symptoms only. Their presence can been confirmed in plants primarily by:

Indexing: Symptoms are induced in a sensitive indicator plant after transmission by grafting, mechanical inoculation or by a vector. This is time-consuming and requires greenhouse space.

Electron microscope (EM): Virus particles can be seen under an electron microscope but if none are seen the specimen, although free of detectable virus particles, cannot be guaranteed virus-free. This method can be used for ***CyMV*** and ***ORSV***.

ELISA tests: Enzyme-liked immunosorbent assays (ELISA) are available commercially for ***CyMV***, ***ORSV*** and ***OFV***. These kits, if used with suitable controls, provide a rapid and reliable procedure especially for testing plants used in meristem tip propagation (Dept. of Primary Industry, Tas., 1993).

Overwintering: In infected orchids, soil contaminated with frass from infected orchids.

Spread: All viruses affecting orchids are spread ***by vegetative propagation*** from infected plants. New plants automatically carry the virus. Tissue culture may spread viruses unless techniques chosen prevent this method of spread. ***CyMV*** and ***ORSV*** are not spread by ***insects***. It is likely that ***OFV*** is spread by a species of insect. Other virus diseases of orchids, eg bean yellow mosaic and cucumber mosaic virus, are spread by ***aphids***. ***CyMV***, ***ORSV*** and ***OFV*** are spread from plant to plant in infected sap by leaf contact, during handling of the crop and on secateurs and knives during pruning and flower gathering. Viruses affecting orchids are not considered to spread from tobacco on the hands of smokers although the related tobacco mosaic virus ***(TMV)*** is spread in this way. ***Seeds*** are virus-free but may become contaminated with green frass from infected parent orchids. ***ORSV*** is present in ***soil or pots*** contaminated with green frass from infected orchids. ***ORSV*** and ***CyMV*** may also be spread by pollen.

Conditions favouring: Symptoms may vary with the temperature and be more obvious at high light intensities. Incidence of ***CyMV*** and ***ORSV*** is correlated with length of time plants have been in cultivation, frequency of handling and use of tissue culture for orchid propagation.

Control: Virus in a plant cannot be eliminated so the aim is ***to minimise spread***. Regularly test to see which plants are infected. As commonly available virus-testing kits only test for ***CyMV*** and ***ORSV***, growers still have to rely, to a great degree, on visual symptoms. As orchids can be symptomless virus 'carriers' there is the possibility of these in mixed collections, so all plants with an unknown history should be treated as if they had virus infection.

Cultural methods: Good culture and possibly higher temperatures may assist in retarding the progress of virus infection and may prevent their expression in plants already infected. Avoid injuring or abrading plants.

Sanitation: There is no known cure, so infected plants should immediately be destroyed (burnt), or if this is not practiced, segregated.

Tools and other implements used for cutting flowers, roots or leaves should be ***sterilised*** before each plant is trimmed, potted, etc. In practice, larger growers may have batches from the same seed-line or mericlone. Such batches could possibly be treated as if they were a single plant and blades sterilised only once before each batch. ***Procedures*** include ***dipping blades*** in methylated spirit to which 10% water has been added to prevent evaporation, ***soaking blades*** in 10% trisodium phosphate (a virus-inactivating compound) or in 3% sodium hypochlorite for 3 minutes (Gowanlock 1989). Use 2 pairs, one to soak in readiness for the next plant. Always check that the method is ***still currently recommended***. ***Discard solutions*** as recommended, eg when they become discoloured. Commercially available secateurs spray disinfectant on to the secateur blade, however, there is ***no guarantee*** that spread will never occur when using such secateurs. ***Alternatively blades may be flamed*** to red heat to decontaminate tools. ***Handle plants*** as little as possible especially seedlings. ***Wash hands*** thoroughly when moving between sections of collections and handle healthy orchids first. ***Containers*** should be sterilised with a suitable disinfectant prior to potting. ***When repotting, avoid soil contamination*** by placing fresh newspaper on the bench each time a new cultivar, or group of a clone is handled, dispose of this soil in newspaper each time. ***Reduce seed contamination*** by removing all green orchid frass.

Plant quarantine: Where infected plants cannot be eliminated they should be segregated in a location as far as possible from healthy plants.

Disease-free planting material: Do not propagate vegetatively from infected plants. Seed is virus-free but it should not be contaminated with infected frass from the parent plant. Index before propagation by tissue culture. Avoid infection of seedlings and virus-tested orchids; segregate them from older plants which may carry virus.

Pesticides: Although insects do not spread ***CyMV*** and ***ORSV***, they do spread some other viruses. It is good practice to control aphids and other insect pests (Taylor (1989a).

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas aeruginosa*) may affect orchids, especially *Phalaenopsis*, *Cattleya* and *Vanda*, other hosts, eg onion and tobacco. Symptoms are varied, sometimes a brown watery area with an irregular yellow boundary with brown droplets oozing out. Sometimes brown drops can be squeezed from the ***leaf***. At other times the ***leaf tip*** has alternate dark and light bands across it. The leaf looks watery except at the tips where it is brittle and dry. ***Overwinters*** in soil, sewage. See Vegetables M 5.

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) occurs in Australia. It is considered to be a serious disease of orchids overseas. Amber spots develop on ***leaf blades***. Spots turn brown and spread throughout the leaf. If infection is at the lower end of the leaf then the upper portions will turn yellow for lack of food. ***Stems*** can also be attacked. The rot is most serious if stem is attacked at ground level. ***Rhizomes*** and ***pseudobulbs*** can also be attacked. Entire plants may be killed. This disease frequently follows attack by orchid beetle larvae and similar insects. See Vegetables M 5.

Others: ***Erwinia cypripedii*** on *Cypripedium* sp. and *Paphiopedilum* sp. ***Peudomonas cattleyae*** has been recorded on *Cattleya* sp. and *Phalaenopsis* sp. (Fahy and Persley 1983).

FUNGAL DISEASES

*The most serious fungal diseases of orchids are caused by **grey mould** (Botrytis cinerea) and **root rots** caused by Phytophthora and Pythium spp.*

Fungal leaf spots (*Cladosporium* (= *Gloeosporium* spp.), *Cercospora*, *Colletotrichum*, *Physalospora, Phyllosticta*). It is ***difficult to distinguish*** fungal leaf spots from spots caused by virus and bacterial diseases and environmental conditions. ***Favoured*** by injury, overcrowding, high humidity. See Annuals A 5.

Fusarium wilt

(*Fusarium oxysporum* (most commonly), *F. moniliforme* and *F. solani*). These species cannot be confirmed as pathogens until detailed tests have been made. With control of *Pythium* and *Phytophthora* root rots in orchids by some of the newer fungicides and of *Glomerella* by other fungicides, the residual problems caused by *Fusarium* have become clearer (Taylor 1989b). The ***symptoms differ*** from those caused by *Glomerella* in that the ***leaves*** die from the ***bottom upwards*** rather than from the tips and the middle of the leaf down to the pseudobulb. Also *Fusarium* may cause a ***yellowing of leaves***, produced by toxic materials. Sometimes the infection begins in a young 'lead' or ***flower spike*** and spreads progressively into the ***older pseudobulbs***. Both *Glomerella* and *Fusarium* can ***kill pseudobulbs*** and final symptoms of the two diseases may be similar, so there may be ***some confusion***. Some diseased pseudobulbs have brown-purple spots or flecks inside them but this is not a reliable symptom. ***Flowers*** of some varieties fail to open properly, producing 'sleepy' conditions, and cut flower spikes are so short-lived that they are worthless. The quality of flowers may be reduced. ***Fusarium-free planting material:*** Do not plant infected seed tubers. Select *Fusarium*-free propagating material and grow it in *Fusarium*-free media. ***Fusarium-free compost:*** Orchid compost material such as bark, scoria, sawdust, peanut shells, sand and stone chips that have been ***in contact with soil*** are likely to be contaminated with *Fusarium*. Pasteurise compost (60^{o}C for 30 minutes) to kill *Fusarium* but not beneficial organisms. ***Commercial producers*** grow orchids on ***steel mesh*** or wooden slatted benches, well raised above the ground to prevent splash of spores on to plants. See Vegetables M 9.

Glomerella leaf blight

, anthracnose (*Glomerella cingulata* = *Colletotrichum gloeosporioides*) affects orchids, especially ***cymbidiums*** (Taylor 1989a, 1989b). In most seasons damage is limited to the death of tips of ***leaves***, and does not spread. However, in other seasons, the initial symptoms are a soft rotting anywhere on the leaf which spreads in defined zones down to the pseudobulb, so ***killing the plant***. Infections are followed 1-4 weeks later by the appearance of pin-point sized black spots which are the spore producing bodies (acervuli). ***Overwinters*** on dead bases of older leaves. ***Favoured*** by plant injury. ***Cultural methods:*** Protect plants from rain with glass or plastic providing that this does not affect the 10^{o}C difference between day and night temperatures that are required for flower initiation. Provide good ventilation. If necessary use forced air ventilation. Provide appropriate spacing of plants and only have 1 tier of them. ***Sanitation:*** Tear off diseased leaves to prevent infection growing into the pseudobulb and killing the plant. ***Resistant varieties:*** Grow or clone only new cultivars that have moderate to high resistance to *Glomerella* as tested by an indexing method. ***Pesticides:*** ***Chemicals*** may be used on production lines. Bordeaux mixture is an effective fungicide but may ***damage flower spikes***. Other fungicides may be applied during flowering (Taylor 1989a). See Fruit F 5, Trees K 5.

Grey mould

(*Botrytis cinerea*) may cause spotting of ***flowers and flower stalks*** if conditions are damp. Translucent spots may result if ***buds*** of flowers are wet with rain or irrigation water. Grey mould can be difficult to control. See Greenhouses N 22.

Powdery mildew

(*Oidium* sp.) has been recorded on native Orchidaceae (Shearer 1994). See Annuals A 6.

Pseudobulb and root rots

Black crust (*Mycoleptodiscus* sp.) has been isolated from ***cattleya*** species or hybrids in north Qld. Infections begin as small brown spots on the ***pseudobulb***, sometimes surrounded by a slight clear halo. Dark elliptical spots develop, becoming very distinct long, narrow, black lesions expanding vertically on the plants. Lesions may be slightly depressed and the pseudobulb shrivels as disease progresses (Forsberg 1994).

Black pseudobulb rot (*Pythium ultimum*) affects orchids, particularly ***cymbidiums***. The ***pseudobulb*** may be infected with this fungus at either the base or the top. Roots are not usually damaged. Rotted tissue is dark brown to very black (a pinkish look indicates that the fungus responsible is probably *Fusarium*). If the infection is progressing from the base, ***leaves*** gradually yellow and wilt. ***Phytophthora*** (*Phytophthora nicotianae* var. *parasitica*) causes rotting of roots. ***Cultural methods:*** Avoid over wet media and ensure good drainage. Avoid overwatering, especially in the cooler months of the year. ***Sanitation:*** Discard badly affected plants. Cut away rotted pseudobulbs cleanly from other healthy ones and destroy them. ***Resistance:*** ***Phosphoric acid*** will assist in controlling *Phytophthora* and *Pythium*. It controls them by stimulating the natural resistance of plants to these fungi. ***Pesticides:*** Plants may be drenched with one of the systemic fungicides such as furalaxyl or metalaxyl.

Phomopsis rot (*Phomopsis* sp.) may rot ***pseudobulbs, rhizomes and leaves*** of ***cattleya***. Black dots (fruiting bodies) on rotted areas.

Others: Rhizoctonia root rot (*Rhizoctonia solani*), ***sclerotium stem rot*** (*Sclerotium rolfsii*).

See Vegetables M 6.

Rusts

(Uredinales)

Rusts (*Puccinia*, *Uromyces*) occur on Orchidaceae. ***Native orchidaceae*** seem to be little affected by disease other than by rusts. Some rusts on orchids are long cycles, eg produce many different types of spores. Affected ***leaves*** senesce early and plants produce few flowers (Nichol et al. 1988, Shearer 1994). Rust reduces ability of *Thelymitra crinita* to produce ***flowers*** and might affect ***survival of endangered species***, eg *T. macmillanii* (Shearer 1994). *Puccinia* occurs on *Caladenia radialis, Uromyces thelmytra* on *T. crinita, U. microtidis* on *Microtis unifolia, Uromyces* spp. on *Lyperanthus nigricans, Prasophyllum* spp. (Nichol et al. 1988). See Annuals A 7.

Tropical American orchid rusts (*Coleosporium* sp., *Phenospora* spp., *Uredo* spp.) are not known to occur in Australia. They attack a range of cultivated orchids in tropical America, including *Cattleya*, *Dendrobium*, *Odontoglossum, Spathoglottis*. Severely infected plants become unthrifty and even die. Small, orange or brown pustules develop on ***leaf undersurfaces***. As the infection spreads, the ***leaf uppersurfaces*** may also be ruptured by the pustules. The infected area is usually circular and a yellow region surrounds mature lesions. The pustules often turn black with age. They tend to develop in a concentric pattern which gives the infected area the appearance of a target spot. The upper surface of the leaf directly above infected tissue becomes yellow. Spores are ***spread*** by wind or water splashing to other susceptible orchids; rusts are also spread by the movement of infected orchids. ***Plant quarantine:*** There is considerable international trade in tropical orchids amongst commercial growers as well as hobbyists. Plant quarantine authorities in Australia have, on occasions, intercepted rust-infected orchid plants imported from overseas (Com. of Aust. 1989).

NEMATODE DISEASES

Nematode populations are low in most orchid collections because most epiphytic and many terrestrial orchids are grown in soil-less media that is not conducive to large nematode populations. See Vegetables M 10.

INSECTS AND ALLIED PESTS

***Twospotted mite** is the most serious pest affecting orchids. Orchid beetle, scales and mealybugs are also common pests.*

Aphids (Aphididae, Hemiptera) may attack ***foliage, buds and flowers***. In severe infestations, growth may be stunted, leaves and flowers distorted. Sooty mould can develop on the honeydew secreted by the aphids.

Cotton aphid, melon aphid (*Aphis gossypii*) is a small species and its colour varies. Individuals in the same colony may be yellow, green to almost black. See Cucurbits M 53.
Palm aphid (*Cerataphis lataniae*) may infest lantana, orchids and palms. The wingless form is dark, disc-like with a white fringe and may be mistaken for a species of whitefly. This aphid may play a part in spreading cymbidium mosaic. See Palms H 3.
Others: Orchid aphid (*Cerataphis orchidearum*) and ***yellow orchid aphid*** (*Sitobion luteum*).

Aphids are possibly involved in the transmission of ***virus diseases***. ***Control infestations*** as soon as observed. Home gardeners can gently wash aphids off. See Roses J 4.

Caterpillars (Lepidoptera)

An orchid butterfly (*Hypolycaena danis turneri,* Lycaenidae): Caterpillars feed on flowers of orchids, eg the native ***Cooktown orchid*** (*Dendrobium bigibbum*) and exotic ***Vanda spp.*** in northern Australia especially Cairns. If ***buds and flowers*** are not available caterpillars feed on ***seed pods, leaves***, or even ***younger stems***. ***Mature caterpillars*** are densely covered with minute hairs, and generally deep red or green. ***Pupa*** is attached to stem of the food plant (Common and Waterhouse 198).

Others: Budworms (*Helicoverpa* spp., Noctuidae), ***looper caterpillars*** (*Chrysodeixis* spp., Noctuidae).

If only a few plants are infested, caterpillars may be hand picked. The biological insecticide, *Bacillus thuringiensis* (Dipel®) may be applied regularly as a preventative. See Annuals A 8.

Mealybugs (Pseudococcidae)

Dendrobium mealybug (*Pseudococcus dendrobiorum*)
Longtailed mealybug (*P. longispinus*)
See Greenhouses N 25.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus,* Tarsonemidae). See Greenhouses N 26.
Orchid mite (*Tenuipalpus pacificus,* Tenuipalpidae) feeds on the surface of orchid ***leaves***, causing dark spots and eventual death of the tissue. The development of this species is slow. The duration of a life cycle is at least 64 days. ***Other false spider mites***, eg *T. brevipalpus,* may also infest orchids causing ***virus-like symptoms*** which spread with the infestation. These symptoms can be confusing as they can be seen long after the initial infestation when there are few or no mites present. They are consistently more prevalent on ***leaf undersurfaces***. It may be necessary to use a miticide. See Beans (French) M 31.
Twospotted mite (*Tetranychus urticae*) is considered by ***cymbidium growers*** to be ***their most serious pest***. A reduction in mite damage resulted in reduced need for nitrogen, phosphorus and potassium fertilisers. The mite feed on ***leaf undersurfaces*** causing speckling and silvery appearance. The edges of the leaves curl, providing shelter for the mites. Severe damage causes deterioration and lowers flower production in the current season's blooms, and causes smaller and fewer blooms in following seasons. Mite damage to the ***blooms*** causes watery spots which become necrotic, spoiling the appearance of the flower. ***Try to control this pest before the buds appear*** because flowers can also be damaged. Remove from the area old pieces of leaf, other plant parts and weeds which are alternative hosts of this mite. Prevalent in warm, dry weather. ***Cultural methods:*** Overhead irrigation could help reduce infestation but may damage flowers. ***Pest management:*** A ***predatory mite*** (*Typhlodromus occidentalis*) can maintain long term control of twospotted mites in commercially grown cymbidium orchids. Other problems affecting cymbidium orchids and flare-ups of twospotted mites, may be controlled using pesticides which are harmless to the predatory mite. See Beans (French) M 29.

Orchid beetle, dendrobium beetle (*Stethopachys formosa,* Chrysomelidae, Coleoptera) is a pest of commercial orchids and infests ***dendrobium***, especially *Dendrobium speciosum*, also cymbidium, cattleya. ***Beetles*** are ***12-15 mm*** long and have hard, yellow forewings, each with 2 conspicuous black patches (Fig. 174). The forewings are specialised wing covers. When approached or touched beetles usually drop to the ground, where they hide. ***Larvae*** are thick-set and cream coloured, and covered with slime. ***Pupae*** are covered with a white foam-like material and are usually found around the base of the plant. ***Beetles*** usually feed on ***leaf uppersurfaces*** and

occasionally on the lower surface, rapidly removing the whole surface tissue. They also feed on ***seed pods and buds***. ***Larvae*** bore into the succulent tissues of new ***shoots, stems and pseudobulbs***. This opens the way for secondary decay organisms such as bacterial soft rot. ***Adults and larvae*** may both damage ***young foliage, buds and flowers***. Additionally, slime and excreta soon spoil the blooms. ***Pupae*** are covered with a white substance very like styrene foam. Sometimes the pupae are attached to plants or (more often) they are partly buried amongst the roots. ***Sanitation:*** Adults are hard to kill with pesticides and collection night and morning and destruction by hand is the best method of control. Hold a newspaper below the plant to catch them. Because of the difficulty in killing larvae inside the stems with pesticides, infested stems should be pruned out and burnt as soon as the infestation is noticed and before much damage has been done. ***Pesticides:*** If this pest is troublesome, regular applications of an insecticide directed towards the surface feeding adults and larvae may be necessary. See Trees K 15.

Scales (Hemiptera)

Armoured scales (Diaspididae): More than 25 species of armoured scales attack orchids worldwide. ***Cymbidium scale*** (*Leptosaphes machili*) infests cymbidiums, orchids and related plants. It is a small dark brown scale, similar to purple scale in shape. ***Orchid parlatoria scale*** (*Parlatoria proteus*) infests orchids, citrus, date palms, other plants. This is a very tiny creamy-white to fawn scale, about 1-2 mm long. Scales may feed on both upper and lower surfaces of leaves and small yellow patches develop on leaves due to their feeding. They tend to congregate close to the midrib. ***Orchid scale*** (*Diaspis boisduvalii*) infests orchids and palms, possibly some other plants. ***Adult female scales*** are roughly circular. The male scales are smaller, more elongated and have 3 ridges along them. Scales can build up to large numbers before being noticed because they tend to congregate under sheathing leaves around the base of the plant. The leaves go yellow and the plant stops growing. Also ***oleander scale*** (*Aspidiotus nerii*). See Citrus F 39.

Soft scales (Coccidae): Vast quantities of honeydew are produced. This causes the growth of sooty mould and attracts ants. Species include ***hemispherical scale*** (*Saissetia coffeae*), ***nigra scale*** (*Parasaissetia nigra*), ***soft brown scale*** (*Coccus hesperidium*). See Citrus F 41.

Scale makes plants unsightly. They may gather on ***leaf undersurfaces*** so that their presence is not noticed until the uppersurface turns yellow in the areas above them. Scale-damaged leaves never regain their green colour. In severe infestations, the eyes of the ***pseudobulbs*** may be destroyed. ***Overwinters*** on infested orchids, other hosts. ***Spread*** by movement of infested plants. ***Control***: ***Monitor*** orchids for the presence of scale insects. Small infestations washed off carefully by hand or may be gently rubbed off with an old soft toothbrush. ***Pesticides:*** Commercial growers may apply insecticides when orchids are not flowering. See Citrus F 39, F 41.

Thrips (Thripidae, Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) commonly causes silvering of ***leaves***. Small, thin black thrips about 3-4 mm long may be seen on leaf undersurfaces. See Greenhouses N 24.

Orchid thrips (*Chaetanaphothrips orchidii*) infests orchids, especially ***cattleya***. Nymphs are tiny, yellow and mainly feed on the ***foliage***, causing silvering.

Plague thrips (*Thrips imaginis*) may damage or disfigure spring ***blooms***, sometimes causing curling, deformities and irregularities in colour. Both ***nymphs and adults*** feed amongst ***flowers***. Occasionally they attack ***new foliage***. Thrips infest the buds when flower spikes are appearing. See Roses J 6.

Home gardeners could collect thrips with a small damp paint brush, wiping them off gently with a damp clothe or dusting. ***Commercial growers*** usually control thrips with insecticides. See Roses J 6.

Others: Common ***greenhouse pests*** may infest orchids in greenhouses, eg ***slaters*** (Crustacea), ***millipedes*** (Dilplopoda), ***European earwig*** (*Forficula auricularia*) and a ***cockroach*** (*Shelfordia orchidae,* Blattodea). ***Crickets and grasshoppers*** outdoors may chew holes in buds and flowers. Ensure that there are no weeds, long grass or empty plant pots near the orchids where these insects may hide. ***Green vegetable bug*** (*Nezara viridula*), ***orchid weevil*** (*Orchidophilus aterrimus*), ***greenhouse whitefly*** (*Trialeurodes vaporariorum*) and other species may also infest orchids.

SNAILS AND SLUGS

Snails and slugs may cause serious damage to buds, flowers, leaves, stems and green root tips of orchids during the growing season. ***Orchid snail*** (Zonitidae) is a tiny species (shell diameter 2 mm) which frequently lives in pots of orchid compost and feeds on the tips of roots and young shoots (Hocking 1980) (Fig. 175). ***Others: Common garden slug*** (*Deroceras* sp), ***common garden snail*** (*Helix aspersa*, Helicidae). See Seedlings N 70.

VERTEBRATE PESTS

Mice, rats and birds may damage orchids. ***Possums*** may eat flower buds of orchids growing on trees in gardens. See Fruit F 13.

Non-parasitic

*After virus diseases and twospotted mite infestations, **cultural problems** are the next most serious problems affecting orchids. Often they are confused with symptoms caused by virus diseases.*

Environment: The cultural requirements of orchids vary depending on the species and the location. Most orchids require ***semi-shade.*** Long exposure to ***sun*** may damage leaves. Protect plants from ***wind***. Orchids require high humidities but good ventilation. Roots must be kept ***moist*** but not wet, there must be ***good drainage***. Different species require different ***temperatures*** for growth and flowering. Avoid fluctuating temperatures. ***Frost*** will damage most flowers (McMaugh 1994). Many orchids need an open, free-draining media. Many are epiphytes and can be grown attached to pieces of bark, wood or living trees.

Nutrient deficiencies, toxicities: Most orchids respond to ***supplementary feeding***, individual species have different requirements. ***Cymbidiums*** need a high-nitrogen fertiliser after flowering throughout spring and summer. They should not be fertilised with large quantities of nitrogen in autumn during flower initiation.

Pesticide injury: ***Blooms*** are highly susceptible to damage so that phytotoxicity can be a problem at a certain stage of flowering. Early flowering whites are more susceptible than later varieties. ***Copper oxychloride*** or copper hydroxide may damage leaves resulting in copper spot (Taylor 1989d). ***Mycorrhizae:*** Excessive use of fungicides on orchids may upset the symbiotic relationship they have with mycorrhizal fungi. These fungi help orchids take up nutrients from the potting mix. If the process is interfered with, leaves may gradually yellow and growth will slow (McMaugh 1994). See Trees K 18.

Pollination: ***Orchid dupe*** (*Lissopimpla excelsa*, Ichneumonidae, Hymenoptera): Some terrestrial Australian orchids (*Cryptostylis*) emit a perfume so closely resembling the sex attractant of the female orchid dupe that the male eagerly attempts to copulate with the flower. In the process they acquire a burden of adhesive pollinia which may be transferred to other blooms when they repeat the process of pseudocopulation. ***A fly*** (*Mycomya* sp.) pollinates a ground orchid. ***Ants*** (Formicidae) often remove pollen caps from flowers, causing withering and browning of flowers. ***Bees and wasps*** (Hymenoptera) may pollinate orchids causing them to wither prematurely.

Others: ***Algae, moss, fungus gnats*** and other problems associated with greenhouse plants may affect orchids. See Greenhouses N 27, N 28. ***Mycorrhizae:*** Some orchid seeds may be difficult to germinate unless a specific fungus is present. See Trees K 18. ***Phalaenopsis spot*** has been associated with long periods of humid weather but the exact cause is unknown (Taylor 1989d). ***Pollution*** from exhaust fans and other equipment may damage orchids (Fig. 176). ***Tetragonum spot*** on the leaves of *Dendrobium tetrogonum* is quite normal (Taylor 1989d). ***Other dark spots*** occur on orchid leaves the causes of which are unknown (Taylor 1989d).

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The Orchid Review (1893-1984)
Local Orchid Societies, Australian Orchid Soc.

See Preface xii, Australian native plants N 9, Greenhouses N 28

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural varieties: Orchids make lovely container plants. They are the most expensive cut flowers. ***Resistant varieties:*** Some orchids are hardier than others, eg cymbidiums. ***Virus-tested orchids:*** Only purchase or propagate from virus-tested orchids. Growers intending to import orchids should ensure that plants are from a quarantine ***approved source*** and ***free from viral and other problems*** as all diseased plants are destroyed when detected in quarantine.

Establishment and Maintenance

Propagated by seed or division, tissue culture. Different types of orchids require different cultural conditions. A range of media specifically tested for suitability for orchid tissue culture and flasking or for orchid seed is available. Diseases and pests should be ***monitored*** in commercial crops. Regular virus-testing may be necessary. ***Cultural methods:*** Provide adequate spacing of pots, good ventilation and appropriate cultural practices. ***Sanitation:*** Remove all dead leaves and leaf bases to prevent decaying plant material from accumulating around the base of plants. As orchid viruses can easily be ***transferred to healthy plants*** by handling, it is important to wash hands and disinfect tools between plants. See Orchids G 3. Preferably handle healthy plants before handling diseased plants. ***Pesticides*** may damage and buds and flowers. ***Bordeaux mixture*** which controls most leaf diseases of cymbidiums should not be applied during flowering (Taylor 1989c).

Postharvest

Harvest stage: Handle flowers carefully as they are easily bruised. Usually optimal stage for harvest is 3-4 days after bud opening. If cut at too early a stage of bud development orchids will not properly open. When individual flowers are harvested the peduncles should immediately be placed in a tube with a rubber or plastic cover. Older flowers from the lower part of the inflorescence are shorter-lived than younger flowers from the upper part. Flowers are very sensitive to ethylene (reddish flower colour, hastening of withering, etc). Pollinated flowers wilt quickly; only 2 ***pollinated orchids*** in a box can reduce the longevity of other non-pollinated flowers. ***Storage:*** Do not refrigerate orchids below 10^{o}C (Jones and Moody 1993, Sacalis 1993). ***Transport:*** Flowers in tubes. Whole spikes may be packed 100 flowers to the box in moisture-retentive boxes. Immediately upon arrival peduncles should be recut and replaced in clean water in vials or in vases with floral preservative ***Vase life:*** Refill vial solutions regularly. Individual cymbidium spikes in vases may last for 6-8 weeks (Jones and Moody 1993, Nowak and Rudnicki 1990).

Palms

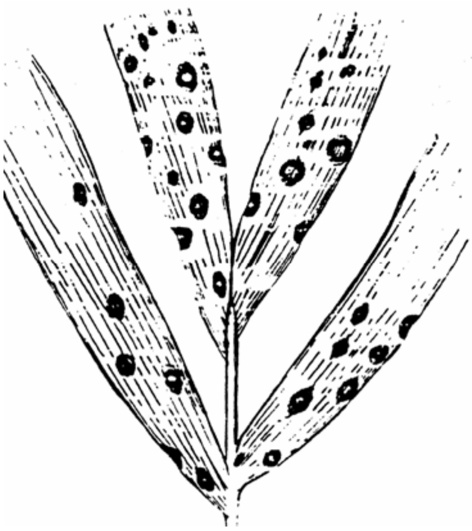

Fig. 177. Fungal leaf spots (adapted from Duff, 1989).

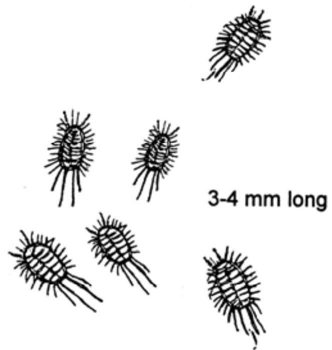

Fig. 178. Mealybugs (*Pseudococcus* spp.) are white, fluffy and easily seen.

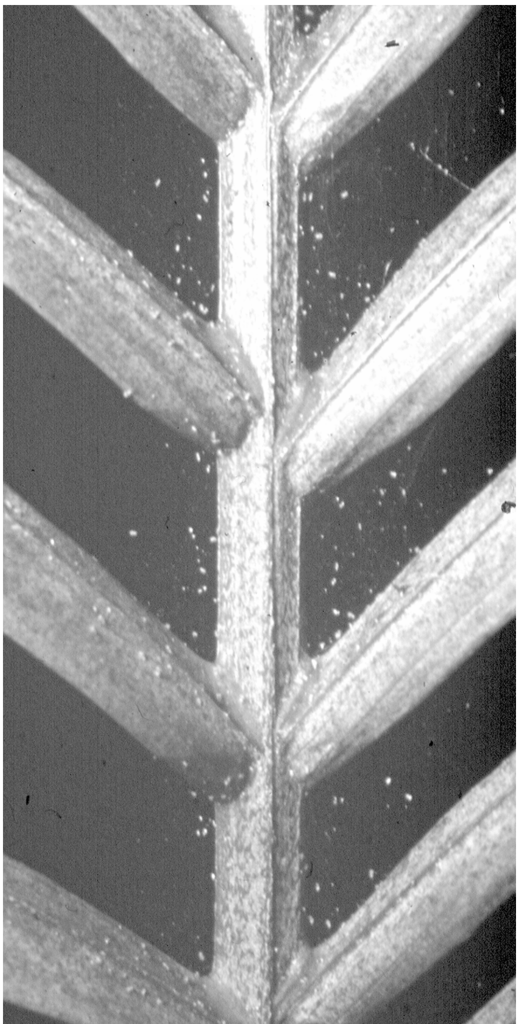

Fig. 179. Twospotted mites (*Tetranychus urticae*) crawling over webbing.

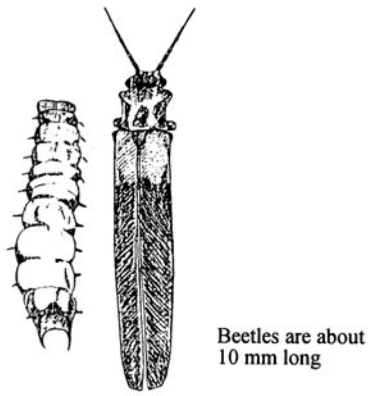

Fig. 180. Palm leaf beetle (*Brontispa longissima*) and larva (adapted from Fenner 1989).

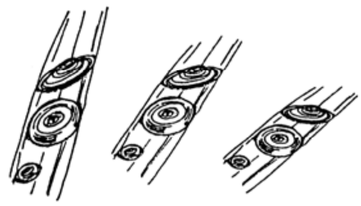

Fig. 181. Tiny armoured scales (Diaspididae) are 1-3 mm long.

Fig, 182. Greenhouse thrips (*Heliothrips haemorrhoidalis*).

Palms

Family Arecaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf spots
  - Root and stem rots, wilts
- **Nematode diseases**
- **Protozoan diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Mealybugs
  - Mites
  - Palm leaf beetle
  - Scales
  - Thrips
  - Weevils
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities
- Pesticide injury
- Poisonous properties

WEEDS

The date palm (*Phoenix dactylifera*) is probably one of the earliest crops to be cultivated and its propagation has spread to most of the drier parts of the world. Palms are generally a hardy group of plants.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Some species are subject to ***serious virus diseases*** overseas but these are not known to occur in Australia.

Kentia palm mosaic (unconfirmed virus) may cause a yellow mosaic on ***new fronds*** of *Howea forsteriana*, fronds may recover.

Palm ringspot (roystonea virus) affects *Chamaedorea seifrizii*, *Ravanea rivularis* and *Roystonea regia.* ***Leaflets*** develop yellow ringspots which later turn brown, and lack of vigour. Plants may die prematurely (Bodman et al. 1996).

Others overseas: ***Cadang-cadang*** (viroid) infects coconut (*Cocos nucifera*), oil palm (*Elaeis* spp.) and buri palm (*Corypha elata*) and is estimated to have killed ***> 30 million trees*** in the ***Philippines and Guam***. The disease produces symptoms on mature palms which include characteristic mottling and a gradual reduction in fruit size and number until no more fruit is set. Death follows a long period of decline. Its method of spread is not known. ***Foliar decay*** (virus) infects coconut palm and native palms in ***Vanuatu***. It causes yellowing and death and prevents the use of potentially higher yielding palms in Vanuatu. The disease is ***spread*** from native vegetation to introduced palms by the cixiid bug (*Myndus taffini*). While local cultivars in Vanuatu are tolerant or resistant, the Malayan Red Dwarf cultivar and its hybrids are very susceptible. ***Lethal yellowing*** (mycoplasma-like organism) is a ***devastating disease*** causing rapid death to coconut and at least 20 species of palms including many ornamentals. It is a threat to the various countries of the ***Pacific*** which rely on the coconut and its products and has been particularly severe in Jamaica and Florida. Symptoms consist of nut fall, leaf yellowing, flower blackening followed by browning of the spear leaf and death. ***Spread*** by a leafhopper (*Myndus crudus*), by vegetative propagation and by the movement of infected seedlings, suckers and plants. The only effective control has been the use of varieties with ***some resistance***, eg the Malayan Dwarf variety and its hybrids. Antibiotics have been used in small plantings. ***Control:*** ***Quarantine risks:*** Although coconut and oil palm are not commercial crops in Australia, a very large number of palm species are grown as ornamentals. These and some native species could be at risk from the introduction of these and other diseases. Lethal yellowing has a wide host range and seedlings or suckers of ornamental species could be the means for introducing the disease. Although cadang-cadang has been positively identified on only a few palm species it may have a wider host range. ***Quarantine precautions:*** Prior approval is required to import plants of all palm species and importation is discouraged if they can be propagated from seed. If approval is granted plants must be fumigated against possible insect pests, and grown in ***post-entry quarantine***. The import of coconut seedlings is prohibited. As cadang-cadang is known to be seedborne the import of seed nuts will only be permitted from safe sources and subject to growth in post-entry quarantine (Com. of Aust. 1987). See Fruit F 4, Trees K 4.

BACTERIAL DISEASES

Bacterial leaf blight (*Pseudomonas alboprecipitans = P. avenae*) causes large elongated brownish areas on ***leaves*** of the fishtail palm (*Caryota mitis*).

Bacterial wilt (*Pseudomonas solanacearum* biovar III) causes vascular discolouration of stems. Alexandra palm (*Archontophoenix alexandrae*) is ***susceptible***, palms die. See Tomato M 6.

FUNGAL DISEASES

Fungal leaf spots

Bipolaris incurvata is perhaps the ***most common*** fungal leaf spot of palms in NT nurseries and affects many species of palms, eg kentia palm (*Howea* spp.) and golden cane palm (*Chrysalidocarpus lutescens*).

Cylindrocladium quinquiseptatum may ***severely affect*** American cotton palm (*Washingtonia filifera*).

False smut (*Graphiola* sp., *Stylinia* sp.) may affect *Livistona* spp. and date palm (*Phoenix dactylifera*).

Palm leaf blight, anthracnose (*Colletotrichum* sp.) affects many species.

Others: *Brachybasidium pingae*, *Cercospora*, *Exserohilum*, *Pestalotiopsis*, *Phomopsis* and ***phytophthora leaf blight*** (*Phytophthora* spp.,), *Pseudocercospora* spp. Some fungi only invade damaged tissue.

Symptoms vary with the fungus, but commonly ***brown to black spots*** frequently surrounded by a ***yellowish-green halo*** develop (Fig. 177). During humid conditions fronds may start dying at the tips leaving a shredded appearance. ***Secondary fungi*** (*Alternaria*, *Curvularia, Colletotrichum* and *Fusarium* in some cases) may invade leaf spots after the initial fungus has caused the damage or after damage by sunscorch or other factors (Duff 1991). See Annuals A 5.

Root and stem rots, wilts

Damping off (*Gliocladium vermoeseni*, *Phytophthora* spp., *Polyporus microsporus*, *Pythium* spp., *Rhizoctonia* sp., *Sclerotium rolfsii, Thielaviopsis paradoxa*), may affect palm seedlings (Weale 1991). See Seedlings N 66.

Gleocladium stem rot (*Gliocladium vermoseni*) forms pinkish spore masses at the base of the ***oldest fronds***. Canes die. Infection usually follows injury.

Phytophthora collar, stub or root rots (*Phytophthora* spp., *P. palmivora*) may affect some palms when planted in heavy waterlogged soils with ***poor drainage***, eg Queen palm (*Arecastrum romanzoffianum)*, *Caryota mitis*, *C. urens* and coconut. Many palms seem to be ***resistant***. Palms develop an unthrifty appearance with a crown of pale or yellow leaves. If severely stressed by overfertilising, waterlogging or other factors, plants may wilt or collapse suddenly and die. In some species symptoms appear as a ***leaf blight***. Only plant susceptible palms in well drained soils. See Trees K 6.

Others: ***Upper stem rot*** (*Thielaviopsis paradoxa*), *Fusarium* sp., and *Pythium* sp. may cause root, stub or bud rots. ***Fusarium wilt*** (*Fusarium oxysporum*) may be important commercially overseas and is being investigated in Sydney. ***Ganoderma butt rot*** (*Ganoderma zonatum*) has been identified in > 30 species of palms across south eastern USA. Initial symptoms are wilting of leaves. This is usually followed by the appearance of fruiting bodies. A palm tree can then die within a year of their appearance.

See Trees K 7.

NEMATODE DISEASES

Nematodes do not appear to be a serious cause of disease in Australia. Nematodes recorded in association with palms in Australia include ***ring nematode*** (*Criconema* sp.), ***root knot nematodes*** (*Meloidogyne*), *Filenchus, Hemicriconemoides, Scutelloma, Tylenchus* (McLeod et al. 1994). ***Red ring disease*** (*Rhadinaphelenchus cocophilus*) causes ***serious losses*** of palms in the Carribean. (Com. of Aust. 1987). See Vegetables M 10.

PROTOZOAN DISEASES

Sudden wilt, Marchitez sorpresiva or Hartrot is a ***lethal disease*** affecting coconuts and oil palms in South America. It is thought to be caused by a protozoa (*Phytomonas staheli*) (Com. of Aust. 1987).

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Green peach aphid (*Myzus persicae*)
Palm aphids (*Cerataphis lataniae, C. variabilis*)
Aphids may infest new growth. The wingless form of the ***palm aphid*** (*C. variabilis*) is often mistaken for a whitefly because it is dark and disc-like with a white fringe. Overseas, *C. palmae* may also infest palms. See Roses J 4.

Caterpillars (Lepidoptera)

Palmdart butterflies (*Cephrenes* spp. Hesperiidae) may be ***serious pests*** of native and exotic palms, eg Alexandra palm (*Archontophoenix alexandrae*), bangalow palm (*A. cunninghamiana*), featherleaved palms (*Chrysalidocarpus* spp.), queen palm (*Arecastrum romanzoffianum*) and coconut. ***Orange palmdart*** (*C. augiades sperthias*) occurs south from the Torres Strait Islands down the east coast of Australia to Sydney, infesting palms, especially bangalow palm (*A. cunninghamiana*) and cabbage palm (*Livistona australis*). ***Yellow palmdart*** (*C. trichopepla*) occurs in northern areas of Australia infesting palms but especially young sprouting coconut palms. ***Butterflies*** have orange and brown wings and are often called skippers or darts because of their unusual manner of flight. They are active on sunny days. ***Caterpillars*** are slender, translucent and greenish-grey or brownish depending on the species and about ***70 mm*** long. They have a prominent, striped head and wriggle actively when disturbed. Each caterpillar folds a section of ***frond*** around itself and secures it in place with webbing. It hides in this shelter during the day and eats sections of young leaflets and fronds to the midrib, giving palms a ragged appearance. Caterpillars pupate in the shelter. Sometimes caterpillars of the orange palmdart may pupate within sewn leaves of nearby plants. ***Mickey birds*** are active predators. Regular applications of insecticides may be necessary during the summer.

Others: ***Case moth*** (Psychidae) caterpillars may be a minor pest of bangalow palm and princess palm (*Dictyosperma album*). ***Caterpillars*** grow to about ***25 mm*** long, and are pale with orange or red bands. They graze the surface tissue of ***palm fronds*** and construct a silken bag decorated on the outside with pieces of palm fronds, in which to live. Damaged sections eventually turn brown. See Trees K 13. ***Lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars shelter in developing fronds and web adjacent leaflets together by silk strands. They feed on very young fronds and the damage is only obvious when the fronds have developed. See Pome fruits F 112. ***Painted apple moth*** (*Teia anartoides*) caterpillars have tufts of hairs on their back and feed on young soft palm fronds. Other hairy caterpillars which coil when disturbed are occasionally troublesome. See Pome fruits F 113. ***Yellow peach moth*** (*Conogethes punctiferalis*) caterpillars destroy developing seeds in seed heads and on fruits of *Planchonia careya* and *Livistona humilis*. See Stone fruits F 133.

Other caterpillars may not really be pests: ***Palmfly*** (*Elymnias agondas australiana*, Nymphalidae) caterpillars feed on palms, especially lawyer palm on ***Cape York Peninsula***. Caterpillars are green with paler stripes and an unusual forked tail. Butterflies are handsome with dull brown and white wings with 2-3 prominent eyes on the hindwing. **A palm moth** (*Agononexa phoenicia*) is a minor pest of Alexandra palm in northern Australia. Caterpillars are slender, small and grey, and feed on ***leaf undersurfaces*** from inside a flimsy silken web. Moths are small, grey with hairy, fringed slender wings, the upper one of which has a longitudinal dark band up to ***20 mm*** long. Caterpillars of a small, dull grey **moth** (*Blastobasis sarcophaga*) with hairy fringed wings feed on tropical to subtropical kauri pine catkins (*Agathis robusta*), fruit of *Syzygium paniculatum*, on fallen palm fruits in Sydney and also on dead eucalypt litter. Caterpillars of a ***butterfly*** (*Deudorix epijarbas diovis*, Lycaenidae) feed in fruits of *Caryota rumphiana* on Cape York Peninsula.

See Annuals A 8, Fruit F 8.

Mealybugs (*Pseudococcus* spp.)

Mealybugs (*Pseudococcus* spp.) are ***serious pests*** of palms which have persistent, long, sheathing leaf bases that shelter mealybugs making their control difficult (Fig. 178). Developing fronds may be distorted and misshapen if infested while still folded in the crown. Weakened plants, eg those grown in very dry situations or those held in pots for too long, are ***very susceptible***. Bamboo palm is very susceptible. See Greenhouses N 25.

Mites (Acarina)

Privet mite (*Brevipaplus* sp., Tenuipalpidae) is a false spider mite and has a wide host range. It is common on palms, azaleas and gerbera (Bodman et al. 1993). **Mites** are microscopic (0.25 mm long) and only half the size of adult twospotted mites. Their legs extend forward and backward and they may be confused with the star-shaped hairs on the lower surface of kentia palms. Mites are found on ***leaf undersurfaces*** and on stems and leaf stalks. They are slow moving, red or orange and lay bright red eggs. Their feeding on palms results in yellow flecks which are often ***mistaken for disease***. Otherwise their damage is similar to that of twospotted mites except that they do not form webs and are usually not found in large populations.

Twospotted mite (*Tetranychus urticae,* Tetranychidae) is a ***major pest*** of palms during hot dry conditions (Fig. 179). Damaged fronds appear dull and lifeless or have faint white or yellowish mottle. If feeding continues, leaves yellow and may drop prematurely. Damage may be severe on weakened palms planted in a dry situation or on neglected indoor palms in a dry atmosphere. ***Regular hosing*** of leaves will help to reduce numbers. Slender lady palm (*Rhapis humulis*) is ***more susceptible*** than broad lady palm (*R. excelsa*). See Beans (French) M 29.

Palm leaf beetle (*Brontispa longissima,* Chrysomelidae, Coleoptera)

Palm leaf beetle (*Brontispa longissima,* Chrysomelidae, Coleoptera) is an introduced beetle which has ***devastated*** coconut palm, royal palm, Carpentaria palm, MacArthur palm and Alexandra palm in tropical regions such as Darwin, Cooktown and Torres Strait Islands (Fenner 1989). ***Beetles*** are narrow, flat, about ***10 mm long***, orange and black with a wide yellowish-brown band near the head (Fig. 180). They have 2 spines on the end of the body. They are sluggish during the day and move at night. Numbers increase rapidly in a new area. ***Larvae*** are plump and cream and about ***10 mm*** long with a series of spines down each side and a pair of curved hooks at its rear which resemble those of an earwig. Beetles shelter within the folds of ***new leaves*** and chew large areas of soft, surface tissue. They cause considerable damage to ***palm fronds and hearts***. Damaged areas turn brown and as leaves expand take on a scorched appearance. Once leaflets expand, they move on to new unexpanded leaves. Very young palms are more seriously damaged than older plants because their leaves open much more slowly. Plants become unsightly, and if attacks persist, vigour is reduced and plants may die.

Do not confuse palm leaf beetles with several native beetles which are minor pests but also feed on palm leaves. ***Anadastus sp.*** can be distinguished from the introduced palm leaf beetle by conspicuous knobs on the end of the antenna. ***Hemipeplus australicus*** feeds on the leaves of some palms in tropical areas of Australia. It is small, somewhat elongated beetle only about ***4 mm long***. ***Plesispa sp.*** feed between unopened leaves causing damage similar to that caused by the palm leaf beetle.

Biological control: The ***muscardine fungus*** (*Metarhizium anisopliae*) can infect palm leaf beetles and their larvae causing death. Attempts to establish a ***parasitic wasp*** (*Tetrastichus brontispae*) are being researched. Geckos and green tree frogs probably eat adults and possibly larvae but are unable to control infestations. ***Plant quarantine:*** Cairns and parts of northern Qld have been ***declared quarantine areas***. Growers must register plants sold from the quarantine area. ***Insecticides*** may be applied to unfolded leaves. Thorough penetration is essential. Repeat applications are usually recommended. If the leaves are very tightly folded, separate them by gentle handling and twisting. Seek advice from local departments of agriculture. See Trees K 15.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***White palm scale*** (*Phenacaspis eugeniae*) infests palms, magnolia, New South Wales Christmas bush, geebung, lilly-pilly, protea, viburnum, waratah and many other species. ***Adult female scales*** are white, pear-shaped and about 2.5 mm long. ***Male scales*** are smaller and covered with a white cottony substance which obscures their outline. There may be several generations in one year. White scales are mainly found in groups on ***leaf undersurfaces***, but if numerous, also on leaf uppersurfaces. ***Leaf upper surfaces*** develop yellow blotches where scales feed, leaves wither and die as numbers increase. ***Others:*** ***Circular black scale*** (*Chrysomphalus aonidum*), ***date palm scale*** (*Parlatoria blanchardi*), ***fern scale*** (*Pinaspis caricis*), ***orchid parlatoria scale*** (*Parlatoria proteus*), ***red scale*** (*Aonidiella aurantii*). See Citrus F 39.

Margarodid scales (Margarodidae): ***Cottony cushion scale*** (*Icerya purchasi*). See Citrus F 41.

Soft scales (Coccidae): ***Nigra scale*** (*Parasaissetia nigra*), ***pink wax scale*** (*Ceroplastes rubens*), ***soft brown scale*** (*Coccus hesperidum*), ***tessellated scale*** (*Eucalymnatus tessellatus*). See Citrus F 41.

Scales congregate on ***petioles, leaf sheaths, both surfaces of fronds and around crowns*** (Fig. 181). Some yellowing occurs on the tissues where they feed. Young scales attack developing leaves but are not obvious until they are adults and leaves are mature. Some scales are ***easily dislodged***. Because leaves are long-lived, hard scales can become established. ***Sooty mould*** which grows on the ***honeydew*** produced by ***soft and margarodid scales*** and which makes plants unsightly can be removed by regular hosing. Infestations of ***soft scales*** may be controlled by applications of white oil. On palms the concentration of insecticides and white oil should be reduced to ***avoid damaging leaves*** and do not apply on hot days. When treating potted plants allow excess spray to run into pots. See Citrus F 39, F 41.

Thrips (Thripidae, Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause ***leaf silvering***. Leaves are also disfigured by the dark sticky drops of ***thrips excreta***. Thrips and their excreta are usually found on ***leaf undersurfaces*** (Fig. 182). See Greenhouse N 24.

Plague thrips (*Thrips imaginis*) in some years may appear in large numbers and feed on ***flowers*** causing premature browning of the flowers and reduced fruit set. Control is not usually necessary. See Roses J 6.

Weevils (Coleoptera)

Palm weevil borer, four-spotted coconut weevil (*Diocalandra frumenti,* Curculionidae) is a seed feeder of palms especially Canary Island date palm (*Phoenix canariensis*) and coconut, also cotton, sorghum and some other plants. ***Larvae*** attack ***all parts of the palm***, especially leaves, fruit-stalks and roots causing premature fruit fall. They bore into ***leaf bases*** from the trunk to the leaflets. The ***trunk*** can be bored at all heights. Natural enemies in Australia are not presently known. Where the insect is known to occur, cuts made to remove leaves should be painted with an acrylic paint or tree wound dressing to avoid attracting adult insects (Brough et al. 1994). ***Palm seedborer,*** kentia palm seed borer (*Coccotrypes dactyliperda*, Curculionidae) adults (weevils) bore into palm seed.

Seed weevils (Bruchinae, Chrysomelidae) feed on fleshy tissue of ***palm seeds*** preventing germination. Seeds show a marked reduction in weight and a tell-tale exit hole (although sometimes it may be covered with a flap of tissue). Fat, white, legless ***larvae*** feed in seeds of native species of *Calamus.* Weevils and their larvae will attack ***seed*** while it is ***on the tree***. See Seeds N 75.

Sugarcane weevil borer, New Guinea sugarcane weevil (*Rhabdoscelus obscurus,* Curculionidae) is a ***major pest*** of palms and sugarcane in north Qld. ***Weevils*** are about ***10 mm*** long, of variable colour with 6 distinct patterns of light and dark markings. They may live for years and feed on the tops of palms which may die from the attack. Female weevils can live for possibly years and lay up to 600 eggs on the epidermis and leaf bases. ***Larvae*** are white, legless with a dark reddish brown head and about ***8 mm*** long. Up to ***several hundred larvae*** may feed and develop within the ***trunk*** of a ***single*** 4-6 year-old coconut trees. They pupate after several months in a fibrous cocoon in the tree. Secondary disease organisms may invade damaged areas, palms may die and blow over. ***Borers in all plants are difficult to control chemically.*** Infested plants should not be sold. Do not use bagasse in potting mixes as this may attract adults. Remove dead fronds and infested palm debris to reduce level of infestation. Infested plant material and debris should be ***destroyed***. A ***parasitic fly*** (*Lixophaga sphenophori*) has been released and under favourable conditions may bring about a high degree of control. ***Predators*** include rats which eat the cocoons and the cane toad which feeds on adults. The ***green muscardine fungus*** (*Metarhizium anisopliae*) also attacks borers under favourable conditions. Some palm species are more ***susceptible*** than others (Halfpapp and Elder 1994). Seedlings and small plants may be sprayed with ***insecticide*** (Brough et al. 1994).

Control of seed-eating pests is usually ***impractical***, although if seed is thought to be contaminated it should be treated with insecticide ***before sowing***. See Trees K 11, K 17, Vegetables M 17.

Others:

Giant grasshopper (*Valanga irregularis*) and ***migratory locust*** (*Locusta migratoria*) in the tropics may chew huge chunks from ***palm leaves***, often leaving just midribs. Damage is unsightly, and may stunt growth. Young plants may die. Squashing is effective on small palms, sprays may be necessary in nursery stock. Attacks on larger palms are difficult to control. Ensure plants are healthy so that they may recover from attack. ***Longicorns*** (Cerambycidae) occasionally bore holes into trunk and crown shafts of some palms. The scattered exit holes do not appear to cause any major damage or reduce the structural strength of trunks. ***Larvae*** bore shallow tunnels usually in the softer upper part of the trunk (where it exudes sawdust) or sometimes in the crown and crown shaft (where it exudes a white waxy sap that resembles toothpaste). ***Termites*** (Isoptera) may quickly destroy palms in tropical areas. Termites attack palms from below the ground, invading roots and progressively damaging the trunk. By the time the termite damage is noticed, the plant is usually too badly damaged to be saved. Termites are ***difficult to control*** and ***regular inspections*** of palms are necessary in tropical areas. Any obvious termite colonies in the area should be destroyed along with dead or dying tree stumps. ***Others: Ants*** (Formicidae, Hymenoptera) may be attracted to dates. ***Driedfruit beetles*** (Nitidulidae) feed in flowers of palms and pandanas (*Platychoropsis*). ***Earwigs*** (Dermaptera) may invade the crowns of palms. ***Millipedes*** (Diplopoda) may eat fleshy roots of palms. ***Plantsucking bugs*** (Hemiptera) may feed on dates. ***Springtails*** (Collembola) and ***wireworms*** (Elateridae) may attack seedlings. ***Whiteflies*** (Aleyrodidae), eg ***coconut whitefly*** (*Aleurodicus destructor*) and ***greenhouse whitefly*** (*Trialeurodes vaporariorum*), may attack palms; their activities are followed by sooty mould which develops on their exudates.

SNAILS AND SLUGS

Snails and slugs can damage seedlings and newly potted up plants. See Seedlings N 70.

VERTEBRATE PESTS

Birds may feed on dates. ***Mice and rats*** at certain times of the year may quickly gnaw through stems of young palms in nurseries; they may be controlled by baiting. See Fruit F 13, Seeds N 77.

Non-parasitic

Environment: ***Hail*** may tear large pieces from leaflets, leaf segments, inflorescences and other areas. Damaged areas may be invaded by ***secondary fungi***, eg *Alternaria*, and damaged plants should be sprayed immediately with a fungicide. ***Freezing damage*** may occur when hail collects in sunken sites such as the top of the crown and around objects at the base of trunks. As it thaws adjacent plant tissue can be damaged. Many species of palms, especially those of tropical origin, are sensitive to cold especially ***frost*** (Bodman 1995). ***Young plants*** are more susceptible than mature specimens, but even they may be damaged. ***Roots***, especially the growing tips, are very sensitive to freezing. Ground temperatures of -2^{o}C may cause considerable damage. Because palms have a ***single growing apex***, if that is irreparably damaged death follows. Frost injury is indicated by blackening of the foliage and collapse of developing leaves and brown patches on mature fronds. ***Susceptible species*** collapse dramatically, usually going brown or black with the crown becoming a soggy mess. Protect from mild frosts by planting close to buildings or large shrubs, or under protective canopies of established trees. In cold areas, sensitive species must be grown in glasshouses. ***To prevent sunburn*** (high temperatures which physically burn tender leaves) most species need to be protected from direct exposure to hot sun for the first 2-3 years and then gradually acclimatised (hardened) to the effects of sun. Shade-loving palms should be protected at all times. Premature or unexpected exposure to hot sun results in white or brown papery patches on leaves. In severe cases whole leaves or whole plants may die. Crowns of older palms (and sometimes younger specimens) of *Howea* and Bangalow palm may take on a ***twisted*** or lopsided appearance with most fronds seeming to end up on one side. Trunks may bend or kink below the crown. Damage by wind, hail, tree branches, or perhaps pest or disease organisms, is thought to be the cause. Most palms need ***a plentiful supply of water and good drainage*** during active growth, eg in spring and summer. Palms are generally quite ***resistant to dry soil*** but in cases of severe dryness, fronds and leaflets take on a wilted appearance and may fold together or curl inwards. Palms may stay in a wilted state for long periods without obvious damage, although constrictions in the trunk or very short internodes may occur. Following drought, tips of leaflets usually wither and dry back. ***Hot dry winds*** may damage developing fronds of sensitive species. When they open they have grey or white papery patches. ***Strong winds*** may shred leaves. Columnar trunks are very resistant, even the long slender ones merely bend during cyclones. It is important to know the ***general environmental conditions*** a particular species of palm requires, eg ***Lady palm*** (*Rhapis multifida* Jade Empress) tolerates an air conditioned environment and low light levels, and is long lived in containers.

Nutrient deficiencies, toxicities: Many seedling palms die due to ***excessive use*** of ***chemical fertilisers***. Older palms may also suffer from deficiencies (Reed 1988). ***Nitrogen deficiency*** is common in coastal districts with deep sandy soil. It causes crowns to yellow and older leaves to whiten, yellow or even bleach, with dead patches on leaflets. ***Zinc deficiency*** (little-leaf) has been reported in laboratory tests. ***Salt burn:*** In coastal districts, onshore winds deposit salt from seawater on leaves. Many species are ***sensitive***. Margins of leaflets are burnt and become white and papery. Usually only causes a minor setback to growth and affects the plant's appearance. Hose plants down thoroughly after onshore gusts where practical. ***Excessive soil salinity*** may also cause foliage burns and root rots. ***Sensitive species*** include *Arecastrum romanzoffianum* (generally tolerant), also *Chrysalidocarpus lutescens, Phoenix rupicola*. *Caryota* spp. are ***especially sensitive*** to salt burn (Jones 1984). Excessive salinity can be prevented by using good quality potting mixes and good irrigation practices. Reduce the use of fertilisers with a high salt index, eg potassium chloride, sodium nitrate and ammonium nitrate. Use slow release fertilisers with caution in hot weather, some brands may be more suitable than others. Ensure irrigation applied is sufficient to leach excess salts out of pots once per week or fortnight. ***Monitor*** salt levels. ***Hot weather*** can also promote leaf scorching if the soil mix is allowed to dry out, for even less than 1 hour! The decreased moisture in the mix causes salt levels to increase dramatically which then causes foliage burn (Reed 1988).

Pesticide injury: Polishing foliage of indoor palms with white oil to clean leaves and create a glossy appearance or control scale may cause patches of dead brown tissue, oil should not be used stronger than a dilution of 1:60 with water and this can be further diluted to 1:80 during hot weather. Some miticides may damage palms, so test on a few plants first before large scale use.

Poisonous properties: ***Severe skin rashes*** and itching may result from contact with juice of Carpentaria and some other palms when collecting or cleaning fruit. ***Palms with spiny*** trunks or leaves should not be used indoors or planted where children play.

Others: ***Only prune*** unwanted clusters of fruit or dead fronds. If the top of a palm is cut off the growing apex is removed and the stem will die. A ***projectile firing fungus*** (*Sphaerobolus stellatus*) of minor importance may grow on wood products or manure in potting mixes and disfigures plant surfaces. The small black or brown fruiting bodies about 1 mm across are found on the surfaces of leaves and stems (Brough et al. 1994). ***Sooty mould*** grows on the excretions of sucking insects, eg mealybugs, soft scales, whiteflies, disfiguring them. ***Spiders, flies and cockroaches*** often live among palm fronds.

WEEDS

Weeds amongst palms growing ***in the field*** may be controlled either by mulches, cultivation, mowing or by herbicides. ***Post-emergence*** desiccant-type (contact) or systemic herbicides are suitable for controlling weeds under date palms. ***Pre-emergence*** herbicides may be used during establishment. See Trees K 21. Weeds in ***indoor containers*** may be controlled by using weed-free mixes, mulching the surface or by pre-emergence herbicides.

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Dates in Western Australia (WA Farmnote)
Growing Palms (NT Agnote)
Leaf Spot Diseases of Palms (NT Agnote)
Palm Leaf Beetle (NT Agnote)
Palms (WA Farmnote)
Palms : Indoors (SA ABG Leaflet)
Production of Kentia Palm Seedlings (NSW Agfact)

Associations, Journals etc. (Jones 1989)

Australian Chapter, West Pymble
Australian Kentia Palm Corporation (AKP)
Australian Palm and Cycad Society
GrowSearch (database (Qld DPI)
Kentia Association
North Queensland Palm Society
Palm and Cycad Society of New Zealand
Palm Society of the Northern Territory
Palm Society, Kansas, USA (Journal - Principes)
Specialist Palm Growers
Townsville Palmetum Botanic Gardens

See Preface xii, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Dates and coconuts have virtually supported whole civilisations and are ***still major crops*** in north Africa and Polynesia. Palms have historically and traditionally been of great importance and used for building materials (timber and thatch), clothing, ropes, fuel, furniture and food. Although modern technology has superseded many of their uses, they are ***still used today*** for food (date, coconut, oil, betel nut, sago, palm sugar), medicine, baskets, buildings, clothing, oils, varnishes, wines and spirits, fuel and fodder. In ***ornamental horticulture*** they are used as potted plants for ***interior landscaping,*** for ***outdoor landscape plantings*** in groups or in palm gardens and for ***floral arrangements*** (especially those leaflets arising from a single base area like a fan). Those selected as potted plants adjacent to pathways, or for floral work, should not be spiny. Palms are ***expensive*** because they ***grow slowly*** so they are not used for quick cover. An expert database systems for palms called ***PALMS*** (Prototype Application of Language Meaning Structures) has been developed to provide information on palms for Florida conditions by the University of Florida.

Resistant varieties: Certain species are more prone to particular diseases (Forsberg 1987). For example, ***sago palm*** (*Cycas revoluta*) are susceptible to mealybugs; ***parlour palm*** (*Chamaedorea elegans*) to salt toxicity and spider mites; ***sentry palm*** (*Howea* spp.) to mealybugs, scale and salts. Where practical grow palms which have ***some resistance*** to local problems.

Plant quarantine: Plants sold from ***designated quarantine areas*** in Qld, must undergo prescribed pesticide treatments for ***palm leaf beetle*** before dispatch.

Disease-free planting material: Prevent introduction of diseases and pests. Only purchase or propagate from plants ***guaranteed free from diseases and pests***. Select new plants from other nurseries carefully and segregate them until shown to be healthy. Avoid in ground palm plantings near nursery areas. Some ***diseases*** of palms, especially *Rhizoctonia solani* and *Sclerotium rolfsii*, are introduced in germination media, planting containers and seed.

Establishment and Maintenance

Propagation: By seed, tissue culture. If seed is contaminated it can be treated with ***insecticide*** before sowing. Palm seeds are often slow and difficult to germinate. ***Advanced specimens*** of many palms can be ***transplanted*** successfully provided that a significant portion of the root system is removed intact and that correct after care is provided. For very large palms obtain expert advice and use proper equipment.

Cultural care and maintenance of potted palms: Different palms require different conditions. For most palms, the key to good growth is ***adequate watering***. However, water frequently only if the palm is growing actively, otherwise water only to keep the soil damp. Use ***well drained potting mixes*** to discourage *Pythium* and *Phytophthora* and keep foliage dry or ensure it dries rapidly. Provide good air circulation. If either the soil or the atmosphere, ie near heaters or air conditioners, is too dry, leaves are likely to dry out and brown on the tips. ***Humidity*** can be increased by hosing the fronds or by misting them with water. Provide adequate ***light*** as low light encourages soft foliage which is prone to injury. Try to provide filtered or indirect sunlight. ***Avoid excess nitrogen and low potassium*** which could predispose palms to leaf diseases. Fertilise only when palms are actively growing. ***Excess fertiliser*** may kill palms. Rooms with daily ***temperatures*** between 18 and 25^{o}C are acceptable, higher temperatures are preferable. Palms can be rotated between indoor and shady outdoor positions. Avoid placing palms under or near overhead ***fans*** or severe burning of fronds will result. Container palms grow best when ***partially pot bound***. New roots are produced regularly and on mature plants they may develop above ground and vigorous potted specimens may be pushed up out of the pot or the pot may crack. Palms should be repotted every 2-3 years. Indoor palms may live for ***4-5 years*** provided they are fed and watered regularly and given an out-of-house rest and hosing down each month or so. ***Avoid injury*** to plants during repotting. When planted out they require protection from sun and wind. Young palms will not compete with ***grass or weeds***.

Sanitation/Plant quarantine: Destroy and segregate diseased palms. If possible, spray or wipe leaves of ***indoor palms*** to remove dust, mealybugs, scales and twospotted mites once a month with dilute soap solution, then rinse leaves with clean water. Palms will shed or hold fronds depending on the species. The only ***pruning*** required is to remove old untidy fronds for the sake of appearance. Preferably remove diseased fronds and plant debris, but if considered necessary, frayed leaflets may be singed off with a flame rather than cutting with scissors. ***To prevent contamination from soil,*** stand pots on coarse gravel aggregate at least 50 mm deep or better still, on raised benches. ***Disinfect*** working benches, work areas and equipment regularly. Use clean disinfected pots and tools. ***Pasteurise*** or treat potting mixes. See Greenhouses N 22, Nurseries N 51.

Pesticides: Various fungicides and insecticides are registered for use on palms. If *Pythium* or *Phytophthora* is suspected ***irrigation water*** may need to be treated.

Postharvest

Florist greens: ***Harvest*** fully mature leaves of parlour palm (*Chamaedorea elegans*), they may be ***stored*** in moisture retentive boxes at 7^{o}C for 2-3 weeks (Nowak and Rudnicki 1990).

Potted plants: ***Fan palms*** (*Chamaerops* spp.) and ***parlor or good luck palms*** (*Chamaedorea* spp.) need dispersed light or half-shade and moderate watering. They are ***ready to sell*** when plants are well established in pots with roots visible on the outside of the soil ball. ***Fan palms*** (*Chamaerops* spp.) require dispersed light or half shade and moderate watering. They grow in variable temperatures, withstand dry air and may be stored or transported for up to 10 days in darkness at 13-16^{o}C and relative humidity of 75%. ***Parlor or good luck palms*** (*Chamaedorea* spp.) require that the soil ball be kept moist and the temperature remain at about 18-20^{o}C (Nowak and Rudnicki 1990).

Roses

Fig. 183. Virus symptoms on rose. ***Left :*** Line patterns. ***Right :*** Vein-banding. Dept. of Agric. NSW.

Fig. 184. Anthracnose (*Sphaceloma rosarum*), grey spots with definite black margin. Dept. of Agric. NSW.

Fig. 185. Black spot (*Marssonina rosae*), black feathery spots. Dept. of Agric. NSW.

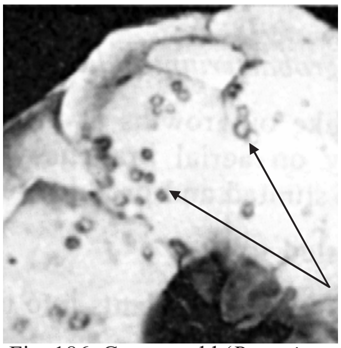

Fig. 186. Grey mould (*Botrytis cinerea*). Each spot is caused by the germination of one spore. Dept. of Agric. NSW.

Fig. 187. Stem canker (*Leptosphaeria coniothyrium*). Dept. of Agric. NSW.

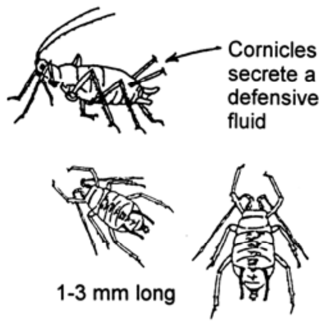

Fig. 188. Aphids (Aphididae) have 2 cornicles.

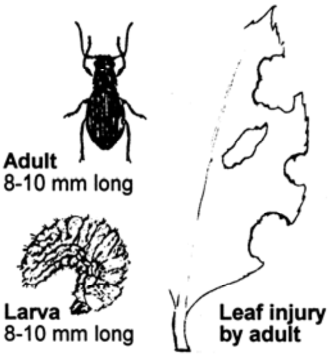

Fig. 189. Fuller's rose weevil (*Asynonychus cervinus*). Dept. of Agric. NSW.

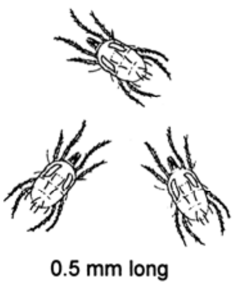

Fig. 190. Twospotted mites (*Tetranychus urticae*) are microscopic.

Fig. 191. Plague thrips (*Thrips imaginis*).

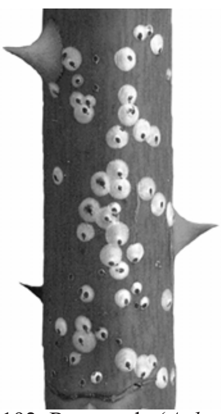

Fig. 192. Rose scale (*Aulacaspis rosae*), round female scales.

Fig. 193. Leafcutting bee injury (*Megachile* spp.). Dept. of Agric. NSW.

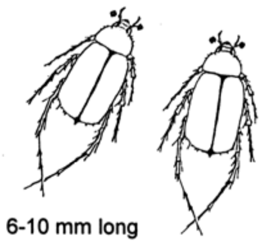

Fig. 194. Nectar scarabs (*Phyllotocus* spp.).

Roses

Rosa spp., *Rosa hybrida*
Family Rosaceae (rose family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Scientific name: Apple mosaic, *Prunus* necrotic ringspot, tobacco leafcurl virus.

Host range: Each virus has its own host range. ***Apple mosaic virus***, eg apple, chestnut, hazelnut, hops, *Prunus* spp, rose, ***Prunus necrotic ringspot virus***, eg *Prunus* spp., hops, rose (more than 40% of roses were infected in Victoria during 1984). ***tobacco leafcurl virus***, eg honeysuckle, rose. Overseas, also rose ring pattern, rose rosette virus, rose streak, rose yellow mosaic, strawberry latent ringspot and tobacco streak.

Symptoms: Symptoms only develop on ***leaves*** (Fig. 183) but there is usually a general reduction in bush size, number of flowers per bush and rose quality. Leaf symptoms vary and include ***veinbanding*** (a narrow band of yellow along the entire vein network of the leaflet, an isolated area of the leaflet or only around the margins, probably caused by tobacco leafcurl virus), ***chlorotic mottling*** (a yellow mottle involving the minor veins of the leaflet which may gradually spread to a general yellowing of the whole leaf) and ***line patterns*** (many lines or broad bands of pale green or creamy-white tissue, probably caused by *Prunus* necrotic ringspot virus). Virus expression depends on variety and environmental conditions. Viruses may be latent (does not induce symptoms).

Overwintering: In canes, buds and roots of infected plants. Although only leaves show symptoms, virus is present in all parts of the plant.

Spread: All virus diseases of roses are spread by ***vegetative propagation***, eg scions (budding and grafting material) and rootstocks from infected rose plants. *Prunus* necrotic ringspot is also spread by ***pollen*** which may lead (rarely) to infection of the parent plant (this may be the only way of natural spread), not by seed. Tobacco leafcurl is also spread by ***cotton whitefly*** (*Bemesia tabaci*), a recent introduction to Australia.

Control: To minimise spread:

Sanitation: Commercial growers are advised to discard infected rose plants. Home gardeners do not need to remove infected plants.

Disease-free planting material: Do not use mosaic-infected plants for budwood or rootstock. Purchase ***virus-tested rootstock and scions*** from specialist propagators who obtain rose propagation material from **Crop Health Services (Crop Hygiene)**, Institute for Horticultural Development, Agriculture Victoria.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) is a sporadic disease and is more serious on young nursery stock than on older plants in the field. Galls ranging in size from a pea to a football develop at the base of ***canes***, on ***roots*** and sometimes on ***aerial branches***. Infected plants lack vigour, are stunted and produce few flowers. ***Hairy root*** (*Agrobacterium* sp.) also occurs on roses. See Stone fruits F 125.

Others: ***Bacterial leaf and stem blight*** (*Pseudomonas syringae*) (Strider 1985). ***Bacterial leaf spot*** (*Xanthomonas* sp.) affects ground cover roses (Bodman et al. 1996).

FUNGAL DISEASES

Anthracnose

Scientific name: Imperfect Fungi:
Anthracnose (*Sphaceloma rosarum*
(= *Elsinoe rosarum*)

Host range: Roses.

Symptoms: Small, circular, black spots with ***well defined margins*** appear on ***leaves*** (Fig. 184); spots caused by black spot (*Marssonina rosae*) are ***feathery***. As anthracnose spots enlarge, their centres become grey and may later fall away, while the margins remain distinct. Defoliation does not occur to the same extent as with black spot. Young green ***stems*** and ***flowers*** may also be attacked. Anthracnose is often confused with black spot, however, it is not as common, nor as serious.

Overwintering: Infected plants, canes, fallen leaves.

Spread: Spores (conidia) are spread by wind; by the introduction/movement of infected plants.

Conditions favouring: Cool, humid weather.

Control:

Resistant varieties: Varieties vary in ***susceptibility***. *Rosa multiflora,* which is often used as a rootstock, is particularly susceptible.

Pesticides: Anthracnose may be controlled by the same ***fungicides*** used for black spot.

Black spot

The most common and serious disease of roses.

Scientific name: Ascomycetes:
Black spot (*Marssonina rosae*) (= *Diplocarpon rosae*) Do not confuse with anthracnose (*Sphaceloma rosarum*) or other minor leaf spotting fungi eg *Mycosphaerella*.

Host range: Roses.

Symptoms: More or less circular black spots with fringed margins up to 10 mm in diameter develop mainly on ***leaf uppersurfaces*** (Fig. 185). Spots vary in number from 1-20 per leaf. During damp weather, examination of the feathery spots with a hand lens shows small black blisters (fruiting bodies or acervuli) which contain spores (conidia). Severely affected leaves yellow and fall prematurely. Repeated defoliation weakens plants, causes dieback of stems and reduction in size and number of flowers. ***Young canes*** of susceptible varieties may also develop spots.

Overwintering: In susceptible varieties, in lesions on canes, as mycelium in fallen leaves, and prunings from infected plants.

Spread: Spores (conidia) are spread by wind, rain or water splash from infected plants, fallen leaves and prunings from infected plants. By the introduction of infected plants.

Conditions favouring: Warm (13-23^{o}C), wet conditions especially in spring.

Control:

Cultural methods: ***Avoid overcrowding beds*** and overhead irrigation, eg use drip or hydroponic systems; if overhead irrigating do so early in the day so foliage is dry before evening. ***Avoid overfertilising*** which causes soft growth which is very susceptible to black spot. ***Mulching*** early in spring can serve as a mechanical barrier between spores formed on old fallen leaves and new growth (in susceptible varieties the fungus overwinters on the canes).

Sanitation: Although the fungus can grow as a saprophyte on fallen leaves and prunings, the importance of collecting them has been overstressed (it is impossible to collect all fallen leaves and in susceptible varieties the fungus may overwinter on canes). ***Prune out*** infected canes during pruning, and destroy all fallen leaves and prunings. In home gardens, first infected leaves in spring can be removed, providing foliage is not wet.

Resistant varieties: Varieties vary in ***resistance***.

Pesticides: ***Fungicides*** may be applied to ***susceptible varieties*** when warm, humid conditions commence. Make sure that both leaf surfaces are wetted with fungicide. Baking soda when mixed with horticultural oil is also effective. See Roses J 4.

Damping off (of cuttings)

Black root rot, black mould (*Chalara thielavioides*) occurs on ***cuttings*** during ***prolonged storage*** under wet conditions, and in the ground. Cuttings become olive-green to dark-brown or black, roots do not develop, cuttings usually ***die***. Inspect cuttings before and after storage, discard diseased ones. ***Dust*** healthy cuttings with fungicide before storage and again before planting. ***Destroy diseased cuttings*** whether in the ground or purchased. Rose common rootstock (*Rosa multiflora*) is moderately ***susceptible***.

Crown canker (*Cylindrocladium scoparium*, Imperfect Fungi) is usually only found on ***young rooted cuttings*** if excessively watered in poorly drained sites. Initially a slight discolouration of the stem bark at soil level and above develops. Later, the discolouration deepens to dark brown and tissue appears water-soaked. Lesions tend to coalesce, forming continuous brown to black areas. Girdling of the main stem ***kills the plant***. Destroy all diseased plants. ***Inspect*** new plants for disease before planting and destroy any that are infected. No chemical controls are available.

Others: ***Other fungi*** may cause damping off on rose cuttings, eg ***grey mould*** (*Botrytis cinerea*).

See Seedlings N 66.

Downy mildew

Downy mildew (*Peronospora sparsa*) is more severe on ***young growth*** than older tissue, and occurs during cool, humid weather (optimum 18^{o}C and > 85% relative humidity). Purplish to dark brown irregular spots, many of which are angular in shape, develop on ***leaves***. In humid weather, a downy growth of fungus develops on leaf undersurfaces beneath the spots. Young leaves droop and fall off readily. Purple spots, streaks and blotches develop on ***stems and flower stalks***. When severely infected, young shoots die back. Purplish brown spots may develop on ***petals***. If ***flower buds*** are infected, flowers may be deformed. See Annuals A 5.

Grey mould

Grey mould, blossom blight, petal spot, *Botrytis* (*Botrytis cinerea*) is common during cold wet springs. ***Flower buds*** turn brown and decay. Petals of partially opened ***flowers*** turn brown and shrivel. In wet weather, affected areas become covered with furry, grey spores. ***Petals*** of fully-opened flowers develop small ring-like markings which are reddish in light coloured varieties and creamy-white in dark coloured varieties. Each ring-like marking indicates where a spore has germinated (Fig. 186). ***Petals*** become more ***susceptible*** as they age. See Greenhouses N 22.

Powdery mildew

Powdery mildew (*Sphaerotheca pannosa* var. *rosae*) is a ***common and serious disease*** of roses. ***On young leaves*** slightly raised blister-like areas become covered with a white powdery fungal growth. Extensive areas of both leaf surfaces are covered. Leaves become curled and distorted as they expand, older leaves are not usually distorted. Areas of infected leaves usually die. ***New shoots*** may become covered with powdery spores and misshapen. Small patches of white fungus may develop around or close to ***thorns*** on ***canes***. ***Flower buds*** may be attacked and may either fail to open or open partially. ***Petals*** may also be attacked becoming distorted, dwarfed and eventually dried. The fungus ***overwinters*** on canes (especially around the ***thorns***) as well as on plant debris. Spores do not require free water on leaves to germinate, dew is sufficient. ***Biological control:*** The use of a yeast-like antagonistic fungus (*Sporothrix flocculosa*) plus a surfactant (to reduce dependency on humidity) is being researched for the control of powdery mildew in commercial crops (Belanger et al. 1994). ***Susceptible varieties*** include many hybrid teas, polyanthus, climbers and ramblers such as Dorothy Perkins. ***Resistant varieties*** include shiny leaved climbers such as Cecile Brunner. ***Fungicides*** are registered for use. ***Baking soda*** when mixed with horticultural oil and applied every 8-10 days (more often than for commercial fungicides) is also effective. One recommendation is a level teaspoon baking soda or sodium bicarbonate to each litre of water, the use the surfactant or horticultural oil assists it to adhere. The long term effect on rose foliage or soil is unknown. This mixture is reputed also to be effective against powdery and several other fungi on a range of plants (Horst et al, 1992). See Annuals A 6, Cucurbits M 52.

Rust

Rust (*Phragmidium mucronatum*) infects ***leaves*** of roses during warm, wet or humid weather in spring, summer and autumn. Only leaves are attacked. Bright orange powdery spots (uredia containing spores) develop on ***leaf undersurfaces*** in spring and summer. Towards the end of summer, dark brown to black spore masses (telia) appear amongst the orange uredia. ***Leaf uppersurfaces*** become speckled with yellow. Severely affected leaves fall prematurely. Repeated severe rust infection reduces plant vigour. Cultivars vary in ***susceptibility***. Many other rusts (*Phragmidium* spp.) affect roses overseas. See Annuals A 7.

Stem cankers, cankers, dieback

Scientific name: Ascomycetes:
Stem canker (*Leptosphaeria coniothryium*)
Other fungi may also cause stem cankers and dieback, eg *Botryodiplodia, Botryosphaeria ribis, Cercospora, Coryneum*, *Cylindrocladium scoparium.*

Host range: Wide range of woody plants, eg rose, apple, pear, raspberry.

Symptoms: ***Canes*** infected with *Leptosphaeria* develop pale yellow or reddish spots on the bark. These later enlarge, turn brown, develop cracks and become sunken. Numerous tiny black pin-point spore-producing structures (pycnidia) develop on these areas which produce spores (conidia). In ***more resistant varieties*** canker development may be checked where the branch joins the main stem but in susceptible varieties, the canker may progress down the stem to the base of the plant, eventually killing it (Fig. 187). ***Pruning stubs*** are the most common sites of canker development. Stubs usually die back to the first node anyway, but they are not necessarily infected.

Overwintering: Infected rose canes and other hosts. Debris from infected plants. Some of the fungi which cause stem cankers may be found on the thorns and other dead tissue on rose plants.

Spread: Spores are spread from the fruiting bodies by wind and water splash.

Conditions favouring: The fungus is a ***weak parasite*** and infects host plants through dead or dying tissue; poor pruning practices, pruning stubs, flower-gathering, tying abrasions, thorn scars, frost damage. Damaged areas enlarge due to infection and become brown, purplish or grey. Wet weather.

Control:
Cultural methods: If frost is prevalent, protect plants during the winter months. Do not prune during wet weather.
Sanitation: When pruning or gathering flowers, use ***sharp secateurs*** and make a clean slanting cut (no frayed edges) close to the main stem or immediately above a bud. Cut off infected canes well below the discoloured area and just above a bud. If stem canker is a serious problem, ***sterilise secateurs*** between cuts. Seal large cuts to prevent soft centres from shrinking which allows moisture and fungal spores to enter.
Resistant varieties: Varieties vary in ***resistance***.
Pesticides: None are recommended.

Others

Root rots (*Phytophthora* spp. *Pythium* spp.) especially in ***hydroponic systems*** (Bodman et al. 1996).
Silver leaf (*Stereum purpureum*) may cause dieback of ***older roses***. Small brownish shell-shaped fruiting bodies with mauve gills may later develop on dead stems. See Trees K 8.
Verticillium wilt (*Verticillium dahliae*) uncommonly causes wilting of foliage and dieback of branches. It may be restricted to one side of the plant, the other side remaining healthy. Underlying woody tissue is brown. See Vegetables M 9.

NEMATODE DISEASES

Root knot nematodes (*Meliodogyne* spp.) causes plants to look unthrifty, stunted and yellow. Symptoms may be confused with deficiencies and fungal root diseases. Small galls develop on roots. See Vegetables M 10.

Other nematodes may be associated with rose roots, resulting in yellowing of foliage associated with generally poor plant vigour, eg ***dagger nematodes*** (*Xiphinema* spp.), ***root lesion nematode*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus, Rotylenchus*), also *Aglenchus, Basiria, Criconema, Criconemoides, Ditylenchus, Haplolaimus, Helicotylenchus, Hemicycliophora, Macroposthonia, Paratrichodorus, Pateracephalanema, Pseudohalchus.*

INSECTS AND ALLIED PESTS

Aphids

Aphids are the most common insect pests of roses.

Scientific name: Aphididae, Hemiptera:
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum euphorbiae*)
Rose aphid (*Macrosiphum rosae*)
Rose-grain aphid (*Metopolophium dirhodum*)
Several other small, pale greenish species.

Host range: Most species found on roses can infest a wide range of plants. ***Potato aphid***, eg ornamentals, vegetables, weeds, ***green peach aphid***, eg ornamentals, fruit, vegetables, weeds, ***rose aphid***, eg rose, ***rose-grain aphid***, eg rose, grain.

Description and damage: ***Adult aphids*** are small, plump, slow moving, winged or wingless, ***1-3 mm*** long, green, yellow, pink or brown depending on the species and food plant. Most aphids have two tubes ***(cornicles)*** protruding from the end of the body (Fig. 188). ***Nymphs*** look like adults but are smaller and wingless. Nymph skins are shed as they pass from one nymphal stage to the next and are found on infested leaves and buds. They are particularly noticeable after winged aphids have left the plant. ***New shoots, leaves and flower buds*** are commonly infested and distorted by aphids sucking sap. Leaves may be shrivelled and plants weakened. New shoots may be distorted by ***other pests***, eg broad mite and cyclamen mite. Most aphids secrete ***honeydew*** on which ***sooty mould*** grows and which attracts ***ants***. Ants deter natural enemies. Honeydew, sooty mould and aphid skins disfigure plants. Aphids spread many ***virus diseases*** into and within many crops during feeding, eg the green peach aphid can transmit over 100 virus diseases. However, aphids ***do not transmit*** virus diseases of roses.

Pest cycle: Gradual metamorphosis (live nymphs, adult female) in warm climates with many generations each year. In areas where the winter is cold, eggs may be laid in autumn.

Overwintering: In warm areas there is no overwintering. In cooler areas most aphids infesting roses may overwinter on other hosts, eg green peach aphid may overwinter on peach.

Spread: By winged forms flying from other hosts, assisted by wind. Introduction of infested plants and cuttings carrying nymphs and eggs.

Conditions favouring: Humid conditions during spring and autumn. New growth on roses, abundant herbaceous weeds and shady areas. The ideal temperature for growth and reproduction of aphids is about 22^{o}C and most activity occurs during months when these milder temperatures prevail, eg ***spring and autumn*** (development only takes place from 5-33^{o}C). The rose-grain aphid is favoured by wet, cooler climates.

Control:

Cultural conditions: Interplanting with certain plants (garlic, chives, onions) which are reputed to ***repel*** some species of aphids by their aroma, may give some control on miniature roses. On plants other than roses, where aphids might be vectors for virus diseases, such repellent plantings or sprays would not give sufficient control to prevent the introduction and spread of virus diseases. If practical reduce shade.

Sanitation: Remove herbaceous weeds which are alternative hosts. Weed growth should be prevented around seedbeds and crops.

Biological control: Aphids are attacked by a range of natural enemies in spring, including ***predators***, eg larvae and adults of the common spotted ladybird (*Harmonia conformis*) and transverse ladybird (*Coccinella repanda*), lacewing larvae (Neuroptera), midges (Chironomidae, Diptera) and hover fly larvae (Syrphidae, Diptera). A ***lacewing*** (*Mallada signata*) can be purchased. ***Parasitic wasps*** (*Aphidius* spp., *Aphytis* spp.) lay eggs inside the bodies of aphids killing them. ***A. colemani*** may be very effective in unsprayed glasshouses; however, it does not parasitise the rose aphid. Virus, fungal (*Entomophthora* spp., *Verticillium lecani*) and other ***diseases*** may also contribute towards regulating populations. ***Economic damage*** may occur on roses before these natural enemies exert some control, but all of these may produce a reasonable level of control on some other hosts when migrations cease. Heavy autumn rains and the early fall of peach leaves in autumn also kill large numbers.

Physical and mechanical methods: Aphids may be ***hosed off*** rose shoots (temporarily). This procedure may damage soft-foliaged hosts. ***Aluminium mulch*** on the ground is reputed to disorientate aphids by reflecting the blue colour of the sky. Australia's hot climate creates problems with its use.

Pesticides: Foliage treatments: Commercial growers should ***monitor*** aphids weekly. Inspect the tips of 5 plants at each of 6 widely spaced locations throughout the crop, spot spray if > 5 of the 30 plants are infested (Brough et al. 1994). Aphids may be controlled with systemic insecticides during spring and autumn when aphids are first seen. Depending on the insecticide. repeat applications may be necessary. Use a coarse spray with a good pressure. Most general purpose rose sprays or dusts contain an insecticide effective against aphids. Some insecticides (aphicides) are effective against aphids only. ***Soil treatments:*** Granular systemic insecticides may be applied to soil outdoors. As they have to go into solution in soil moisture before they can be taken up by plant roots they must be applied well before aphid infestations are expected. One application may provide control for many weeks.

Caterpillars (Lepidoptera)

Leafroller moth (Tortricidae) caterpillars feed mostly on leaves which they web together. ***Ivy leafroller*** (*Cryptoptila immersana*), ***lightbrown apple moth*** (*Epiphyas postvittana*), ***orange fruitborer*** (*Isotenes miserana*). See Pome fruits F 112.

Loopers (Geometridae): ***Bizarre looper*** (*Anisozyga pieroides*), ***twig looper*** (*Ectropis excursiana*). See Avocado F 19.

Others: ***Castor oil looper*** (*Achaea janata*, Noctuidae) feeds on the ***foliage*** of rose, avocado, cherry, guava, on the flowers of mango and on the young leaves of eucalypts, *Syzygium* (Myrtaceae), wattle and mimosa (Mimosaceae). ***Painted apple moth*** (*Teia anartoides*) caterpillars may skeletonise leaves. ***Moth*** (*Chionophasma lutea*, Lymantriidae) caterpillars have been reported on roses, avocado, begonia, forget-me-not (*Myotis*), macadamia and other plants (Common 1990).

Caterpillars may occasionally chew ***leaves*** but ***buds*** are most seriously damaged. Damage is sporadic in that it may not occur the following season. See Annuals A 8.

European earwig (*Forficula auricularia*)

chews ***rose petals*** giving them a ragged appearance. Flowers are also spoilt by their presence and excrement. See Vegetables M 14.

Fuller's rose weevil

Scientific name: Curculionidae, Coleoptera: Fuller's rose weevil (*Asynonychus cervinus*) is a sporadic pest of roses. Other weevils may also damage roses, eg ***apple weevil*** (*Otiorhynchus cribicollis*), ***garden weevil*** (*Phlyctinus callosus*).

Host range: Many broadleaved plants, ***ornamentals***, eg camellia, gardenia, hydrangea, camphor laurel, rose, dahlia, eucalypt, *Pinus radiata*, ***fruit***, eg citrus, passionfruit, peach, plum, ***vegetables***, eg French bean, ***field crops***, eg Paddy's lucerne, ***weeds***, eg blackberry, fat hen.

Description and damage: ***Weevils*** are hard, rounded, grey-brown beetles about ***8-10 mm*** long. They have a short, broad snout, and usually show a faint crescent-shaped mark on each side of the wing covers. They feed at ***night***. ***Larvae*** are about ***6-7 mm*** long when fully grown and are grey-white. ***Leaves and shoots:*** Fuller's rose weevils (and garden weevils) may chew the edges of leaves, giving them a ragged saw-toothed appearance (Fig. 189). The greater part of the leaf may be chewed away leaving only the mid-vein and leaf stalk. Newly emerged adults prefer the tender foliage, while older weevils prefer tougher fibrous tissue, eg canes. ***Roots:*** Larvae may gnaw the bark of older roots, sometimes partially stripping bark off in short sections causing serious damage. The extent of root damage by the larvae on roses is not well documented. Larvae may destroy the fibrous root systems of beans, cucumber and tomato and gouge out the main root.

Overwintering: As larvae in soil or as unhatched eggs beneath loose bark, in curled dead leaves, in debris on the ground. Also as hibernating adults. Weevils emerge from pupae in the soil during summer between December and March. In dry summers, emergence is delayed until after good rains in February or March.

Spread: By crawling, by infested debris or mulch.

Conditions favouring: Common during late summer and autumn, mainly in coastal districts. Waterlogging is unfavourable to larvae and drought can prevent adult emergence. Damage on roses (and woody plants, eg citrus) usually only occurs near weedy ground, attack resulting from a spill over from nearby weeds. Herbaceous plants, eg French bean, may be attacked by larvae if planted in previously infested weedy ground.

Control: Control measures are not effective once plants have been attacked.

Cultural methods: Good weed control helps to suppress weevil numbers. Minimise damage to ***herbaceous plantings*** by thorough early preparation of land by digging/ploughing in weeds in late summer and growing a non-host crop, eg oats, to be cut or grazed and ploughed in as recommended.

Sanitation: If only a few plants are affected, weevils can be collected at night.

Biological control: ***An egg parasitoid*** (*Fidobia citri*) is important on citrus.

Plant quarantine: Eggs laid underneath the fruit calyces of citrus are a ***quarantine pest*** for exports to Japan.

Pesticides: Insecticide may be applied to plants when damage is first observed and confirmed by ***monitoring*** weevils. For citrus trees attacked by weevils, spray trunks and soil when weevils are first seen feeding on leaves. This reduces the number of eggs laid (Brough et al. 1994).

Mites (Acarina)

Spider mites (Tetranychidae): ***Twospotted mite, red spider*** (*Tetranychus urticae*) is the ***most serious pest*** of roses, especially under hot, dry conditions. ***Adult mites*** are just large enough to be seen without a hand lens. They are small, globular, almost translucent pests, up to ***0.5 mm*** long with 4 pairs of legs. Adult mites vary in colour from green-grey to bright-red. The mites have distinctive dark markings on either side of the body which are particularly large and prominent in adult females (Fig. 190). In winter adult females turn orange-red. Nymphs and adults are mainly found on ***leaf undersurfaces*** where they pierce the plant surface and suck sap. They spin fine webs on which they crawl around and to which they attach their eggs. ***Leaves*** are a dull speckled grey-green colour (sandy mottle). When severely infested leaves wither and fall prematurely. ***Do not confuse*** damage to leaves by twospotted mite with leafhopper (Cicadellidae) or greenhouse thrips (*Heliothrips haemorrhoidalis*) injury. Spider mites (*Tetranychus* spp.) are ***monitored*** prior to spraying (Brough et al. 1994, Karlik et al. 1995). See Beans (French) M 29, Trees K 24 (Table 3). ***Other spider mites: Banana spider mite*** (*T. lambi*), ***bryobia mite*** (*Bryobia rubrioculus*), ***European red mite*** (*Panonychus ulmi*).

Other mites: Bunch mite (*Brevipalpus californicus*, Tenuipalpidae), ***citrus bud mite*** (*Eriophyes sheldoni*, Eriophyidae), ***citrus rust mite*** (*Phyllocoptruta oleivora*, Eriophyidae).

Plague thrips

Scientific name: Thripidae, Thysanoptera: Plague thrips (*Thrips imaginis*)
Other species also infest ***rose flowers*** including:
Hairless flower thrips (*Pseudanaphothrips achaetus*)
Onion thrips (*Thrips tabaci*)
Tomato thrips (*Frankliniella schultzei*)
Greenhouse thrips (*Heliothrips haemorrhoidalis*) mainly infests ***leaves.***

Host range: Wide range of buds and flowers of exotic and native plants, grasses and weeds.

Description and damage: All stages feed by rasping surface tissue and sucking exuded sap. ***Adult thrips*** are small, elongated, dark coloured insects about ***1 mm*** long with 2 pairs of narrow fringed wings which lie flat when at rest. Plague thrips are light brown (onion thrips are yellow-grey to brown-grey) and are visible to the naked eye when numerous as minute specks in flower heads (Fig. 191). Thrips are easily observed by shaking them out of flowers on to a white surface. ***Nymphs*** are creamy and mostly feed on ***pistils and stamens*** reducing fruit and seed formation. Thrips enter opening ***buds and flowers*** and feed between the ***petals*** which brown prematurely and wither. Dark excrement on light coloured blossoms adds to the disfigurement. Petals of red varieties are silvered, streaked and blotched, before turning brown. Flowers may not open properly, and may be distorted and discoloured. Other agents may also cause buds to yellow, brown and fall, eg too much or too little water, excess chemical fertiliser.

Pest cycle: Gradual metamorphosis (egg, nymphs, prepupal stage in soil, adult) with many generations each season. Thrips lay eggs in the folded petals of unopened buds and in all parts of the flowers and young leaves adjacent to the blossoms. See Greenhouses N 24.

Overwintering: In warm areas, they breed continuously in flowers and all stages are found throughout the year. In cooler areas, they may overwinter in the prepupal stage in the soil.

Spread: By adults flying, assisted by wind. Movement of infested plant material. Thrips reinfest flowers from nearby vegetation.

Conditions favouring: Spring and early summer. When soil moisture decreases during summer, numbers decrease. ***Previous autumns and winters*** of above average rainfall and mild temperatures, followed by dry, sunny, spring weather. Plants under ***water stress*** are very susceptible. Sporadic pest in huge numbers some seasons and absent or uncommon in others.

Control:

Cultural methods: ***Heavy rain*** kills large numbers. In a garden situation hosing may be equally successful but may damage open flowers.

Sanitation: If only a few plants are affected, old infested flowers can be removed and placed in a plastic bag, the neck secured to prevent thrips escaping, and left in the sun for at least 3 days.

Biological control: ***Predators*** are present but their effect is slight compared with the weather. Heavy rain kills thousands of thrips. A ***tiny wasp*** (*Ceranisus* sp.) has been found on garden hosts of greenhouse thrips in NSW coastal districts. This exerts some control.

Physical and mechanical methods: Thrips avoid rose blossoms if ***foil-wrapped boards*** are placed around the plant base so that they extend 300-600 mm beyond the canopy. Apparently, like aphids, they are disorientated. It is claimed that if these shiny boards are placed in position several weeks before flowering they are superior to certain soil insecticides. See Roses J 5.

Pesticides: ***Foliage treatments:*** ***Monitor*** thrips by examining flowers of 5 plants at each of 6 widely-spaced locations throughout the crop. Spray if > 6 out of 30 plants are infested (Brough et al. 1994). Eggs are laid ***within plant tissues*** where they are protected. Apply 2 insecticide treatments, allowing time between treatments for eggs to hatch. This time varies with the species of thrips and time of the year, but in general 2 weeks between treatments is effective.

Adult thrips which have emerged from pupae in the soil at the time of the 1st treatment will also be killed by the 2nd treatment. When treating thrips in blossoms, the aim is not only to kill them but also ***to prevent reinfestation***. This is difficult, as thrips feed and shelter within opening buds and partly opened flowers, out of reach of insecticide treatments. If monitoring is not being carried out, regular spraying during spring at intervals should be started as soon as buds start to colour. Foliage and young flower spikes should be sprayed as soon as the flower buds appear. To avoid injuring bees, spray late in the day when bees have returned to the hive.

Soil treatments: Outdoor plants may be treated with soil granules as flower spikes are appearing. Repeat applications may be necessary during spring when grasses and bush dries out in surrounding areas.

Rose scale

Scientific name: Diaspididae, Hemiptera:
Rose scale (*Aulacaspis rosae*)
Occasionally other scales infest roses including:
Red scale (*Aonidiella aurantii*, Diaspididae)
Cottonycushion scale (*Icerya purchasi,* Margarodidae)

Host range: Mainly rose, also blackberry, loganberry and raspberry.

Description and damage: Only ***canes*** are attacked. All stages feed by piercing and sucking. It is an armoured scale so there is no sooty mould. ***Female scales*** are circular, white and about ***2.5 mm*** in diameter (Fig. 192). ***Young male scales*** are narrow, white and about 1 mm long. Adult males are tiny 2-winged insects. Rose scale mainly infests ***older canes*** which appear white, but younger growth may be attacked if infestations are heavy or neglected. Canes may weaken and die.

Overwintering: As reddish eggs beneath the female scale covering on canes of host plants.

Spread: Nymphs crawl; also by the movement of infested plants and cuttings.

Conditions favouring: Indiscriminate use of insecticides may kill natural enemies.

Control:

Sanitation: Destroy infested prunings.

Biological control: Many natural enemies control infestations, eg a ***web-forming moth*** caterpillar (*Batrachedra* spp.) reduces populations.

Disease-free planting material: Do not propagate from infested plants. Exclude from greenhouses by carefully examining newly purchased stock.

Pesticides: After pruning and before bud burst, dormant plants may be sprayed with ***petroleum oil*** which will not affect the natural enemies of the scale. Ensure that bases of canes are wetted by spray. Oil sprays may ***injure canes*** of some climbing varieties. ***Lime sulphur*** may be used instead of winter oil, but it stains painted trellises, fences, garages and houses, and it is ***injurious to buds*** that have broken > 5 mm and to roses that are ***not truly dormant***. Alternatively, apply an insecticide early in spring when the 1st generation of crawlers is active, and again several weeks later to kill crawlers which have hatched from eggs which were not killed by the 1st spray. Sprays alone ***do not provide*** satisfactory control. See Citrus F 39.

Others:

Greyfurrowed rose chafer (*Trichaulax philipsii,* Scarabaeidae). ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*) is not usually a problem but can rapidly build up to epidemic proportions. ***Leafhoppers*** (Cicadellidae) may cause leaves to become finely speckled. ***Metallic flea beetles*** (*Altica* spp.) and ***redshouldered leaf beetle*** (*Monolepta australis*) may chew leaves and flowers.

VERTEBRATE PESTS

Parrots and other birds may tear open and feed on the ***soft canes of new spring growth***.

Non-parasitic

Environment: ***Light:*** Roses grow in full sun and very bright indirect light. ***Temperature: Frost and snow*** can damage soft wood, cutting plants back to ground level. ***Extreme heat*** will burn or scorch leaves and 'blow' the flowers. ***Photosynthesis decreases*** when leaf temperatures are > 30°C regardless of light levels. ***Water: Bent neck*** is caused by a water deficit. Some cultivars are very susceptible. It is caused by picking too early before the top of the stem has developed enough woody tissue (lignin) to support the bloom, embolism preventing water uptake and microbial blocking of the stem. It may be overcome by purchasing roses that are slightly more open, recutting under water, acidifying water with 300 ppm citrus acid (pH 3.5) and using tepid water (40°C). ***Failure of the rose bud to open*** derives from a water deficit in the bud caused by water-flow resistance through the flower peduncle. ***Insufficient soil moisture*** is one of the commonest causes of poor growth. Sufficient water must be able to penetrate to the deepest roots to encourage a deep root system resistant to dry spells. Thick grass mulch or compacted soil may prevent water penetration. ***Leaf crisping*** (rapid dehydration of leaves once cut) is due to high sucrose levels in leaf cells due to leaf transpiration. It occurs during winter in closed greenhouses under high intensity discharge lamps and in carbon enriched environments. Growers can reduce leaf crisping by lowering vase solution sucrose levels to 1% or by reducing leaf transpiration. Adding abscisic acid to vase solutions reduces transpiration and crisping (Markhart III and Harper 1992).

Leafcutting bees (*Megaliche* spp., Megachilidae, Hymenoptera) are minor pests of rose, lilac and some native plants. ***Bees*** are 6-16 mm long, mostly black, but often have bands of light coloured hair on thorax and abdomen. Larger species resemble honey bees but are more robust and have wider heads. Beneath the abdomen are pollen-carrying hairs. When searching for pollen, bees pass from flower to flower pollinating or cross-pollinating the flowers they visit. Bees hold on to ***leaves*** with their hind legs, and with their mandibles cut out large, almost circular pieces from leaf edges (Fig. 193) to line their nest tunnels in the ground, hollow stems or wood. ***Control is unnecessary*** as damage is usually only noticed after bees have gone. Usually only a few bees cause the damage, if seen, they may be caught with a small net.

Nectar scarabs, white-clothes beetles (*Phyllotocus* spp., Scarabaeidae) are attracted to white items, eg white dahlia or rose flowers or white washing on clotheslines. ***Beetles*** are about ***6-10 mm*** long. A common species is light brown with dark brown tips to the wing covers and hind legs that are much longer than the other legs (Fig. 194). These beetles usually occur in large swarms on ***flowers***. They are pollen-feeders and cause considerable damage by pushing around among the petals with their spiny legs. ***Larvae*** are tiny white curl grubs which mostly feed on decaying organic matter and sometimes on roots, but damage is unimportant. Nectar scarabs are difficult to control as spraying involves spraying the open flowers. To avoid injuring bees, spray late in the day when bees have returned to the hive. ***Mottled flower scarab*** (*Protaetia fusca*) is about ***18 mm*** long. It is also a pollen-feeder and causes similar damage on a range of coloured flowers, but usually occurs either singly or only in twos or threes and is therefore, not a serious pest. See Turfgrasses L 11.

Nutrient deficiencies, toxicities: Common deficiencies include ***iron deficiency*** (yellowing between the veins of new foliage) and ***magnesium deficiency*** (yellowing of older leaves as yellow blotches on either side of the main vein which enlarge until the only green remaining is at the leaf tip or a V-shape near the base). See Citrus F 43. Roses do not tolerate ***salt***, bore water in Adelaide may injure roses. Ensure drainage is good, water heavily and never allow soil to dry out. Damaging levels of salt may decrease the vase life of roses. ***Excessive inorganic fertilisers*** may kill plants. Excessive use of liquid manures may cause soft, lush growth susceptible to disease, eg powdery mildew, later in the year, and wind damage.

Pesticide injury to leaves or petals of some varieties may occur during drought. ***Insecticides:*** Excessive use of ***dimethoate*** (Rogor®) and other organophosphates can cause leaf fall if applied at higher than recommended rates. ***Maldison*** (Malathion®) may damage some rose varieties. ***Oil sprays*** can injure canes of some climbing varieties. ***Fungicides: Copper*** sprays during cool (< 13-14°C) cloudy weather may cause yellowing, reddish spotting of leaves and defoliation. ***Sulphur*** and ***dinocap*** during hot sunny weather (> 28°C) can burn leaves (see also Roses J 7). ***Chlorothalonil*** may damage some rose cultivars during some environmental conditions. Fungicides may be toxic to ***natural enemies*** of some pests. ***Most herbicides*** should not be used on rose beds < 2 years old. During the early spring growth period roses are ***very susceptible*** to herbicide injury. If using ***oryzalin*** (Surflan®) avoid contact with leaves during application and apply only once per season as over-application may result in crop injury. If using ***glyphosate*** (Roundup®, Zero®) avoid drift on to leaves and green canes.

Senescence: By ***autumn***, outdoor roses often show symptoms of ***environmental stress***, eg wind, heat, insufficient water or a combination of these, resulting in silvering of parts of leaves. This should ***not be confused*** with the fungal disease ***silver leaf*** which only occasionally occurs on old roses. In ***mild climates***, leaves may not fall and in many instances, are only removed during pruning.

Others: ***Albino shoots*** occasionally develop on healthy plants. ***Black fungus gnats*** (Sciaridae) may be a minor and frequent pest in greenhouse roses. ***Bull-heading*** of flowers may occur. The flowers of the ***green rose*** (*Rosa chinensis viridiflora*) are naturally green. ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*) and ***mealybugs*** (Pseudococcidae) may infest greenhouse roses. ***Suckers*** weaken roses. Do not confuse suckers (7 small narrow leaflets instead of the usual 5) with water shoots which rejuvenate plants. To remove suckers follow the sucker back to its origin on the root and pull it away gently with a quick upward jerk of the hand.

WEEDS

Prior to planting, prepare rose beds so that they are free from annual and perennial weeds. ***After planting,*** weed-free mulches may be used to control annual weeds and reduce infestation by perennial weeds, but they should not be so thick that they prevent penetration of natural rain to the underlying soil. Weed mats may be used providing they also permit the penetration of rain and irrigation. Any weeds that do develop may be removed by hand, remembering that any soil brought to the surface will act as an efficient seed bed for more weed seed germination. Deep cultivation around rose roots should be avoided. ***Pre-emergence*** and ***post-emergence herbicides*** are registered for use on roses. ***Glyphosate*** (Roundup®, Zero®) is registered for general post-emergence weed control. ***Post-emergence selective herbicides*** are available for grass weeds. Exercise care and follow label directions during the use of all herbicides. As a general rule most herbicides should not be used on rose beds < 2 years old. Roses are very sensitive to ***herbicide injury*** during the spring growth flush.

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NSW Agfacts

Crown Gall of Roses
Diseases of Roses
Fuller's Rose Weevil
Getting Started in Cut Flower Growing (Agdex)
Nectar Scarab Beetles
Thrips

SA Adel. Bot. Garden Leaflet

Rose Culture

Vic Agnotes

Fungal and Bacterial Diseases of Roses
Pests of Roses
Post Harvest Treatment of Cut Flowers
Predatory Mite Compatibility Supplement
Rose Diseases
Rose Growing for Cut Flowers
Rose Pruning
Roses in the Home Garden
Simultaneous Grafting and Rooting of Roses
Virus Diseases of Roses

WA Farmnotes

Common Diseases of Roses
Greenhouse Roses for Cut Flower Production
Virus Diseases of Roses

Association, Journals etc.

Flower Growers Association of NSW
GrowSearch (database Qld DPI)
Growers' Talk
Pictorial Guide Slide Set (APS Press, St. Paul, Minnesota)
Rose and Fruit Tree (RAFT) Group
State/Territory Rose Soc.
The Rose

See Preface xii, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Successful rose growing either outdoors or in greenhouses means selecting the ***correct varieties*** (fashions change, growers must be tuned in on retailer and consumer preferences), and keeping up-to-date with changes in ***cultural practices***. There must be a good water supply and suitable fuel source for glasshouse heating. The site must be close to markets and other services.

Resistant varieties: Where some diseases (black spot, powdery mildew and rust) are a problem, consider using varieties with ***some resistance***, eg to black spot, powdery mildew (Kerruish 1990). Hybrid tea roses are almost immune to black spot. Pernetianas are frost susceptible. Rootstocks are selected for hardiness, disease and pest resistance, graft compatibility and nematode resistance.

Disease-free planting material: Purchase and plant virus-tested plants derived from disease-free budwood and rootstock. ***Crop Health Services*** ***(Crop Hygiene)*** in the Institute for Horticultural Development, Agriculture Victoria, supplies the cut flower industry with ***propagating material*** (scions and rootstock) of many varieties of roses, which is free from viruses and other diseases.

Establishment

Propagation: By grafting scions on to rootstocks, and by cuttings (some grow well on their own rootstock but most grow better when grafted). Roses may also be propagated by seed but seedlings are not replicas of the parent form. Rooting hormones are used for root induction in cuttings. Simultaneous grafting and rooting of roses under mist in greenhouses often suffer from grey mould (*Botrytis*) or other damping off diseases..

Cultural methods: Avoid planting roses in soil known to be ***contaminated*** ***with soil fungi or nematodes*** or treat soil prior to planting. Nematodes can be a problem in WA and many growers treat soil regularly with nematicides. Avoid areas where ***frost*** occurs. For successful rose culture ***climate control*** is essential. The ***vase life of roses*** is best if plants are cultivated at 20-21^{o}C. Cultivation temperatures that vary from the optimal shorten the vase life of flowers (Nowak and Rudnicki 1990). In summer during flowering, temperatures should be 18-20^{o}C. In winter it may drop to 3^{o}C. Roses grow in ***full sun*** or in very bright indirect light. Space plants to ***ensure adequate ventilation*** so that foliage diseases are reduced. Many roses are grown in ***hydroponic culture*** which has the advantage that roses can be grown anywhere and many soil problems are eliminated.

Maintenance

Cultural methods: Roses need abundant water during flowering and limited water during dormancy. Adequate ***irrigation*** is essential but avoid overhead watering after midday. Foliage diseases may be troublesome in ***humid conditions***, especially in greenhouses. Prune and train correctly to reduce incidence of stem cankers. Follow recommended ***fertilising schedules*** and avoid over-applications.

Sanitation: Prompt removal of spent flowers will help to control problems such as grey mould. Prunings and any infected material, leaves and flowers should be destroyed/burnt. Prune out and destroy any infected or cankered canes, eg those with black spot lesions or powdery mildew around thorns, during winter pruning.

Biological control/Pest management: ***Monitor*** aphids, fungus gnats, greenhouse whitefly, mealybugs, mites, thrips and rose scale prior to implementing control measures (Brough et al. 1994). Use ***predatory mites*** to control ***twospotted mite***. Where necessary protect new shoots and leaves with fungicides and insecticides. If predatory mites are being used to control twospotted mite, care must be taken to choose a recommended fungicide or insecticide ***non-toxic to the predators***.

Pesticides: ***Fungicides*** and ***insecticides*** are registered for the control of foliage and flower diseases and pests, eg black spot, rust, powdery mildew, blossom blight, aphids, thrips. Most ***combination rose sprays or dusts*** available to ***home gardeners*** contain a ***fungicide*** which will control black spot, powdery mildew and rust and an ***insecticide*** to control aphids, mites and thrips. ***Baking soda*** (sodium bicarbonate) combined with ***horticultural oil*** is a remarkably effective spray treatment for powdery mildew and black spot of roses (and other plants). It appears to have a broad spectrum activity against several fungi (Ziv and Zitter 1992). Registration of the product is being pursued. In Australia many amateur rose growers over the years, have found that horticultural oil has been very effective against powdery mildew.

Postharvest

Harvest*:** ***Standards are available for roses. They are graded by stem length. Roses are usually harvested when buds open slightly (calyx in a downward position). This will vary for varieties but in general, if given correct preservative treatments, vase life will be better for flowers picked a little more open than those sold in tight bud. One guide suggests that ***red and pink cultivars*** be harvested when first 2 petals begin to unfold and calyx in downward position, ***yellow cultivars*** slightly earlier than red and pink cultivars, and ***white cultivars*** slightly later than red and pink cultivars. In late spring and summer roses may be cut at an earlier bud stage than in autumn and spring. Roses to be ***stored*** should be cut 1-2 days before normally harvested. Hold cut flowers in water at all times and place in cool room to quickly remove field heat until grading (Nowak and Rudnicki 1990).

Storage/Transport: Roses do not tolerate darkness for prolonged periods and should not be stored in water for > 2 days, however, roses may be stored and transported in a variety of other ways. After storage and transport, ***recut stems underwater***, remove at least 25 mm of stem and place in a preservative solution (Jones and Moody 1993, Nowak and Rudnicki 1990, Sacalis 1993 and Salinger 1985).

Vase life: Certain rose varieties, eg Sonia, Belinda, are very sensitive to ***ethylene*** which inhibits opening. Avoid excessive sugar, sun and draughts. Preservative solutions help prolong vase life. Recut stems of ***wilted roses under water*** and submerge the entire rose in warm (40^{o}C) water containing 0.3 g/L citric acid for 2 hours (Jones and Moody 1993).

Trees, Shrubs and Climbers

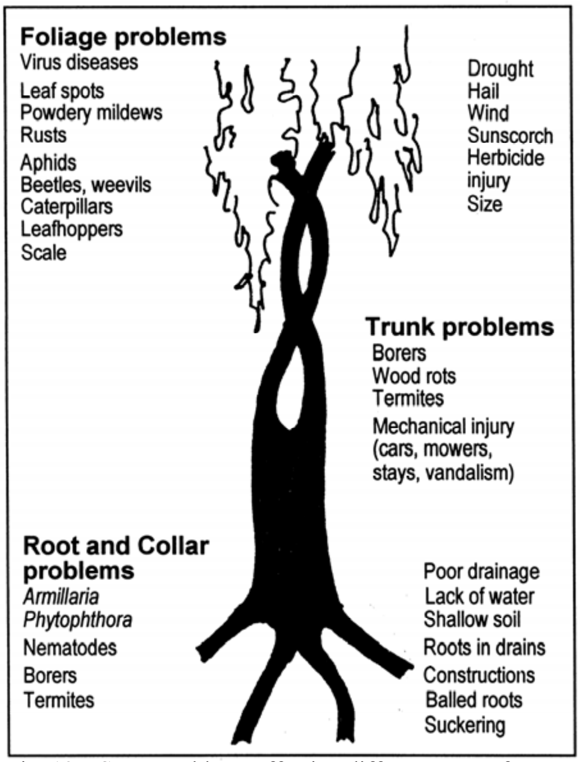


Fig. 195. Some problems affecting different parts of a tree.

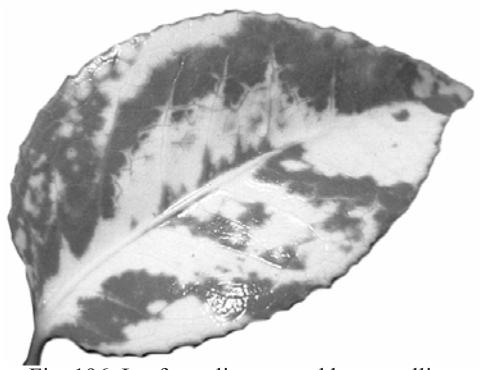


Fig. 196. Leaf mottling caused by camellia yellow mottle virus.

TREES, SHRUBS AND CLIMBERS K 1

Fig. 197. Rhizomorphs of *Armillaria* root rot (*Armillaria* sp.) on peach. Dept. of Agric., NSW.

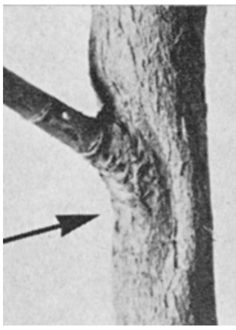


Fig. 198. Canker (Glomerella cingulata) on camellia. Dept. of Agric., NSW.

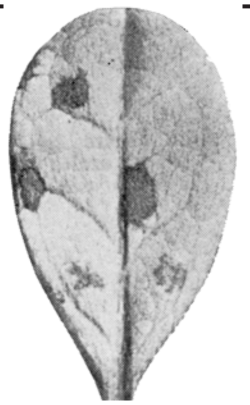


Fig. 199. Fungal leaf spot (*Septoria azaleae*) on azalea. Dept. of Agric., NSW.

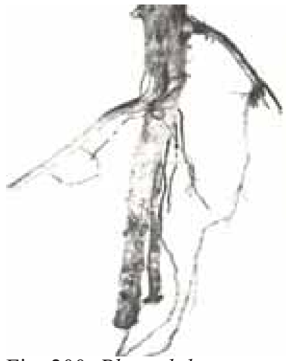


Fig. 200. *Phytophthora* root rot on citrus, lack of fibrous rootsd. Dept. of Agric., NSW.

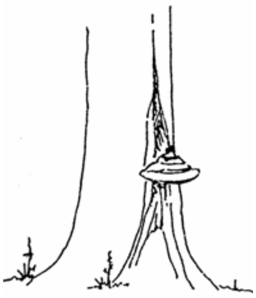


Fig. 201. Wood rot fungal fruiting bodies.

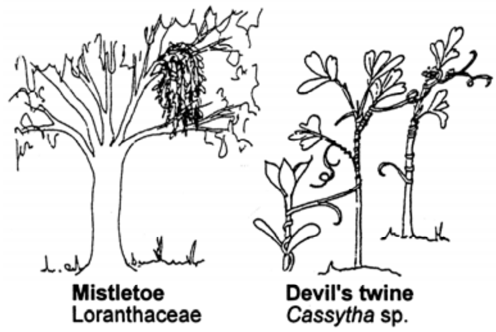


Fig. 202. Parasitic plants.

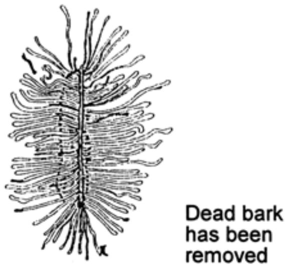


Fig. 203. Elm bark beetle (*Scolytus multistriatus*) damage. Vertical egg gallery made by the female, tunnels made by the growing larvae radiate from it.

Fig. 204. BEETLE BORERS. ***Left*** *:* Longicorn beetle (Cerambycidae) and larva (up to 45 mm long). Dept. of Agric., NSW. Larva in the sapwood of *E. saligna* (oval exit holes). B. J. Elliott. ***Centre :*** Jewel beetle (Buprestidae) cobra-shaped larva (about 30 mm long) on a background of frass packed tunnels (oval exit holes). For. Com., NSW. ***Right :*** Round exit holes of elephant weevil (*Orthorhinus cylindrirostris*). Dept. of Agric., NSW.

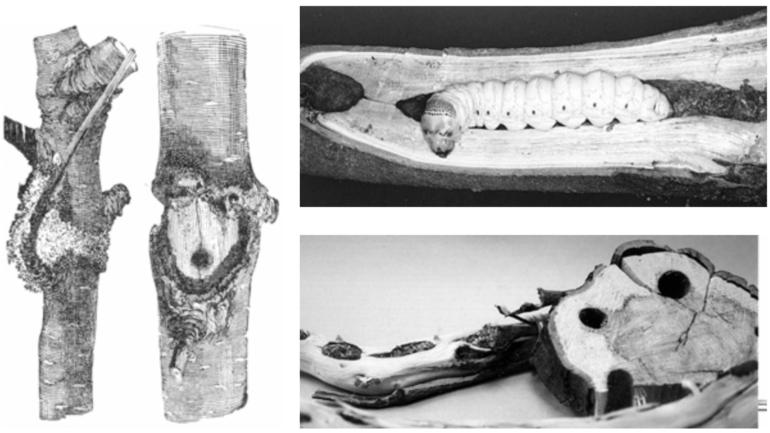


Fig. 205. MOTH BORERS. ***Left :*** Fruit-tree borer (*Maroga melanostigma*) damage. Dept. of Agric., NSW. *Right :* Wattle goat moth (*Xyleutes encalypti*) caterpillar (up to 150 mm long) and tunnels. B. J. Elliott.

Fig. 206. Termites (Isoptera) are usually 4-10 mm long, termite damage. Dept. of Agric., NSW.

Fig. 207. Cases (up to 60 mm long) of the leaf case moth (*Hyalarcta huebneri*).Dept. of Agric., NSW.

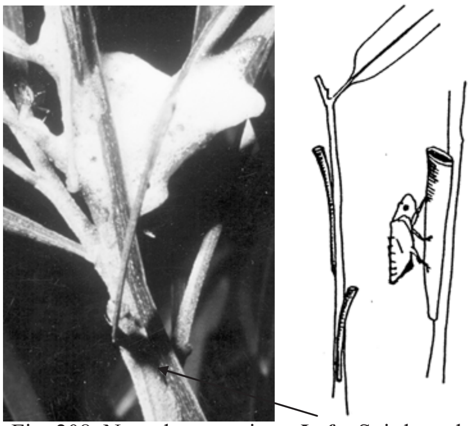


Fig. 208. Nymph protection. ***Left :*** Spittle and nymph. ***Right :*** Froghopper and cases.

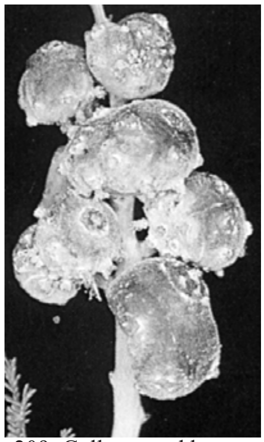


Fig. 209. Galls caused by a wasp (*Trichilogaster trilineata)* on wattle. H. J. Elliott.

Fig. 210. Red-shouldered leaf beetle (*Monolepta australis*).

Fig. 211. Leafhopper (Cicadellidae) injury to mulberry leaves.

Fig. 212. Oak leafminer (*Phyllonorycter messaniella*) damage. For.Com. NSW.

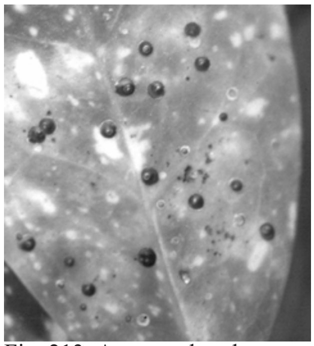


Fig. 213. Armoured scale (Diaspididae) on aucuba leaves.

Fig. 214. Christmas beetle (*Anoplognathus* sp.).

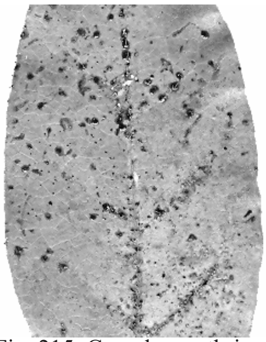


Fig. 215. Greenhouse thrips (*Heliothrips haemorrhoidalis*) spots of excreta on viburnum.

Fig. 216. Weevil injury (Curculionidae) to camellia.

Fig. 217. Lichens (algae and fungi) on a dead branch. Dept. of Agric., NSW.

Fig. 218. BENEFICIAL ROOTS ON PLANTS.

Fig. 219. Encircling roots in pot.

Trees, shrubs
and climbers

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases are ***uncommon*** in ornamental trees, exceptions include camellia (Fig 196), daphne, hydrangea, *Kennedia,* paeonia, flowering *Malus* and *Prunus* (mostly latent). Avoid propagating from infected plants. ***Virus-tested planting material*** is available for some plants, eg daphne. Using insecticides to control any insect vectors is not practical. Select ***resistant varieties***. See Fruit F 4.

BACTERIAL DISEASES

Bacterial diseases are also ***uncommon***; there are exceptions. Bacterial diseases are controlled in nurseries, field control is often not practical. Plant ***bacteria-free nursery stock***.

Bacterial canker (*Pseudomonas syringae* pv. *syringae*) affects many trees. See Stone fruits F 124.
Bacterial leaf spots (various bacteria) occur on walnut, mulberry. Bacterial spots may look similar to fungal leaf spots, some tend to be ***small black*** and ***angular***. See Vegetables M 5.
Bacterial wet wood (various bacteria) affects the ***xylem*** of some trees, eg elm, and often enters through ***wounds*** from pruning, tree injections. Symptoms include dark brown discolouration, ***weeping of fluid*** that turns brown in air, wilting of some branches. There is no known control, prune with care and repair damage promptly.
Crown gall (*Agrobacterium* spp.) mainly attacks Rosaceae. See Stone fruits F 125.

FUNGAL DISEASES

Armillaria root rot

Scientific name: Basidiomycetes:
Armillaria root rot (*Armillaria* spp.)
Especially *A. luteobubalina*

Host range: Most exotic and native ***trees***, eg banksia, bottlebrush, casuarina, cypress pine, eucalypt, grevillea, hebe, photinia, melaleuca, myrtle beech, protea, radiata pine, tamarix, wattle, willow, ***fruit***, eg citrus, pome and stone fruit orchards, grapevine, raspberry, rhubarb, ***vegetables***, eg potato.

Symptoms: Plants of all ages may be killed in ***patches***. Symptoms are similar to those caused by ***other root diseases***, eg reduced growth, dieback of branches, plants die. In autumn, during cool, humid weather, clusters of ***small honey-coloured mushrooms*** may form at the base of affected trees. Caps are 40-150 mm across, gills on freshly expanded caps are white, stalks up to 250 mm long, the ring is white. *Armillaria* grows in sheets between bark and wood of ***roots*** producing a white spongy sapwood rot, and may ringbark them. It may grow to the root collar and into the stem and ultimately girdle and kill trees. Some species produce string-like, dark brown ***rhizomorphs*** of various lengths and up to 3 mm in diameter. In Victoria, *A. luteobubalina* produces few rhizomorphs. In cooler, wetter conditions in

Tasmania, rhizomorphs form on roots, stumps and dead trees. Occasionally, eg in pome and stone fruits, rhizomorphs grow freely only on the root surface (Fig. 197), on others they grow on the root surface and may also be partially embedded in the bark. On some hosts, cream fan-like hyphae grow under bark on ***stems***. See Australian native plants N 1 (Fig. 373). Trees may weep kino or gum (eucalypt, wattle) or resin (conifers). Bark at tree bases may split.

Overwintering: As mycelium or rhizomorphs in diseased plants, decaying roots or stumps in the soil for many years. Rhizomorphs ***do not grow on soil.*** *Armillaria* can survive in stumps for > 30 years.

Spread: ***Rhizomorphs*** grow out from infected stumps, tap roots and buried logs and penetrate adjacent host roots; by direct root contact. ***Flood water*** spreads infected soil or root pieces. ***Movement*** of old decaying tree stumps, soil on equipment. ***Spores*** from fruiting bodies spread by ***wind*** can only infect dead or injured wood and stumps, not living trees.

Conditions favouring: Trees weakened by drought, fire, insects, or established on recently cleared native areas, where old stumps and roots, particularly of eucalypts, remain. Light, sandy, moist soil. Generally, the ***larger the food base*** and ***closer the host to it***, the greater the chance of rapid infection and death. Native trees with slow rotting tap roots, eg bloodwood, are a greater threat than trees with shallow easily removed roots, eg stringybark, or trees with quick rotting roots, eg red gum.

Control is only attempted in ***orchards*** or ***small plantings***. Avoid planting previously infected sites. Once *Armillaria* has invaded the main trunk there is no effective control at present.

Cultural/sanitation: ***Before planting***, ringbark native trees and leave for > 6 months before removal to deplete starch reserves and reduce infection centres. Deep rippings and clearing land of stumps and roots, fumigation, and cultivation of annual crops prior to establishing an orchard, reduces incidence of infection. Delay planting permanent crops for 2-3 years to allow remaining roots to rot. Spread may be ***slowed*** in ***established plantings*** by pruning out infected larger roots or removing soil up to 600 mm around the butt; exposure of roots to sun and air for several months may kill *Armillaria*. Prune overhanging branches 600 mm above ground to let sunlight reach butts and exposed roots. Also ***treat adjacent trees***. Treat cut surfaces with a quick drying plastic paint. Remove root pieces of native timber close to, or beneath infected trees, burn diseased material. Irrigate and fertilise affected trees.

Biological control: No effective biological control agents are available at present.

Resistant varieties: Plant ***susceptible species***, eg avocado, persimmon, pecan, walnut, on ***resistant rootstocks*** in areas where *Armillaria* is known to occur or treat soil in some way. Little is known of the resistance of Australian native plants.

Physical and mechanical methods: In established plantings, ***trenches*** (incorporating herbicide or sheeting) may be dug around infected and adjacent trees to help prevent rhizomorphs spreading to adjacent trees through soil.

Pesticides: Fumigation is successful in light-textured soils of low moisture content and is used to treat soil before planting in contaminated areas or where *Armillaria*-killed trees are being replaced.

Cankers *(trunks, branches and twigs)*

Scientific name/host range: Imperfect Fungi and Ascomycetes. Some canker fungi affect many woody species, eg ***Botryosphaeria ribis*** (= *Dothierella* sp.) and ***Glomerella cingulata***. Others only have a more limited host range, eg ***cypress canker*** (*Seiridium unicorne*) affects some conifers, ***Diplodia pinea*** some pines, ***Endothia gyrosa*** some eucalypts (see Australian native plants N 1, Fig 370), ***Cytospora platani*** affects plane trees, ***Eutypa armenicaea*** affects apricot and grape. Cankers may also be caused by viruses, bacteria or other agents.

Symptoms: Cankers are dead, often sunken localised areas of ***bark*** on branches, twigs or trunks (Agrios 1988). Healthy tissue next to cankers may increase in thickness and be ***slightly raised***. Canker fungi are active mainly in the cambium and phloem (under bark) but may invade sapwood. After entering the host they expand in all directions but especially longitudinally. Phloem and sapwood invasions results in ***sunken cracked areas*** (Fig. 198) that may expose the xylem and exude kino. In some canker fungi, eg *Dothierella,* black fruiting bodies of the fungus may develop in the bark of affected limbs.

> Cankers may be ***annual***, ie lesion development is contained by the host defence mechanisms within the first year of invasion, eg *Botryosphaeria*; ***perennial***, ie concentric rings formed when invasion by the pathogen is walled off but it survives to reinvade healthy tissue in the following year, eg large target-like cankers on *E. calophylla* and *E. gomphocephala*; ***diffuse***, ie spreading out, eg *Cryptodiaporthe* which attacks Proteaceae, eg *B. coccinea, B. grandis* and *Dryandra sessilis*). ***Some fungi***, eg *Botrytis cinerea, Phomopsis* attack stems but do not cause typical cankers.

Twigs, shoots, branches or trees may die due to girdling or the development of numerous cankers. Limbs and trees dieback, trees decline. Cankers are more serious on ***fruit trees,*** eg apple, which may lose vigour and die, than on ***forest trees*** which are not usually killed (exceptions) but suffer reduced growth, timber quality and wind damage.

Overwintering: In the cankers on host plants. Also sometimes as a ***saprophyte*** on ***dead stems***.

Spread: Spores produced on cankers are spread by wind, water splash, contaminated pruning and harvesting tools, insects. Canker fungi ***enter stems*** through wounds (pruning, flower cutting, insects, machinery, wind breakage, leaf scars from natural leaf fall, lenticels and lesions from other stem diseases). Cankers may be ***secondary invaders*** of already damaged tissue, eg by frost.

Conditions favouring: ***Stressed trees*** (eg by drought), trunks and limbs damaged by insects (borers) and pruning cuts. Wet weather. ***Plantations*** where secateurs, wounds and picking flowers accelerates spread, eg banksia stands.

Control is difficult.

Cultural methods: Trees should be kept vigorous but avoid rapid soft growth which may be susceptible to some canker fungi, eg *Glomerella*. Avoid wounds. Prune in dry weather.

Sanitation: Reduce ***number and size*** of wounds. ***Prune*** affected shoots or branches properly off at least 100 mm below cankers, burn prunings. Pruning may destroy the shape of ornamentals.

Resistant varieties: Some cultivars are more resistant than others (Agrios 1988).

Physical and mechanical methods: Trim wounds and dress with water-based acrylic paint or horticultural sealant. ***Fire*** is a practical tool for the regeneration of native plant communities after infestation with canker.

Pesticides: If cankers are a problem on ***new growth*** on some trees, eg *Glomerella* on fruit trees, fungicides may be applied before, during and immediately after leaf fall and to protect pruning and harvesting wounds.

Fungal leaf spots (*Cercosporella, Cercospora*, *Guignardia*, *Septoria*) affect many trees (Fig 199). Some are unsightly, result in defoliation and reduce vigour, but many do not cause serious damage. The only practical control on trees is the use of ***resistant varieties.*** Fungicides are only justified in ***nurseries***. ***Some fungi***, eg *Alternaria*, *Pestalotiopsis*, may colonise leaves damaged by sunscorch or drought. Sunscorched leaves have papery, greyish areas. Small black specks (fruiting bodies) which produce spores develop in these areas. Leaves may yellow and fall. See Annuals A 5.

Phytophthora root and collar rots

Scientific name: Eumycetes:
Phytophthora root and collar rots (*Phytophthora cinnamomi* **(Pc)**, *Phytophthora* spp.) are the best known fungal diseases in Australia causing ***major losses*** in nurseries, horticultural crops, cut flowers, pasture and field crops (Cahill 1993). Often called ***dieback***.

Host range: More than 900 species of ***ornamentals***, eg azalea, bush flowers, eucalypt, ***fruit***, eg avocado, citrus, ***vegetables***, eg brassica, rhubarb, ***field crops***, eg lucerne, ***weeds***. ***Pc*** has a wide host range, other species may only attack one species or plant family. Some plants are attacked by several *Phytophthora* spp.

Symptoms: Seeds, seedlings and cuttings may be attacked causing ***damping off***. Symptoms on foliage of ***older plants*** are similar to dieback caused by *Armillaria*, borers, drought, waterlogging, etc. (Davison 1994). Trees fail to produce vigorous new growth, ***larger branches*** may ***die back*** quickly or over years. Mature trees may die during dry summers, reduced root systems cannot take up adequate water. ***Root rot*** usually commences on the small fibrous roots, lateral roots may look bare (Fig. 200). Small laterals are killed and cankers may form on larger roots. If the soil is wet for long periods, the fungus may also attack permanent larger roots and crown. ***Collar rot*** usually results from infections at or near soil level. Bark may gum, be damp, soft, with discoloured wood underneath. Later, bark dries and cracks, wood underneath hardens and dries. Cankers may develop and trees may be ringbarked and die. If ***rootstocks*** are ***more resistant*** than stems, collar rot may be confined to just above the bud union. Collar rot may spread to roots or to the trunk, and on to ***leaves*** and ***fruit*** causing gumming and brown rot (citrus). Vigorous new growth may produce new bark on some hosts and prevent further spread.

Overwintering: May survive for years in infected host roots, plant debris and soil, thick-walled spores (oospores, chlamydospores) in soil. See Avocado F 21 (Fig. 111).

Spread: Considered to be introduced and spread by humans. Spores and mycelium in drainage, flood and irrigation ***water***, by movement of contaminated ***soil*** as deliveries, in containers, on tools, machinery, vehicles, footwear, diseased ***nursery stock***, by wind splashed ***rain or irrigation*** from the soil surface onto lower parts of trees (trunk and fruit). At suitable soil temperatures and moisture, ***Pc*** liberates ***zoospores*** which swim in soil water and infect fibrous roots.

Conditions favouring: Prolonged rain, over-irrigation, poor drainage, soil and under-tree aeration. Optimum temperature varies with the species of *Phytophthora*. When ***soil dries out***, activity ceases, cankers on roots heal round the edges, and new fibrous roots are formed (Fig. 200). If ***soil becomes wet again***, there is a renewal of fungus activity, surface roots in the zone most subject to drying out are the last to be affected. Planting roots ***balled*** in soil different to the one into which it is planted, creates a natural watercourse, roots developing into it are readily infected with ***Pc*** if present. Soils ***low in organic matter*** and antagonistic microorganisms. ***Herbicides***, eg atrazine and simazine, are sometimes considered to change the balance of soil microflora in favour of *Phytophthora*. ***Root injury*** favours root rots. ***Trunk damage*** favours collar rots.

Control is difficult and may involve different strategies and may vary depending on the crop (Cahill 1993, St J Hardy et al. 1994). ***For disease to occur***, there must be ***Pc*** present, a susceptible ***host*** and a favourable ***environment***. Staff must be ***trained*** to use diagnostic kits, to seek expert help and prevent spread. ***Nursery accreditation schemes*** exclude ***Pc*** from nurseries in WA. See Nurseries N 55, N 56.

Cultural methods: Avoid planting contaminated sites if infection is favourable. ***Rotate crops.*** If necessary, improve drainage, raise seed and cuttings beds, improve soil structure. ***Add organic amendments*** to increase antagonistic micro-organisms and production of ammonium which may be toxic to ***Pc***. Prepare ground early to avoid abundant undecomposed crop debris, or deep plough to bury it. ***Plant crowns*** just clear of soil and bud unions 50-150 mm above ground level, ***avoid mounding*** soil or mulch up around trunks and making dished depressions around trees. Prune back low-hanging branches to at least 600 mm above ground. If collar rot occurs, remove soil from affected butts to allow rapid drying and easy examination. Light pruning before spring growth, plus appropriate irrigation and fertiliser. ***Soil-less mixes*** and ***hydroponic systems*** reduce the risk of infection in some crops. In ***avocado*** fertilise to maintain root rot tolerance, eg potassium, superphosphate, etc. In ***bush areas***, understorey plants can be manipulated by fire.

Sanitation: Remove and destroy severely infected plants promptly and as soon as possible after harvesting. Do not compost. Practice ***nursery hygiene***. See Nurseries N 51.

Biological control: ***Suppressive soils*** are fertile and high in organic matter, microorganisms, eg amoebae, fungi, nematodes, and antagonistic to ***Pc***. A ***sterile red fungus*** is used in cereal crops. ***Other fungi*** have been researched but do not seem promising. *Trichoderma* has been used preventively against ***Pc***, *Pythium* and *Rhizoctonia* on rhododendron, gerbera and other plants in field and containers. ***Mycorrhizae*** do not seem important in ***Pc*** control, but this may apply only to some hosts.

Resistant varieties: Plant resistant or tolerant ***species*** or ***rootstocks*** in contaminated soil and adjacent areas. Understoreys in bush areas may be manipulated using resistant species (Coloquhoun and Petersen 1994). Resistant ***jarrah provenances*** can be identified by tests and micropropagated. Natural seasonal changes in ***oak bark*** affect susceptibility (Robin et al. 1993). Resistance may be ***induced*** using by ***genetic engineering***. Double stranded ***RNA*** viral genomes are being researched to either induce resistance or deliver non-virulent genes.

Plant quarantine: About 500,000 ha have been placed in quarantine by the Forestry Department in WA. ***Avoid introducing*** infected plants, cuttings, soil and water to disease-free areas. Isolate new plants (unless guaranteed ***Pc-free***) until their disease-freedom is established (practical with containers but difficult for plants to be planted directly into soil). See Nurseries N 51.

Disease-free planting material: Plant ***Pc-free*** seeds, seedlings, cuttings and nursery stock from ***Pc-free nurseries*** in ***Pc-free soil***. In some areas it may be an offence to sell or bring in to, or remove from, premises any plant which is infected with ***Pc***.

Physical and mechanical methods/Pesticides: ***Pc*** occurs deep in soils, preventing rapid eradication in the field. ***Soil/mixes*** used for cutting and seed beds may be ***pasteurised*** or ***solarised*** (only to 250 mm in some climates, eg NT), or fumigated. ***Seeds or cuttings*** may be dipped in ***fungicides***. Fungicides tend to be ***suppressive*** only, and may be applied either as a ***soil drench or as granules*** before or after planting out or at the first signs of infection (after severely infected plants have been removed) or as a regular preventative treatment. ***Highly contagious sites*** may be contained by fungicides, or by keeping sites ***completely bare*** for many years or by 'spot' treating isolated pockets with a fumigant by trained personnel after stumps and roots of trees have been removed. ***Collar rot:*** Remove diseased and surrounding tissue to healthy tissue, paint wounds with a fungicide paint. ***Irrigation water:*** Various filters and chemicals are used to eliminate ***Pc***. See Nurseries N 53, Water N 90. ***Phosphorous acid*** (phosphanate) applied as a foliar spray, aerial application, or by stem injection may assist control of ***Pc*** (and *Pythium*) on some hosts. It stimulates the natural resistance mechanisms to some of these fungi (not *P. megasperma*). Currently the most practical technique for control of ***Pc*** in small native communities, is foliar applications of phosphorous acid (St J Hardy et al. 1994). In plant communities already infested with ***Pc***, one application gives excellent control of disease over several years. Phosphorous acid is inexpensive, has a low toxicity to plants and animals, is highly mobile within the plant and is useful for endangered and rare species and on high value sites.

Powdery mildews (Erysiphales) affect many trees, eg crepe myrtle. ***New leaves and shoots*** are covered with whitish spores, leaves may roll, shoots of some species may die. Powdery mildew may be a problem on ***trimmed hedges***, eg *Photinia,* where there is abundant new growth, or mainly in ***nurseries***, eg eucalypt. Avoid clipping susceptible hedges, otherwise tolerate disease or replace with a ***resistant variety or species***. ***Fungicides*** are only justified on nursery stock. See Annuals A 6.

Root, stem and crown rots
(summary)

Armillaria root rot (*Armillaria* spp.) causes whitish fungal plaques between sapwood and bark at ground level and rhizomorphs on some roots. See Trees K 4.

Damping off (*Phytophthora*, *Pythium, Rhizoctonia*), also ***chalara root rot,*** black mould (*Chalara thielavioides*), ***cylindrocladium crown canker*** (*Cylindrocladium scoparium*), ***grey mould*** (*Botrytis cinerea*). See Seedlings N 66.

Phytophthora collar and root rot (*Phytophthora* spp.). See Trees K 6.

Rhizoctonia disease (*Rhizoctonia solani*) symptoms depend on the growth stage of the host, eg damping off, root rots and collar rots of older plants. On azalea it may cause a ***leaf blight***.

Rosellinia root rot, white root rot (*Rosellinia necatrix*). See Pome fruits F 110, Protea K 120.

Sclerotinia rot (*Sclerotinia sclerotiorum*) causes a white cottony rot on which black ***sclerotia***, about 0.5-10 mm, long develop.

Sclerotium rot (*Sclerotium rolfsii*) attacks ***stems*** at soil level, ringbarking plants. A white thread-like growth develops on which tiny round white ***sclerotia*** (size of cabbage seed) occur. Sclerotia later brown.

Woody root and butt rots (Basidiomycetes): ***Tinder punk*** (*Phellinus* spp.). See Conifers K 46, Trees K 8.

See Fruit F 7, Vegetables M 7.

Rusts (Uredinales, Basidiomycetes) infect many trees, eg birch, poplar, wattle, willow. ***Leaves*** are unsightly and fall prematurely. Depending on the weather, rust diseases may be more severe in some seasons than others. Removal of infected trees is not recommended (gall rust on wattle is an exception). The only practical control for rust diseases on trees is the use of ***resistant varieties***. ***Fungicide applications*** are only justified on ***nursery stock***. See Annuals A 7.

Wilts are ***destructive***, difficult to control and there is usually no cure for infected plants.

Dutch elm disease (DED) (*Ceratocystis ulmi,* Ascomycetes) is not known to occur in Australia. It lives primarily in the xylem and adjacent cells of elms. The fungus is not soilborne and is ***spread*** by spores carried by certain bark beetles, which do occur in Australia, or by natural root grafts. ***Bark beetles*** introduce the fungus into the xylem of vigorously growing twigs or larger branches on which they feed and from there, as well as from natural root grafts, the fungus spreads to the vascular system, causing ***wilting*** and ***death***. See Elm K 54.

Myrtle wilt (*Chalara australis*, Imperfect Fungi) is associated with the ***death*** of large numbers of myrtle trees (*Nothofagus cunninghamii*) in cool temperate rainforests of Tasmania and southern Victoria. In late autumn or early winter affected trees rapidly wilt. Spores are wind spread and enter trees though wounds. The fungus grows in and blocks the vascular system, of lower stems. Possibly it may also spread by root contact. An insect vector is not known to occur.

Verticillium wilt (*Verticillium dahliae*) is uncommon and only important in ***young trees*** (3-6 years old) which may wilt, decline and die. *Verticillium* is soilborne, invades ***water-conducting tissues*** of roots then moves upwards into trunks and branches. If stem are cut across, ***sapwood*** is brown. See Vegetables M 9.

Wood rots *(heart rots)*

Scientific name: Many mushroom or polypore fungi (Basidiomycetes), eg *Fomes*, *Phellinus*.

Host range: Many ageing tree species.

Symptoms: In living trees most wood rots are confined to older central dead wood ***(heartwood)***. Depending on the part of the tree attacked, wood rots are also called ***root***, ***butt*** or ***stem rots***. ***Brown rots*** decompose cellulose causing a brown rot with a cubical pattern of cracking and crumbly texture. They preferably attack softwoods, eg conifers. ***White rots*** decompose cellulose and lignin, reducing wood to a pale spongy mass. They preferably attack hardwoods normally resistant to brown rot fungi. ***Affected wood*** loses its ***structural strength***, trees may blow over in high winds and temperature extremes. Rotted wood when dry is very light in weight. ***Annual or perennial brackets*** (mushrooms or toadstools) develop on the outside of affected limbs and trunks, usually during autumn or winter one to many years after infection; their appearance usually means that infection is advanced (Fig. 201). They vary in colour and size depending on the fungus. Some wood rotting fungi, eg *Schizophyllum*, are ***weak pathogens*** and are usually only important in older neglected trees. Trees grow as ***compartmented plants*** (Fig 220). In the trunk there are naturally occurring boundaries (not anatomical features) which ***resist to varying degrees***, spread of decay. Compartmentalisation of decay in trees ***(CODIT)*** varies between and within species, and with pathogen virulence, tree vigour and further wounding.

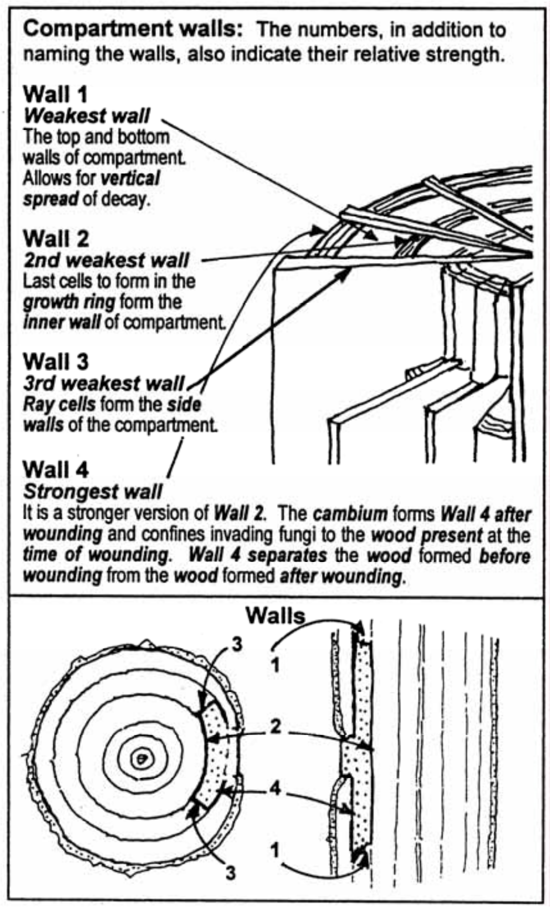


Fig. 220. *CODIT* (after Shigo and Marx 1977).

Fomes can enter through roots in a manner similar to *Armillaria* and, like that fungus, become well entrenched in dead trunks.

Pink limb blight, pink disease (*Corticium salmonicolor*) attacks and kills many woody plants in ***warm climates***. A ***pink encrustation*** which later turns grey, develops on bark. If the branch is girdled, trees wilt, gumming may occur and bark splits and lifts off before the branch finally dies (Fitzell 1994).

Red wood rot (*Trametes cinnabarina*) is a weak pathogen, causing a white wood rot, forming ***orange-red*** leathery brackets (700 mm across, 5-10 mm thick) with pores beneath. Also ***Pycnoporus coccineus*** which is more common.

Ringbarking fuscoporia (*Fuscoporia laevigata* affect silver wattle (*A. dealbata*), blackwood (*A. melanoxylon*), brown boronia (*Boronia megastigma*), cypress pines (*Callitris* spp.), myrtle beech (*Nothofagus cunninghamii*), river red gum (*E. camaldulensis*), mountain ash (*E. regnans*), Victorian Christmas Bush (*Prostanthera lasioanthos*). The fruit body is a ***rusty brown***, pore-bearing sheath on the collar of saplings. It appears to ringbark and kill saplings, rapidly producing a white sapwood rot.

Silver leaf (*Stereum strigoso-zonatum*, *S. purpureum*) is a ***serious disease*** of ***deciduous trees***, eg poplar, stone fruits, also others, eg mountain ash, protea. Affected leaves have a pale-grey, metallic sheen in contrast to the deep green of healthy leaves. Silvering is caused by structural breakdown which allows the epidermis to peel away readily when rubbed or scraped. Trees decline over several seasons. Small ***brownish shell-shaped fruiting bodies*** (20-40 mm across), with ***mauve gills*** underneath, develop on ***recently dead wood*** on trees, stumps or prunings. Spores are released during or soon after rain and are ***spread*** by wind, pruning and harvesting tools and infect trees through pruning wounds < 24 hours old. ***Silvering*** can also be caused by ***twospotted mite*** (*Tetranychus urticae*) which usually occurs in autumn. Remove and burn infected tree. *Trichoderma viride* is used commercially in the UK for control of *S. purpureum*. See Stone fruits F 128.

Tinder punk (*Phellinus* spp.) attacks many species, eg casuarina, cypress pine, eucalypt, melaleuca, myrtle beech, oak, stone fruits and wattle causing a ***white pocket rot***. The ***bracket*** is about ***100 mm*** thick and up to ***100 mm*** wide, ***brown***, hidden in crevices of trunks. It is ***perennial***, heavy, hard (each year adding new growth), rough, often has a cracked upper surface and slopes downwards to a horizontal surface with fine brown to dark rusty pores underneath. See Australian native plants N 11 (Fig. 376).

White yellowish wood rot, rainbow conk (*Polyporus versicolor = Polystictus versicolor*) affects old weakened trees causing a ***soft white rot*** which forms leathery ***smooth grey brackets*** with ***brown bands*** (30-40 mm across, up to 5 mm thick), with cream pores underneath. *Polyporus* may spread into larger branches killing them one at a time.

Yellow heart rot (*Schizophylum commune*) is a weak pathogen causing a white rot and forming ***soft white fan-like brackets*** (10-20 mm across) with ***frilled edges*** and ***gills*** underneath. Only important in older neglected trees, eg fruit trees, pine, citrus.

Others: *Poria, Ganoderma, Peniophora, Lenzites.*

Overwintering: Infected trees, plant debris, stumps.

Spread: Fruiting bodies release ***spores*** which are spread by wind to other trees. Spores gain entry via dead bark, pruning and natural wounds. Most enter through ***damaged tissue***, eg branches broken in storms, borer holes, termite holes or other injuries and then spread through the wood around the entry point.

Conditions favouring: Mild, wet winters, trees ***stressed*** by drought, poor nutrition and ventilation, overcropping, waterlogging, ***wounds***, eg broken limbs, heavy winter pruning, borers, ***reworked trees***, sunburn, hail, root damage. Butt and stem rots may be associated with termites in Eucalypts.

Control: There is no cure for wood rots. ***Monitor*** trees for cavities or fruiting bodies. Once detected monitor regularly. If large trees are affected obtain advice from a qualified arborist as trees may fall over. Decay may be **detected** in trees using visual assessment (Matheny et al. 1994) and various types of equipment (Anon. 1996, Bethge et al. 1996).

Cultural methods: ***Prevent infection*** by appropriate fertilising and irrigation. Minimise sunburn injury to trunks and branches by painting them with flat white plastic paint to reflect the sun, appropriately prune to shade limbs and trunk, prevent leaf fall in summer by controlling diseases and pests (if applicable), avoid reflective mulches. For some wood rots, eg ***silver leaf***, prune when weather is to be dry for > 24 hours afterwards.

Sanitation: Prune (at collars) and shape young trees carefully to ***avoid large pruning cuts***. Prune out all dead limbs and those affected by wood rot and burn. Remove and burn stumps and trees that have died from wood rot. Affected trees near houses should be pruned or cut down. For ***silver leaf*** prune in late summer or early autumn as trees are less susceptible at this time.

Resistant varieties: Species vary in susceptibility. Do not use susceptible trees as windbreaks.

Pesticides: Where disease is prevalent on susceptible trees, treat cuts within hours of pruning with a recommended fungicide. Disinfect tools when moving from plant to plant.

Wood rots *(wood-stains and others)*

Bacterial rots (various) mainly attack wood parenchyma rays. Porosity and permeability of wood to liquids is increased.

Sap-stain fungi, blue-stain fungi (species of *Ceratocystis*, *Cladosporium, Diplodia, Graphium, Hypoxylon, Xylaria*) have pigmented hyphae that grow mainly in the ***ray cells*** that spread through sapwood causing lines of discolouration.

Slow white rots (Ascomycetes), with variable ***black zone lines*** in and around rotting wood, develop in hardwood trees, usually associated with wounds or cankers eg *Xylaria*. ***Cramp balls*** (*Daldinia concentrica*) affect blackwood, casuarina, myrtle beech, silver wattle, etc. Fruit bodies are 10-50 mm across, nearly round, ***shiny black*** to chocolate, dense clusters on trunks and branches (Marks et al. 1982).

Soft rots, eg *Alternaria*, *Diplodia (*Ascomycetes), affect the surface layers of wood pieces maintained at ***continuously high moisture content***, eg poles in soil, cooling towers (Agrios 1988).

Stump removers (*Peniophora gigantea*, *Poria medullaris,* etc) can decay many ***stumps*** of softwoods and hardwoods and destroy the food source of fungi that are potentially pathogenic.

Surface wood-stain fungi (*Aspergillus, Fusarium, Penicillium, Rhizopus*) are fungi that grow on ***freshly cut surfaces*** of wood and impart to the wood the colour of their spores.

PARASITIC PLANTS

Broomrape (*Orobanche* spp., Orobanchaceae) is an ***annual***, has ***no chlorophyll*** and is parasitic on ***roots*** of clover, skeleton weed, shrubs and other plants, depending on its host for water and nutrients. ***Stems*** are yellow-brown to violet, about 250 mm tall with a bulb-like organ attaching to the host root. Flowers are snapdragon-like, seed minute. They occur singly or in clusters and look unsightly with age. ***Hosts*** may wilt during hot weather, but broomrape is economically important only in field crops. ***In urban areas*** most hosts seem to tolerate infestation. Broomrape may be pulled up as it appears in spring, before it sets seed. ***Overwinters*** as seed in soil for years, in some areas as 'bulbs' on host roots for a season. Seed is ***spread*** by rain, wind, birds and host seed contaminated with broomrape seed. Seed only ***germinates*** if a host is nearby. Overseas, ***Fusarium*** and a ***parasitic fly*** (*Phytomyza*) are used to control broomrape in vegetable crops.

Devil's twine (*Cassytha* spp., Lauraceae) is ***perennial***, has ***chlorophyll***, but ***no true roots***, and is parasitic on ***stems*** of trees and other plants (Fig 202). Common in bush areas. ***Stems*** are green, slender, tough, twining and send haustoria into host stems. Leaves are scale-like, flowers small and white in leaf axils. ***Host plants*** may be weakened and die. ***Overwinters*** as seed on soil for years or mixed with host seed, as a perennial on host plants. ***Spread*** by seed mixed with host seed, by animals, equipment, water, soil, movement of infested plants, by growing aerially from host to host. Seeds germinate, stems encircle hosts, develop haustoria, connection with the ground ceases. If no host, seedling dies. Remove by hand in small infestations. Only plant *Cassytha*-free seed in *Cassytha*-free areas. ***Do not confuse*** with ***dodder*** (*Cuscuta* spp., Convolulaceae) which is an annual, has no chlorophyll (orange-yellow stems), no true roots, minute scale-like leaves, white flowers in clusters and is parasitic on stems of herbaceous plants, vegetables, legume field crops and weeds, but not usually woody plants, or with ***strangling non-parasitic climbers*** which twine round stems of other plants, eg wisteria.

Parasitic trees: ***Native cherry*** (*Exocarpos* spp., Santalaceae) is an upright growing shrub or tree in forest areas, has ***chlorophyll***, is parasitic on ***roots*** of ***eucalypts*** when young, later becoming self-supporting (see Eucalypt K 67, Fig 239). Foliage resembles that of casuarina, spread by small seed. ***Western Australian Christmas tree*** (*Nuytsia floribunda,* Loranthaceae) has ***chlorophyll***, is parasitic on ***roots*** of ***grasses*** when young, later becomes self-supporting. Propagated by seed, root cuttings.

True mistletoes (*Amyema*, *Dendrophthoe*, *Notothixos*, Loranthaceae) are ***perennial***, have ***chlorophyll,*** and are parasitic on ***stems*** of trees, depending on hosts for water and nutrients (Fig. 202). There are > 75 spp in Australia. Some are host specific, others infest many species. Many mimic their host in appearance, eg leaf shape. Infested branches die, many mistletoes may ***kill*** a tree. ***Overwinters*** as seeds, perennial infections on host plants. Seed is ***spread*** by birds, wind, rain, movement of infested plants (minor). Seed germinates in droppings of mistletoe birds, producing a searching tip which seeks host tissue. ***Accessible mistletoes*** may be cut off. ***Herbicide*** may be painted on to mistletoe shoots as they grow from their point of attachment. Tree injection has been tried but is slow acting. Overseas ***growth regulators*** applied to bunches prevents fruiting, and so spread, but does not kill it. Follow treatment where practical with fertilising and watering.

NEMATODE DISEASES

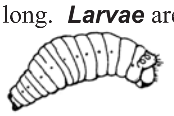
Nematodes have been studied on fruit and vegetable crops but not much on ornamental trees. Many species attack trees and shrubs and probably cause more damage than is realised. Plants appear unthrifty, stunted and yellow, symptoms are readily confused with deficiencies and fungal root diseases. Parasitic nematodes in the soil may cause ***replant diseases*** for some crops, eg apple. ***Root knot nematodes*** (*Meloidogyne* spp.) may infest trees but are usually only a problem on ***nursery stock***. Tiny ***galls*** develop on roots. ***Root lesion nematode*** (*Pratylenchus* spp.) also attacks many plants. They enter and feed in the cortical tissue of small roots. Injured tissue dies and ***dark lesions*** develop on the root surface. Young roots can be girdled. ***Stubby root nematode*** (*Trichodorus* spp.) feeds externally on root tips which ***thicken*** and become ***corky***. Small rootlets are blunt and corky with small lumps on the surface. Roots are sparse. ***Inspect roots*** of all purchases, discard any suspected of being infested. Only propagate from ***nematode-free plants*** and plant nematode-free propagation material in nematode-free cutting and seed beds or soil. See Nurseries N 54, Vegetables M 10.

INSECTS AND ALLIED PESTS

Insects are only one of many factors which can debilitate trees. Not all insects found on trees cause damage.

Aphids (Aphididae, Hemiptera) infest ***new shoots*** of trees, eg elm, oleander, oak. Some aphids have a wide host range, eg ***cotton aphid*** (*Aphis gossypii*), ***green peach aphid*** (*Myzus persicae*), while others, eg ***oleander aphid*** (*A. nerii*), only infest oleander. Aphids suck sap from new growth often causing distortion. Nymph skins and honeydew are seen on infested shoots. Do not confuse aphid injury with hormone herbicide injury to new shoots. Control is usually only carried out on ***nursery stock***. See Roses J 4.

Ambrosia beetles, pinhole, shot-hole (Curculionidae, Coleoptera), some species of Scolytinae, eg *Xyleborus* spp., and all of the 1000 species of Platypodinae), eg ***omnivorous pinhole borer*** (*Crossotarsus omnivorus*) and ***platypus beetle***, mountain pinhole borer (*Platypus subgranosus*) and their larvae, feed on yeast-like ***ambrosia fungi*** (Ascomycetes). Spores carried and cultured by the beetles grow in the moist internal walls of tunnels made by the beetles. Some species attack ***living trees***, many attack ***green unseasoned logs*** in the forest and millyard, but not dry timber (insufficient moisture for the fungus, so larvae die). ***Beetles*** are dark, elongated, tiny, often only a few mm long. ***Larvae*** are tiny, legless, mostly with a ***scroll*** on 1st thoracic segment.



Beetles bore ***round, frass-free tunnels*** (1-2 mm across) deep into sapwood and heartwood. The pest cycle may take 6 months to several years. Females lay eggs at the ends of the tunnels, when fully grown larvae pupate in the tunnels and emerge as beetles through the holes made by the parents. Wood surrounding holes is often ***stained*** by the fungal activity, the holes and the stain affect the ***appearance*** of trees and timber, but mostly ***not its strength***. Infestations in living trees are not controlled, but they may be in green timber.

Bark beetles (Scolytinae, Curculionidae, Coleoptera) in Australia mostly attack ***dead or dying trees***, especially conifers. A few introduced bark beetles, eg ***elm bark beetle*** (*Scolytus multistriatus*) which transmits Dutch elm disease ***(DED)*** (*Ceratocystis ulmi*), and ***fivespined bark beetle*** (*Ips grandicollis*), attack ***living trees. Bark beetles*** are 2-6 mm long, ***larvae*** are legless, cream and tiny, exit holes 1-3 mm. Beetles construct galleries for egg laying in the ***phloem*** beneath the bark of living or dead trees. Larvae chew fine galleries away from the egg gallery, creating a ***characteristic pattern*** (Fig. 203). Bark beetles kill trees either directly through ringbarking or indirectly through introducing disease, eg ***DED***. There is a ***complete metamorphosis*** (egg, larva, pupa and adult) with 1 to several generations each year. Some species, eg ***palm seedborer*** (*Coccotrypes dactyliperda*), are seed feeders. ***Spread*** by beetles flying, infested timber. ***Favoured*** by stress; buildup of numbers in recently felled trees. Control varies with the species. See Conifers K 47, Pine K 109.

Borers *(summary)*

Scientific name: Larvae of ***beetles*** (Coleoptera), ***moths*** (Lepidoptera) and ***wasps*** (Hymenoptera).

Host range: Trees, shrubs and climbers.

Description and damage: ***Larvae*** usually aggregate within a particular tree and are seen when timber is cut or split (Figs. 204-205). Depending on the species, larvae feed in tunnels in the inner bark, sapwood or heartwood of ***trunks, branches and roots***. Species which feed in, and ringbark the inner bark (phloem-cambium), so that water and nutrients cannot be transported, are ***potentially more serious pests.*** Branches and trees may live for years but are seldom attractive and are a potential hazard to life and property. ***External symptoms on bark*** depend on the borer, but include ***bark splitting*** (eucalypts), ***gumming***, ***chewed wood*** and ***frass*** at tunnel entrances, ***exit holes*** of adults, ***death*** or ***breaking*** of limbs, ***trees falling*** in wind, ***cockatoos*** removing wood to extract larvae. Other insects and wood rot fungi may invade tunnels and contribute to further structural weakness.

Pest cycle: Complete metamorphosis (egg, larvae, pupa, adult) with ***1 generation every 3 months to several years***. Eggs are usually laid in bark where larvae initially feed, later larvae tunnel to their preferred feeding depth. When fully fed they mostly pupate in the tunnel close to the surface and emerge through an ***exit hole***. Life histories are often not well known, but larvae of some species live for several years.

Overwintering: Many in trunks, limbs and roots of hosts as larvae and pupae, some also as adults.

Spread: By beetles, moths or wasps flying, movement of infested timber.

Conditions favouring: Beetles prefer to lay eggs on trees which are old or stressed, due to ***poor environmental conditions,*** eg deficiencies, drought, erosion, overcrowding, waterlogging, ***physical damage***, eg fire, wind, snow, soil around trunks, landscaping, buildings, machinery, reworked trees, excessive lopping, poor pruning, bullets, golf balls, vandals, ***chemical injury,*** eg air pollution, gas leaks, herbicide drift, swimming pools, ***attachments***, eg staghorns, mistletoe, ***foliage-feeding insects*** and ***fungal root and wood rots.*** Healthy trees react to larval boring by producing copious ***exudates***, eg resin, gum or kino, which engulf and kill small larvae. Weakened trees do not produce these protective materials in quantity and larvae can establish. Young, apparently healthy trees close to bushland are occasionally attacked.

Control of borers in living trees is ***difficult*** as they are usually not noticed until larvae are deep within wood (fruit-tree borers are exceptions). ***Monitor*** and ***identify*** borer damage during routine horticultural activities.

Cultural methods: Grow young trees ***without checks in growth***. Avoid conditions favouring infestation. For infested trees, provide adequate irrigation, fertiliser and pruning. Only rejuvenate trees if ***roots and butts are sound.***

Sanitation: ***Prune off*** infested branches well below dead or dying wood and fell dead trees before adults emerge. ***Burn*** all prunings and dead trees immediately. Prune at ***branch collars*** so that stubs do not die back, encouraging further borer attack or wood rot fungi. In ***trunks,*** cut back dying or dead bark from margins of damaged wood to healthy wood. If base of main stem is attacked, remove and destroy trees to prevent adults emerging.

Biological control: Populations are usually limited by ***predators***, eg birds, assassin bugs, clerid beetles and ***parasites***, eg wasps and flies parasitise larvae and pupae, their cocoons are often seen in tunnels.

Resistant varieties: Choose species suited to ***climate***, ***site*** and ***not susceptible*** to borers.

Physical and mechanical methods/Pesticides: Trunk injection with insecticides ***does not*** control borer larvae. Bark spraying may kill ***emerging adults***, but effective insecticides are mostly hazardous and persistent. Occasionally trunks and butts of infested high value trees have been sprayed with residual insecticide in spring to kill adults emerging in late spring/early summer. Larvae which live in ***short tunnels***, eg fruit-tree borer, may be killed by removing frass from tunnel entrances, then probing tunnel with soft, pliable wire or by injecting insecticide into them. Soap injected into them makes caterpillars emerge and they can then be killed.

Borers *(beetles - Coleoptera)*

Auger beetles (Bostrichidae) mostly infest ***dying*** or ***freshly dead*** hardwood trees, eg kurrajong, pepper tree, fruit trees, white cedar. They do not re-infest seasoned wood. Depending on the species there are one or more generations each year. Beetles emerge through ***round holes***, 1-6 mm across, in spring. Females usually bore a tiny clean round hole (auger) for egg laying in moist sapwood. Larvae tunnel in moist ***sapwood***, feeding on sugars and starches. Tunnels are tightly packed with fine, powdery frass. Control in trees is not justified. ***Large auger beetle*** (*Bostrychopsis jesuita*) attacks eucalypt, tamarisk, wattle. It is stout-bodied, rough surfaced, dark, 12-18 mm long with down-turned head. See Tamarisk K 123 (Fig. 269). Larvae are thick, white, with short true legs, 10-12 mm long and bore vertical ***round tunnel***s about 5 mm across. ***Powderpost beetles*** (*Lyctus* spp.) attack structural hardwood timber containing sapwood and re-infest dry seasoned timber. ***Lesser grain borer*** (*Rhyzopertha dominica*) is a pest of grain.

Jewel beetles (Buprestidae) usually attack weakened or fire-damaged trees. ***Beetles*** are 15-60 mm long, usually bright, patterned, elongated and flattened with short, toothed antennae. They feed on, and may ***pollinate flowers*** of, trees in summer. ***Larvae*** are up to ***30 mm*** long, cream, ***cobra-shaped*** with a flattened head and thorax (Fig. 204). They tunnel between ***bark and sapwood*** of living trees and move into sapwood to pupate like longicorns. Tunnels are irregularly ***oval*** and tightly packed with frass, ***crescent-shaped lines*** are visible. Beetles emerge through ***oval exit holes*** (10-12 mm). Larval stages can last for many years; occasionally beetles emerge from sawn timber. See Conifers K 47.

Longicorn beetles, greenwood longicorns (Cerambycidae) are ***common tree borers*** affecting many trees, eg citrus, banksia, casuarina, cypress, eucalypt, fig, wattle, willow. Most are ***pests*** of dead limbs and freshly felled trees. Some are ***serious pests*** of weakened or injured trees, causing their death by ringbarking. They do not re-infest dry seasoned wood like drywood longicorns. A few attack living trees (Wang 1995). ***Beetles*** are active fliers, elongated, dark, bodies are approximately 5-80 mm long, with long antennae which sweep backwards beyond the end of the abdomen (Fig. 204). They may be diurnal or nocturnal (hide in the day under loose bark), many feed on flowers, foliage or new bark in summer. They lay eggs directly into the bark. ***Larvae*** are creamy, wrinkled, legless, cylindrical with a ***swollen thorax***, small dark head, well developed chewing mouthparts and are ***8-100 mm*** long (Fig. 204). They mostly feed under the bark in ***the phloem-cambium***. Larvae may tunnel upwards or downwards for a metre or more in trunks and roots for 6 months to 3 years. Tunnels are ***oval,*** packed with coarse frass. They form white pupae in the sapwood. Beetles emerge through usually ***oval exit holes*** (3-15 mm). On smooth-barked trees, dead patches of bark may crack and fall away, leaving exposed sapwood. Depending on their density larvae can ringbark branches or trunks. Some feed on herbs, roots or on seeds and cones. Overseas, some species are vectors of serious diseases affecting living trees, eg ***Monochamus alternatus*** is a vector of the ***pinewood nematode*** (*Bursaphelenchus xylophilus*) in Japan; ***Hylotrupes bajulus*** and ***Stromatium*** spp. can attack seasoned timber, larval stages may last up to 16 years (Com. of Australia 1992).

Weevils (Curculionidae) mostly have an extended head (snout). Larvae of some bore into dying or dead trees, others attack living trees. ***Elephant weevil*** (*Orthorhinus cylindrirostris*) affects brush box, eucalypt, fruit and other trees. ***Weevils*** are 10-20 mm long, grey-black, with long forelegs and prominences on the wing covers and thorax. Antennae are slender and elbowed. They fly mostly at night chewing ***young buds*** and square or rectangular pieces of ***green bark*** from twigs and branches, preferably from freshly-fallen timber when bark is just commencing to wither. See Tamarisk K 123 (Fig. 270). ***Larvae*** are fleshy, creamy, legless and up to ***20 mm*** long. They cause the most damage, tunnelling downwards in stems for about 10 months, well below the bark, into the roots. Tunnels are ***round and tightly packed with frass***. When fully grown they turn around and tunnel upwards, to pupate a few centimetres to 1 m above ground level. There is 1 generation each year. Most weevils emerge in spring through ***round exit holes*** 5-6 mm across (Fig. 204), and lay eggs in the bark, often near the base of the trunk. ***Old nursery trees*** are commonly attacked and exit tunnels cutting across the conducting system may cause wilting. Plant yearling trees to avoid transporting larvae on nursery stock. ***Fruit-tree root weevil*** (*Leptopius squalidus*) graze on leaf surfaces of trees, eg apple, eucalypt, wattle. ***Females*** are grey, about ***20 mm*** long, males are smaller. ***Larvae*** are fat, legless, up to ***20 mm*** long and bore tunnels in deep roots of the same species. Damage is usually minor, but large anchorage roots may suffer significant injury. *L. tribulus* attacks roots of wattles. See Fruit F 11.

See Trees K 10, K 11

Borers *(moths - Lepidoptera)*

Moth borer larvae (Cossidae, Hepialidae and Oecophoridae) differ from those of longicorns, jewel beetles and bark weevils in having ***functional legs***, being able to move freely outside their tunnel. They are usually reddish to palest pink.

Fruit-tree borers (Oecophoridae) are common and damage many trees, eg cherry, wattle. ***Caterpillars*** are fleshy, sparsely hairy, multi-coloured brown-white, ***40-50 mm*** long. They form a ***short vertical tunnel*** usually in a branch fork. During the day they hide in the tunnel and at night they feed on callus tissue around the tunnel entrance. They may ringbark and kill branches or small diameter trees. Tunnel entrances are covered with a webbed mat of brown chewed wood and faeces (Fig. 204). Some also feed on leaves, pulling them into webbed mats. Because caterpillars do not tunnel far into wood, this borer is ***easy to control***. See Fruit F 10.

Ghost moth (Hepialidae) caterpillars may bore tunnels up to ***600 mm*** long in the stems and roots of lilly-pilly and other trees, some tunnel in the ground and feed externally on tree roots. They are not a serious problem in suburban areas. ***Bentwing ghost moth*** (*Zelotypia stacyi*) with a wingspan of 250 mm which attacks eucalypts is the best known. ***Common splendid ghost moth*** (*Aenutus ligniveren*) is a small species, the caterpillars making short tunnels in many trees, eg eucalypt, wattle. Slender trunks may be ringbarked, plants die. ***A. eximius*** has its tunnel entrance usually within 1 m of the ground. Tunnels are up to 500-600 mm long and may extend into the main roots. Caterpillars feed on ***bark regrowth*** around tunnel entrances which are ***covered*** with silk, wood particles and faeces. Pupation occurs in the tunnel, the entrance being previously closed with a silken wad. Moths emerge from spring (Common 1990).

Wood moths (Cossidae), eg ***Australian goat moth*** (*Culama caliginosa*), ***wattle goat moth*** (*Xyleutes encalypti*), ***witjuti grub*** (*Xyleutes* sp.), attack living trees, eg eucalypt, fruit trees, wattle. ***Moths*** are large, grey or light brown, stout, narrow, with hairy or scaly wings and wingspans up to 250 mm. Females deposit eggs into crevices on the bark or other parts of the tree. ***Caterpillars*** are large, fleshy, yellowish or pinkish, up to ***150 mm*** long, with true legs and a stout armoured prothorax (Fig. 205). Caterpillars tunnel in the ***heartwood*** of trunks or large roots, beneath the bark, or rarely, in the soil feeding externally on roots. Tunnels are full of coarsely chewed wood. Caterpillars can feed for years. They may feed on bark tissue around tunnel entrances, covering them with webbed silk, chewed wood and faeces. Pupation takes place in the tunnel close to the bark surface; moths emerge through large irregular exit holes ***3-15 mm*** across. One generation every few years. ***Overwinters*** as caterpillars in trunks and roots. Infestation is not noticed until frass and exit holes indicate that there is already damage within the trunk. ***Giant wood moth*** (*X. cinereus*) caterpillars tunnelling in lower trunk of coastal trees are preyed upon by black cockatoos. Damage by the birds is considerable. See Wattle K 133.

See Trees K 10.

Borers *(wood wasps - Hymenoptera)*

These borers usually attack damaged or stressed ***conifers*** and are regarded as minor secondary pests, however, ***sirex wasp*** (*Sirex noctilio,* Siricidae) has become a ***major pest*** of pine plantations in Australia and New Zealand. Females drill holes with their ovipositor into sapwood of live pine trees, depositing an egg with mucous and spores of a wood rotting fungus (*Amylostereum*). The fungus conditions the wood for the wasp larvae. The ***combination*** of the phytotoxic mucous and the white rot induced by the fungus kills the tree, within 6 weeks to several months after attack. The *Sirex* life cycle extends over 1 year, though some individuals may pass through a 3-month or a 2-year cycle. *Sirex* can complete its life cycle in felled trees or drying timber. See Pine K 109, K 111 (Fig. 266). ***Carpenter ants*** (*Componotus* spp.) nest in tree stumps, decayed wood in trees and timber outside. Their damage can look rather like termite damage except that excavation is more open and free of flutings and their is no faecal spots on internal surfaces (Hadlington 1992).

Bugs (Hemiptera) of many types attack trees.

Crusader bug (*Mictis profana,* Coreidae) is a native bug which feeds on many plants, eg citrus, cassia, eucalypt, grape, hibiscus, rose, wattle, wisteria. ***Adults*** are up to ***25 mm*** long, dark brown or grey with a well-defined yellow St Andrew's Cross on their back and long legs. They fly readily if disturbed. ***1st stage nymphs*** have a red abdomen and look like large ants, later stages are brown and have two small orange spots in the middle of the upper surface of their abdomens. Nymphs and adults suck sap from tips of ***new growth*** causing it to wilt, brown and die. Damage may be important on ***young trees***. Several overlapping generations each season. In spring, females lay eggs on leaves, twigs or fruit and sometimes debris on soil. ***Overwinters*** as adults in sheltered places. ***Spread*** by adults flying, movement of infested plants (minor). ***Favoured*** by warm weather. Control is not usually required. Predatory insects feed on them. On ***nursery stock***, bugs may be collected (by hand), ***insecticides*** may be applied when bugs are first noticed and in severe infestations.

Others: Green vegetable bug (*Nezara viridula*), ***bronze orange bug*** (*Musgraveia sulciventris*), ***Rutherglen bug*** (*Nysius vinitor*).

See Vegetables M 12.

Caterpillars (Lepidoptera): Many caterpillars, eg ***lightbrown apple moth*** (*Epiphyas postvittana*), feed on the foliage, flowers and fruit of many plants while some, eg ***autumn gum moth*** (*Mnesampela privata*), are host specific. Some caterpillars are borers and tip borers. See Trees K 12, K 17.

Anthelid caterpillar, variegated caterpillar (*Anthela varia*, Anthelidae) is a ***sporadic pest*** of many trees, eg eucalypt, grevillea, macadamia, pecan, wattle, willow. ***Moths*** are brown with a wingspan of about 40 mm. ***Caterpillars*** are hairy, brown and grey, up to ***60 mm*** long, solitary or in small groups and eat chunks out of mature leaves. Caterpillars wander on the ground searching for a suitable pupation site in dark crevices, amongst stones, in logs. The coarse silken cocoon may incorporate caterpillar hairs. Caterpillars may cause ***skin irritation***.

Case moths, bag moths, bagworms (Psychidae) are ***sporadic minor pests*** of trees, eg citrus, eucalypt, pine, tea-tree. ***Caterpillars*** are ***up to 80 mm*** long and live in a portable silken case, only the head and thorax protrude during feeding or moving about. If disturbed, head and legs are withdrawn and bag opening closed. ***Cases*** may be decorated with leaf and twig material characteristic for a given species. Caterpillars chew roughly circular holes in ***leaves***, or through one leaf surface giving a 'window pane' effect. Damaged areas brown. Caterpillars prefer mature leaves but may attack young foliage and twigs. They fasten the top of their case to the plant or some adjacent object, and pupate inside. ***Moths*** are rarely seen. Winged males mate with wingless, brown females in the case, eggs accumulate in the case. There are 2 or more generations a year. Young caterpillars ***spread*** from hatching sites by descending on silk threads, or are carried on windblown leaves, insects, birds, or on infested plants. Calm weather prevents their dispersal, so that individual trees may be heavily infested. ***Faggot case moth*** (*Clania ignobilis*) caterpillars feed on fineleaved species of ***cypress pine*** (*Callitris* spp.), or ***pines***. They cover the case with long pieces of twig placed parallel, with one piece usually much longer than the others like a tiny bundle of sticks. ***Leaf case moth*** (*Hyalarcta huebneri*) is the ***most common*** and affects many species, eg eucalypt, fruit trees, pine, tea-tree. Cases are up to 65 mm long, ornamented with pieces of leaves and bark (Fig. 207). ***Ribbed case moth*** (*H. nigrescens*) caterpillars are 35 mm long and feed on brush box, eucalypt, wattle, mostly in drier inland areas. Cases have prominent longitudinal ribs, but are not ornamented with plant material. ***Saunders's case moth*** (*Oiketicus elongatus*) is the largest species with female cases up to 150 mm long. Cases are decorated with short pieces of twig widely spaced and placed at irregular intervals. Caterpillars are stout with yellow markings and feed on a variety of plants. See Avocado F 21 (Fig. 112).

Cup moths (Limacodidae): Caterpillars may ***damage*** *Angophora,* brush box, eucalypt, camellia, dodonea, guava, macadamia, fruit trees. See Eucalypt K 60.

Emperor moths (Saturniidae), eg Australian atlas moth (*Attacus wardi*), emperor gum moth (*Opodiphthera eucalypti*). See Australian native plants N 11 (Fig. 379). ***Hercules moth*** (*Coscinocera hercules*) is Australia's ***most spectacular moth*** and occurs in north Qld on rainforest trees. ***Syntherata janetta*** caterpillars feed on many plants, eg *Podocarpus spinulosa*, also citrus, guava in Papua New Guinea and northern Australia.

Leafroller moths (Tortricidae), eg ***lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars roll leaves together. See Pome fruits F 112.

Loopers (Geometridae): ***Bizarre looper*** (*Anisozyga pieroides*) feeds sporadically on ***foliage*** of plants, eg bottlebrush, cherry, eucalypt, guava, fringed wattle, rose, and on flowers of lilly-pilly, macadamia, mango (Common 1990). ***Caterpillars*** are up to ***25 mm*** long, brown with flanged body segments like a twisted dead leaf and so are rarely noticed. Most common in tropical and subtropical regions. Control is rarely necessary. ***Twig looper*** (*Ectropis excursaria*) infests eucalypt, geranium, gardenia, hakea, hardenbergia, ivy, lemon, radiata pine, rose, tea-tree, walnut, wattle, blackberry and capeweed. See Avocado F 19.

Tussock moths (Lymantriidae): ***Painted apple moth*** (*Teia anartoides*) caterpillars may severely damage trees or shrubs. See Pome fruits F 113.

Tailed emperor butterfly (*Polyura pyrrhus sempronius*, Nymphalidae) is large and handsome. Caterpillars feed at night on featherleaved wattle, also kurrajong, flame tree, camphor laurel, false acacia, poinciana, *Cassia*, *Albizia*, *Celtis*, crepe myrtle. ***Caterpillars*** are up to ***80 mm*** long, fleshy, dark green with yellow longitudinal bands, 2 broad transverse stripes across the back and 4 backward projecting horns on the head. They feed singly or in small groups on mature leaves, which they cover with silk and on which they rest. Tropical to temperate, chiefly coastal.

Noctuids (Noctuidae), eg ***corn earworm*** (*Helicoverpa armigera*), ***native budworm*** (*H. punctigera*), ***looper caterpillars*** (*Chrysodeixis* spp.). See Sweetcorn M 89.

Web moths (Pyralidae, Lepidoptera) infest ***fineleaved*** shrubs. See Tea-tree K 124.

Control is often not warranted. ***Parasitic*** flies and wasps exert some control. If detected early on small isolated shrubs ***hand pick*** and destroy. However, some are hairy and may irritate. Prune off groups of webbed leaves. ***Insecticides***, plus a wetting agent, are mainly used only in ***nurseries*** or on small plants. Apply when caterpillars are small. See Annuals A 8.

Cicadas (Cicadidae, Hemiptera), eg ***double drummer*** (*Thopha saccata*), ***yellow Monday*** (*Cyclochila australasiae*). ***Adults*** are up to 70 mm long, with membranous wings, many are colourful, but do not jump. ***Males*** in summer produce a loud noise by vibrating a pair of cuticle plates (the drums), one on either side of the abdomen. ***Nymphs*** have forelegs for digging and live underground for one to several years, sucking sap from tree roots. After the last nymphal stage, they climb a vertical surface and emerge as winged cicadas, leaving the shed skin attached to posts, etc. Adults suck sap from ***soft shoots*** of trees and shrubs which usually wilt. They produce large amounts of ***honeydew***; egg laying may cause some ***twig damage*** and they are ***noisy***. They rarely need to be controlled. ***Natural enemies*** include cicada bird, magpies, possums, hunting spiders and tree climbing lizards.

Froghoppers and spittle bugs (Hemiptera) suck sap from many plants, eg bottlebrush, casuarina, eucalypt, rosemary, wattle (Fig. 208). Many superficially resemble leafhoppers. They are up to ***12 mm*** long and can jump vigorously (froghoppers). Many are widespread but seldom cause damage.

Froghoppers (Machaerotidae): ***Nymphs*** make, feed and live in calcareous ***tubes*** immersed in their liquid excreta (Fig. 208). Nymphs and adults suck sap from small stems but cause little injury. ***Common froghopper*** (*Chaetophyes compacta*) feeds solitarily, or in small colonies, on young shoots of eucalypt and wattle and are cicada-like, about ***8 mm*** long. Females are large and brown while the smaller males are black. Nymphal tubes may be in clusters. Adults hop if disturbed. ***Spine-tailed froghopper*** (*Machaerota finitima*) infests bottlebrush, casuarina, eucalypt, grevillea, melaleuca, salt bush and wattle. Adults are unusual, small, brown, about ***8 mm*** long, with a prominent, curved spine-like appendage on the back. Usually solitary but may be in small groups.

Spittle bugs (Cercopidae, Aphrophoridae): ***Nymphs*** live and feed enclosed in ***spittle*** either below ground (many Cercopidae) or ***above ground*** often lodged in leaf axils on young shoots (Aphrophoridae) (Fig. 208). Spittle is formed by air being taken into the ventral abdominal channel and expelled posteriorly through a film of anal excreta forming bubbles. Inside the spittle is a soft-bodied nymph. ***Philagra parva*** is widely distributed, abundant and feeds on many plants, eg casuarina, wattle. Adults are solitary, small, brown, cicada-like, about ***4 mm*** long with a narrow pointed head. ***Bathylus albicinctus*** feeds on many similar plants. Adults are small, brown and white, beetle-like, about ***5 mm*** long. ***Anyllis leiala*** is common on eucalypts in eastern Australia.

Gradual metamorphosis (egg, nymph and adult). ***Spread*** by adults flying. Spittle and tubes ***protect nymphs*** against drying out, parasites and predators. The spittle only lasts a couple of weeks during nymphal stages, after which the adult emerges. They are ***minor pests*** kept in check by ***natural controls***, eg parasitic wasps and predators, eg birds, spiders, ladybirds, skinks. Hosing will remove spittle from branches.

Gall insects:

Some insects cause galls on ***leaves, twigs, stems and flower heads*** (may reduce seed formation). Shapes are usually ***characteristic*** of the insects causing them. Some insect plant galls are produced in response to toxins, injected ***by the adult insect during egg laying***, and continued by the developing larvae. The gall is composed entirely of plant tissue which shelters the insect and provides abundant sap for food. The shape of the gall may be dependent on the insect and its sex. Some galls are caused ***by the injection of toxins during feeding***, eg woolly aphid. Depending on their density, galls may cause disfigurement and distortion of ***leaves, stems and flowers***. Galls are abundant on eucalypt and wattle planted on marginal sites for the species. Tree health is seldom affected. In the garden, ***remove*** by pruning and proper disposal, by burning if allowed.

Aphids (Aphididae: Woolly aphid (*Eriosoma lanigerum*). See Pome fruits F 116.

Coccids (Eriococcidae): ***Apiomorpha spp.*** produce unusual galls on eucalypt ***twigs and leaves***. Females are often large, fruit-like and single while the males may be small, tubular and clustered. See Eucalypt K 68 (Fig. 245). They do not appear to affect the tree. ***Other species*** may cause galls on casuarina, eucalypt and wattle.

Flies (Diptera): Maggots of ***eucalyptus flies*** (*Fergusonina* spp.) in association with nematodes (*Fergusobia*) cause galling of leaf, bud and stems of Myrtaceae, especially eucalypts, resulting in loss of seed production. ***Gall midges*** (Cecidomyiidae) may cause galls on wattles and other plants.

Mites (Acarina): ***An eriophyid mite*** (Eriophyidae) feeds on banksia fruit causing unsightly galls. See Banksia K 32.

Psyllids (Psyllidae): ***Schedotrioza spp.*** cause round, woody or fleshy galls. Some species, eg ***Glycaspis spp.***, cause bladder-like galls, solitary or reddish, about 8 mm across on eucalypt leaves.

Thrips (Phlaeothripidae): ***Teuchothrips*** and other species cause galls on wattle and other native plants.

Wasps (Hymenoptera), only a few millimetres long, lay eggs into young plant tissue. The plant is stimulated to produce extra cells so a gall develops. Larvae feed on plant tissue and pupate inside the gall. Adults emerge through holes made in the outside of galls. ***Bluegum eulophid*** (*Rhicnopeltella eucalypti,* Eulophidae) is commonly reared from galls on eucalypt. ***Eulophid wasps*** (Eulophidae) infest Geraldton wax, lowering plant value and increasing the chance of quarantine rejection on phytosanitary grounds. ***Trichilogaster trilineata*** wasp galls develop on silver wattle (Fig. 209). ***Seed chalcids*** (Eurytomidae) infest seed of bottlebrush, eucalypt, wattle and many other Australian native trees. ***Most Torymid wasps*** (Torymidae) are associated with galls or seeds. ***Megastigmus*** is cosmopolitan, commonly yellow-brown, sometimes with metallic patches, is often reared from stem, leaf and flower galls of many plants, eg banksia, *Brachychiton*, eucalypt, hakea, *Helichrysum*, wattle. ***Xenostigmus*** causes galls on hakea buds. See Citrus F 37.

Weevils (Curculionidae): ***Gregarious gall weevil*** (*Strongylorhinus* spp.) larvae cause galls on young eucalypt stems. Trees may break in the wind. See Eucalypt K 61.

Control is difficult. Fertilise to increase tree vigour and resistance to attack. Early pruning and burning of affected stems reduces infestations. Most insect species which emerge from these galls are ***parasites*** of the gall insects. There is no effective chemical control for gall insects on mature trees. ***Nursery trees*** may be sprayed with systemic insecticides at the first sign of galling.

Grasshoppers, locusts, katydids:

Giant grasshopper (*Valanga irregularis*), ***wingless grasshopper*** (*Phaulacridium vittatum*), ***spur-throated locust*** (*Nomadacris guttulosa*), ***katydids*** (Tettigoniidae) and other species can consume ***large quantities*** of foliage. Control immediately on important crops before they become too numerous. They can be removed by hand on small plants. See Eucalypts K 65, Vegetable M 13.

Leaf beetles, flea beetles

Scientific name: Chrysomelidae, Coleoptera

Host range: Various species feed on ***foliage*** of eucalypt, wattle, other trees. Adults and larvae of some species feed on the same host. Some have a wide host range, eg ***redshouldered leaf beetle*** (*Monolepta Australasia*); others have a more limited host range, eg ***eucalyptus leaf beetles*** (*Chrysophtharta* spp., *Paropsis* spp.).

Description and damage: ***Beetles*** vary in size and colour but are usually about ***6-10 mm*** long. Many are slightly bun-shaped and resemble ladybird beetles. They are often brightly coloured and shiny. Antennae are < half as long as the body, the 2nd last segment of the tarsus is rounded into a distinct pad. ***Larvae*** vary in shape and colour.

Metallic flea beetles (*Altica* spp.) chew ***holes*** in leaves of hibiscus and other plants. See Hibiscus K 82.

Redshouldered leaf beetle, monolepta beetle (*Monolepta australis*) may swarm on ***ornamentals***, eg eucalypt, pepper, tea-tree, wattle, ***fruit***, eg avocado, citrus, lychee, macadamia, ***vegetables***, eg cucurbits, ***field crops*** like maize. ***Beetles*** are strong fliers, ***6-7 mm*** long, creamy yellow with a red band across the top of the wing covers and 1 red spot on each wing cover towards the back (Fig. 210). ***Larvae*** are about ***5 mm*** long. Beetles chew ***flowers, buds, leaves and fruit***. Leaves may be skeletonised and trees look scorched; trees close by may be unharmed. Swarms may cause serious damage in 2-3 days. Eggs are laid in the soil surface, especially pasture legumes and kikuyu; larvae feed on grass roots and pupate in soil. Adults emerge after good rains following a dry spell, swarms are more likely in spring or summer.

Swarming leaf beetles (*Rhyparida* spp.) quickly damage ***trees***, eg eucalypt, wattle, ***fruit,*** eg avocado, lychee, ***field crop,*** eg maize, and ***pastures. Beetles*** are shiny, brown or black, about ***3-5 mm*** long, and may swarm in summer and autumn after the first heavy rains of the season. Beetles may skeletonise ***new leaves*** and ***defoliate young plants***, tops of shrubs and large trees; older plants usually recover from attack. Trees look scorched. Minor infestation may interfere with fruit setting. Beetles may strip one plant and leave an adjacent one untouched. ***Larvae*** feed on grass roots, so pasture close by increases incidence.

Others: Eucalyptus leaf beetles (*Chrysophtharta* spp, *Paropsis* spp.) feed on eucalypts, and ***fireblight beetles*** (*Pyrgoides orphana*) on wattles. Beetles and larvae ***severely damage foliage***. Females lay eggs on small twigs or new leaves, in characteristic rafts or collars (distinctive for each species). Larvae fall to the ground and pupate. Adults emerge in spring. See Eucalypt K 61, Wattle K 132.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult), several generations each year.

Overwintering: Depends on the species, but as adults, under loose bark or in tree crevices, or as pupae in the soil.

Spread: By beetles flying and introduction of infested plants.

Control:

Sanitation: On small trees larvae may be squashed and beetles collected as beetles tend to drop to the ground when disturbed.

Biological control: Drought may delay new leaves on which adults and larvae feed. Beetles and larvae may be dislodged in bad weather. ***Predators***, eg birds, feed on beetles and larvae, soldier beetles and other insects feed on eggs and young larvae. ***Parasites***, eg flies and wasps, parasitise eggs and larvae.

Resistant varieties: Trees should be bred for ***resistance*** to serious leaf beetle pests, or consideration could be given to planting ***different species***.

Pesticides: Monitor populations of redshouldered leaf beetles on surrounding trees (Brough et al. 1994). Small numbers of beetles are not important. Swarms may be controlled by insecticides if applied as soon as detected on crops, but can seriously reduce parasite levels.

Leafhoppers, planthoppers, treehoppers (Hemiptera)

Leafhoppers (Cicadellidae) commonly damage leaves of trees, eg ***elm leafhopper*** (*Ribautiana ulmi*), ***apple leafhopper*** (*Edwardsiana australis*). Injury is easily distinguished from twospotted mite and whitefly infestation, by the absence of whiteflies and mites on leaf undersurfaces. Leafhoppers are ***3-4 mm*** long and leave a distinctive ***dotted feeding pattern*** (Fig 211). Control is not usually undertaken. See Azalea K 29, Trees K 24 (Table 3), Vegetables M 15.

Green planthopper (*Siphanta acuta*, Flatidae) infests eucalypt and many garden plants. Adults are nearly ***10 mm*** long, ***bright green***, wings tent-like, generally solitary, nymphs may congregate on young shoots. Found in tropical to temperate regions. Control is usually unnecessary.

Treehoppers (Eurymelidae) eg ***gumtree hoppers*** (*Eurymela* spp.) infest eucalypt, casuarina, wattle. They are up to ***10 mm*** long, ***blackish*** with whitish yellow or orange markings and are triangular in shape. Wings at rest are held roof-like over the abdomen. Adults and nymphs feed together and are attended by ants feeding on excreted ***honeydew***. Lower plant parts are usually covered in black sooty mould. Adults jump when disturbed. See Eucalypt K 61.

Horned treehoppers (Membracidae): ***Green treehopper*** (*Sextius virescens*) feeds on eucalypts. ***Spiny treehopper*** (*Sertorius australis*) feeds on eucalypts and wattles. ***Adults*** are solitary, small, brown, cicada-like insects, about ***8 mm*** long, with a hard, short sharp spine on either side of the head. Nymphs occur in colonies on young shoots. Controlled by natural enemies. See Wattle K 134.

Leafminers are the larvae of moths, beetles, sawflies and flies, eg ***oak leafminer*** (*Phyllonycter messaniella*, Lepidoptera) (Fig 212), ***lantana leafminer*** (*Octotoma scabripennis*, Coleoptera), ***leafblister sawflies*** (*Phylacteophaga* spp., Hymenoptera) and ***pittosporum leafminer*** (*Phytoliriomyza pittosporphylli*, Diptera). Leafminers are usually restricted to one host, or group of related hosts, eg one species attacks azalea, another pittosporum. Each species produces a ***characteristic mine***, eg thin meandering lines, blotches, or a combination of both. Pupation may occur inside or outside the leaf or elsewhere. See Azalea K 28.

Lerp insects, psyllids (Psyllidae, Hemiptera): ***Lerp insects*** commonly infest eucalypts, while ***psyllids*** infest many Australian native plants. Adults of both are small sap-sucking insects, with 2 pairs of wings held roof-like over the head, but are not strong fliers. The nymphs of ***lerp insects*** form a cover, or a lerp, about ***1-5 mm*** across beneath which they shelter and feed. Lerp insects produce ***honeydew*** which attracts ants and on which sooty mould grows, making trees and evergreen plants underneath them black. ***Psyllids*** are free-living, and do not form a lerp covering for their nymphs. They move freely over the surface of foliage, producing malformation and discolouration of leaves and terminal shoots where they feed. Adults are up to ***10 mm*** long. See Eucalypt K 62, Grevillea K 76.

Mealybugs (Pseudococcidae): Many species are pests of native and introduced plants. ***Golden mealybug*** (*Nipaecoccus aurilanatus*) infests Norfolk Island pine. See Conifers K 48, Greenhouses N 25.

Mites
(Acarina) are not generally a problem on trees and shrubs with a few exceptions.

Broad mite (*Polyphagotarsonemus latus*) suck sap from ***leaf undersurfaces*** of many plants, eg camellia, citrus, fuchsia. Leaf edges ***curl under***. See Greenhouses N 26.

Bryobia mite (*Bryobia rubrioculus*) infests deciduous trees, eg fruit trees. They feed on ***leaf undersurfaces*** causing ***whitish mottling***. See Fruit F 12.

Eriophyid mites (Eriophyidae) may infest ***new shoots*** of many plants, eg eucalypt, grevillea and hakea, causing ***distortion*** of leaves and shoots, stunting and a witches' broom effect. Some species may live in ***small blisters*** on leaves. See Eucalypt K 63, Grapevine F 62.

Spider mites (Tetranychidae): ***Twospotted mite*** (*Tetranychus urticae*) causes ***leaves*** to have a sandy, mottled appearance. ***Limbs*** may become ***sunburnt*** due to defoliation. Repeated severe infestations can result in weakening of plants and affect root growth. ***Do not confuse*** twospotted injury to leaves with damage caused by leafhoppers, thrips, whiteflies or deficiencies. Often towards the end of the growing season it is not possible to find mites on leaves as they move to herbage at the onset of cold weather. See Beans (French) M 29, Trees K 24 (Table 3). Also ***European red mite*** (*Panonychus ulmi*). See Fruit F 12.

Sawflies
(Hymenoptera), eg ***callistemon sawfly*** (*Lophyrotoma* spp.), ***cypress pine sawfly*** (*Zenarge turneri*), ***leafblister sawfly*** (*Phylacteophaga* spp.), ***pear and cherry slug*** (*Caliroa cerasi*), ***steelblue sawfly*** (*Perga* spp.), belong to the same order as ants, bees and wasps. Most are host specific; there are exceptions, eg pear and cherry slug. They are called sawflies because most females have a ***saw-like egg-laying apparatus*** for cutting slits in plants into which eggs are laid. ***Larvae*** are ***caterpillar-like*** and mostly feed on leaves in various ways, they mostly pupate either in the soil or in wood at the base of the tree. See Eucalypt K 63.

Scales
(Hemiptera) may infest ***leaves, stems and trunks*** of deciduous and evergreen trees and shrubs. Mostly they are easy to recognise but some, because of their ***tiny size***, are difficult, eg San Jose scale. Infested trees may be unsightly, stunted, ***bark*** may be tight, branches and trees may dieback. Scale-infested ***leaves*** may yellow and never regain their green colour. ***Sooty mould*** grows on the ***honeydew*** secreted by ***soft scales***, making trees and plants underneath look black. The honeydew attracts ***ants***.

Armoured scales (Diaspididae): Adult female scales are white to brownish, roughly circular, 1-2 mm across and attack leaves (Fig. 213) and bark on branches and twigs making them look rough.
Apple mussel scale (*Lepidosaphes ulmi*)
Circular black scale (*Chrysomphalus aonidium*)
Fiorina scale (*Fiorina fiorinae*)
Greedy scale (*Hemiberlesia rapax*)
Latania scale (*H. lataniae*)
Oleander scale (*Aspidiotus nerii*)
Orchid parlatoria scale (*Parlatoria proteus*)
Purple scale, mussel scale (*Lepidosaphes beckii*)
Red scale (*Aonidiella aurantii*)
San Jose scale (*Quadraspidiotus perniciosus*)
White louse scale (*Unaspis citri*)
See Citrus F 39.

Soft scales (Coccidae) vary in size, colour and infest stems and leaves. The most serious damage is caused by the large quantities of ***honeydew*** produced by the crawlers on which sooty mould grows and which attracts ***ants***.
Black scale (*Saissetia oleae*)
Circular black scale (*Chrysomphalus aonidum*)
Hemispherical scale (*Saissetia coffeae*)
Hydrangea scale (*Pulvinaria hydrangea*)
Nigra scale (*Parasaissetia nigra*)
Pink wax scale (*Ceroplastes rubens*)
Soft brown scale (*Coccus hesperidium*)
White wax scale (*Ceroplastes destructor*)
See Citrus F 39.

Eriococcid scales (Eriococcidae), eg ***gumtree scale*** (*Eriococcus coriaceus*), produces honeydew. See Citrus F 41, Eucalypt K 63.

Margarodid scales (Margarodidae) eg ***cottony cushion scale*** (*Icerya purchasi*). See Citrus F 41.

See Citrus F 40.

Scarab beetles
(Scarabaeidae, Coleoptera)

Christmas beetles (*Anoplognathus* spp.) and ***green scarab beetle*** (*Diphucephala colaspidoides*) feed on ***foliage*** of many trees (Fig. 214). ***Spring beetles*** (*Liparetus* spp., *Melolonthiae* spp., other species) may swarm after rain in bush areas, on the ***flower heads*** or ***leaves*** and destroy them. This can seriously affect a wildflower crop, depress orchard fruit yields or prevent the establishment of eucalypts. See Trees K 15, Turfgrasses L 11.

Flower scarabs (*Protaetia* spp.) are stout, active, brown beetles ***15-20 mm*** long. They feed on flowers of many Myrtaceae and Proteaceae and on shoots of wattles and cassias. Solitary insects tear ***flowers*** and tissue of ***new shoots***, while searching for ***pollen***, causing wilting and dieback. A minor pest. Beetles fly noisily during the day. If disturbed they drop to the ground and pretend to be dead. Hand pick. ***Nectar scarabs,*** white-clothes beetles (*Phyllotocus* spp.) are attracted to anything ***white***, even white washing. The beetles are ***pollen-feeders***, and frequently swarm on and destroy the blossoms of white-flowered plants. Larvae are unimportant. See Roses J 8.

Seed insects
feed on the fleshy tissue of seeds rendering them incapable of germination. ***Beetles*** (Coleoptera) cause most damage, especially seed weevils (Bruchidae), Platypodinae (Curculionidae) and Scolytinae (Curculionidae). ***Larvae*** in seeds are fat, white and legless. ***Adults*** vary, and may be unusual curved weevils about ***4 mm*** long with a deflected head or various types of small cylindrical beetles. There may be a marked reduction in seed weight and a tell-tale ***exit hole***. ***Seedharvesting ants*** (*Pheidole*, *Monomorum*, *Meranoplus*) may collect seed from forest trees. See Turfgrasses L 8. ***Caterpillars*** (Lepidoptera) may also feed in seeds. ***Control*** of seedeating pests on trees is usually impractical, but if a batch of seed is contaminated it can be treated with insecticide before sowing. See Seeds N 74.

Stick insects, leaf insects
(Phasmatodea) mainly attack native plants, especially ***foliage*** of eucalypt, wattle and also *Lophostemon*. See Eucalypt K 64.

Termites, white ants (Isoptera) feed on wood (sapwood is preferred), trees, stumps, roots, dead grass, forest litter, palms, potatoes and other materials. The ***giant northern termite*** (*Mastotermes darwiniensis*) is the ***most destructive termite*** in Australia. It attacks any wood in contact with the ground including shrubs and trees; it can also eat leather, certain clothing, paper and other articles (Gerozisis and Hadlington 1995). ***Ringant termite*** (*Neotermes insularis*) is a species commonly encountered by horticulturalists, it feeds on the softer growth rings of living trees, eg eucalypts. ***Niggerhead termite*** (*Nasutitermes walkeri*) forms arboreal nests on trees. Most ***Porotermes spp.*** do not eat sound timber but timber that has begun to decay. In Australia, ***subterranean termites*** (usually ground dwelling and requiring contact with soil or some constant source of moisture) are the ***most destructive species***. The ***West Indian drywood termite*** (*Cryptotermes brevis*) which is also very destructive does not need moisture to survive. ***Subterranean termites*** work from a ***central nest*** situated underground, on tree branches (arboreal termites), in the base of trees, or in mounds above ground from which subterranean tunnels radiate to food sources. ***Nests in trunks of old large trees*** have a large cylindrical pipe above and below the nursery site. In some species (mainly *Coptotermes* spp.), the pipe may be filled with ***mudgut*** (excreta and organic material). Termites are ***highly organised social insects*** and live together in colonies from a few hundred individuals to several million (Fig. 206). Colonies may persist for decades and queen termites may live for 50 years. ***Winged adults*** (reproductives) are about 14 mm long. They leave the nest to become queens and kings, few actually survive because of predation, weather and lack of suitable sites. ***Soldiers*** are mostly sterile, blind, and constitute 2% of the colony. They defend the colony. ***Workers*** are sterile, wingless, white ***(white ants)***, blind with well developed jaws for gnawing food. They comprise 80-90% of a colony. ***Damage*** is caused by ***workers, seeking food,*** travelling to and from the nest in a continuous stream. They cannot exist without communication with the nest. Some species chew galleries along the grain in the heartwood of trunks and branches, leaving only a thin layer of wood between galleries. Large old trees with extensive hollowing out of the main trunk ***may fall in strong winds***. ***Spread*** by winged reproductives up to 2 k but further in wind, or by budding from an existing colony (some species only). ***Favoured*** by old stumps and roots in areas to be planted, neglected old large trees with fungal decay and dead wood, fire scars, machinery damage, wind, snow. ***Control:*** Trees should be ***inspected*** during pruning. Unless termite-damaged branches have fallen off, earthen material is present at the tree base, there are flight cuts or there is a hollow sound when tapped, it can be difficult to be sure that trees are or have been infested by termites. Holes bored to test for termites may provide entry points for wood rot (they should be sealed properly). ***Do not confuse termite injury*** with that caused by bark beetles, borers, wood rot, etc. Because only a few species of termites are considered a serious threat to trees or nearby buildings, termites should be ***identified*** by a person trained to do so. Pest species vary according to the region. ***Seek advice*** on treating termite infestation in trees as treatment varies with termite and tree species. It may be necessary to engage a pest control operator and/or tree surgeon. ***Winter*** is the best time to treat colonies as most individuals are in the nursery area. ***Lace monitors*** (large goannas) in south-eastern Australia lay their eggs in termite mounds.

Thrips (Thripidae, Thysanoptera) are ***1-2 mm*** long, white, grey or brown elongated insects.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) suck sap from many plants, eg azalea, hypericum, viburnum. They suck sap mainly from ***leaf undersurfaces*** where they can be found feeding. Black spots of ***excreta*** are produced (Fig. 215). ***Leaves*** become ***silvered***. In severe infestations, thrips may feed from the uppersurface as well. See Greenhouses N 24. ***Onion thrips*** (*Thrips tabaci*) appears to cause similar damage. See Onion M 68.

Plague thrips (*Thrips imaginis*) congregate in ***flowers*** of many plants, eg eucalypt, roses, causing premature browning. Their feeding reduces fruit and seed formation. See Roses J 6.

Western flower thrips (*Frankiniella occidentalis*) may be a pest of ***nursery stock***. See Annuals A 9.

Tip borers (Lepidoptera) tend to be host specific, eg callistemon tip borer. ***Caterpillars*** are tiny and burrow into the tips of ***new growth***; some also attack ***fruit***, eg oriental fruit moth (peach tip moth). Some beneficially tip prune their hosts, but may ruin the shape of nursery stock. See Bottlebrush K 38, Stone fruits F 131.

Weevils (Curculionidae, Coleoptera) may chew the ***leaves*** and ***stems*** of trees and shrubs. The ***larvae*** of some weevils damage ***roots***.

Garden weevil (*Phlyctinus callosus*) from South Africa, infests azalea, camellia, waratah, vegetables and weeds. ***Adults*** are grey, about ***5-6 mm*** long, the body has curved sides and a pale V mark at the rear. They hide in leaf litter during the day and feed at night on foliage. ***Larvae*** are whitish, legless, live in soil and usually cause minor damage to roots of many plants. ***Adults*** chew holes scalloped from the centre and margins of ***leaves*** (Fig. 216), and excavate small deep rounded holes on the surface of ***stems*** of some plants, eg waratah. Stems of young plants may be ringbarked and die. ***Buds*** may be eaten. ***Complete metamorphosis*** (egg, larva, pupa, adult) probably over 1-2 years. ***Overwinters*** as pupae in soil in early spring. ***Spread*** by adults crawling from breeding areas to crops and from plant to plant; by transportation (egg, larvae, adult) on seedlings, potted plants, boxes. ***Favoured*** in spring and summer, and by heavy growth of weed around the base of plants. ***Weevils are hard to control.*** They can be hand picked at night. Removal of litter on the soil surface of permanent plantings reduces hiding places for adults. ***Effective weed control*** denies larvae their food source and adults their hiding and egg laying sites. Trees may be ***banded*** with sticky material, this may not be practical. ***Insecticides*** may be applied to control the ***adults*** on ***nursery stock***, newly planted shrubs and surrounding soil, at first signs of damage. Insecticides kill most weevils after emergence from soil.

Others: ***Apple weevil*** (*Otiorhynchus cribricollis*), ***black vine weevil*** (*O. sulcatus*) and ***Fuller's rose weevil*** (*Asynonychus cervinus*) chew large ragged pieces from leaf edges. Larvae of some, eg ***elephant weevil*** (*O. cylindrirostris*), bore into dying or sickly trees but do little harm. ***Eucalyptus weevil*** (*Gonipterus scutellatus*) chews eucalypt leaves. ***Ringbarking weevil*** (*Aterpus griseatus*) feeds on twigs of bottlebrush, melaleuca and other plants, they also ringbark stems below ground level.

See Pome fruits F 116, Vegetables M 17.

Whiteflies (Aleyrodidae, Hemiptera): ***Australian citrus whitefly*** (*Orchamoplatus citri*), ***azalea whitefly*** (*Pealius azaleae*), ***greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***cotton whitefly*** (*Bemesia tabaci*) and ***poinsettia whitefly*** (*B. tabaci*-type B) may be pests of abutilon, poinsettia and other plants. Adults and nymphs suck sap from ***leaf undersurfaces***. Honeydew is produced and the associated sooty mould may be unsightly. See Greenhouses N 24.

SNAILS AND SLUGS

Common garden snail (*Helix aspersa*) may climb trunks and feed on ***leaves*** or ***bark*** of shrubs, eg box. See Seedlings N 70, Citrus F 43.

VERTEBRATE PESTS

Rabbits, hares, kangaroos, goats, stock and other grazing animals may damage newly planted trees, which need to be protected by tree guards, fencing or some other means. ***Possums*** chew buds on trees, eg pistachio, grapevines. ***Birds***, eg ***silver eyes***, feed on fruit. ***Cockatoos*** may feed on berries, new shoots and damage bark during their search for borer larvae. ***Honeyeaters*** feed on exuded sap from trunks. See Fruit F 13.

Non-parasitic

Algae, bacteria and fungi

Epiphyllous fungi may cause grey blotches on ***hairy stems and leaf undersurfaces*** of many plants, eg banksia, cotoneaster, grevillea, in humid situations (low lying plants or leaves close to the ground). Fungi grow superficially amongst leaf hairs and do not penetrate the plant. They cause ***cosmetic problems*** in production nurseries.

Lichens consist of an alga and a fungus living in close association for mutual benefit ***(symbiosis)***. The fungus receives food from the alga which receives food and protection from the fungus. They are usually found in damp places on rocks, dead wood, limbs and trunks of trees, but ***they are not parasitic.*** Lichens may be blue-green, grey, yellow or orange, flat and circular or leafy (Fig. 217). ***Trees and buildings*** look unsightly and their corrosive action hastens stonework deterioration. Lichens that inhabit bare rocks begin the first steps in soil formation. Spores are ***spread*** by wind. Control is mostly unnecessary. Lichens on trees may be killed with copper fungicides. Copper may stain buildings. Dead lichens remain for some time but can be brushed off.

Nitrogen-fixing bacteria (*Rhizobium* spp.) in the soil invade roots of ***legumes***, eg clover, wattle, which develop symbiotic nodules (Fig. 218). The plant supplies the bacteria with sugars produced during photosynthesis, while the bacteria fix the nitrogen from the atmosphere into nitrogen compounds that the plant can use. ***Lack of nodules*** results in stunted, weak plants which may die slowly. Plants generally look yellowish and older leaves are bright yellow and fall prematurely. Nitrogen-fixing plants may grow vigorously only if they have functioning nodules and this depends on their encountering appropriate strains of the nitrogen-fixing bacteria in the soil (Cremer 1990). In many areas, these bacteria occur naturally. In some instances, however, it may be necessary to ***introduce*** them to ***nursery mixes***. The addition of bush litter may induce nodule formation. Always check roots of legumes before planting. ***Actinorhizae*** consist of root tissue and Actinomycete fungi (bacteria which form branching threads). Actinorhizae convert the nitrogen in the air to a form that can be used by the plant. Actinorhizae are common on ***trees***, eg alder (Fig. 218), casuarina, *Eleagnus*. See Casuarina K 43.

Proteoid roots and mycorrhiza fungi are independent mechanisms that plants have for increasing their ability to exploit nutrient reserves in soils ***low in phosphorus***. In their absence various types of deficiencies may occur. Plants that form associations with mycorrhiza fungi do not form proteoid roots or their equivalents. Proteoid and mycorrhiza roots apparently improve plant growth, by increasing the absorbing surface of the root system to allow more rapid assimilation of scarce nutrients. They develop best near the soil surface below dense leaf litter. ***Proteoid roots*** are formed by most ***Proteaceae***, eg banksia, dryandra, grevillea, hakea, macadamia, protea, waratah. There is some evidence that their formation is stimulated by soil microorganisms, but this effect is non-specific. Proteoid roots may be coraloid ***(protea)***, or in clusters of short lateral roots arranged in rows along the parent root axis ***(macadamia)*** (Fig. 218). Proteaceae are adapted to using less phosphorus than many other plants, so low-phosphate fertilisers are applied. In the absence of proteoid roots, leaves may yellow and plants do not usually respond to fertiliser application. Addition of leaf mould from under established bushes of the same species may produce a marked improvement in the plant, though not always. Proteoid roots may be ***poorly developed*** in older trees (macadamia), in fertile or bare soil (orchards) and these trees may respond to higher levels of phosphorus fertiliser. ***Mycorrhizae*** (fungus roots) are structures (Fig. 218) which develop from normal feeder roots infected with ***symbiotic fungi***, which do not cause root disease but are beneficial to their host plants (Agrios 1988). ***Mycorrhizae improve plant growth*** by selectively absorbing and accumulating certain nutrients (especially ***phosphorus***), making ***available to the plant*** some normally non-soluble minerals, eg zinc, manganese and copper, by keeping feeding roots ***functional*** longer and by possibly making them more ***resistant*** to infection by certain soil fungi (Brundett et al. 1996, Galea and Poli 1992, Handreck and Black 1994, Hunter 1997, Pfleger and Linderman 1994). Some plants profit and need mycorrhizae more than others. There are thousands of types of mycorrhizae. Some fungi have a wide host range, others are host specific. Several different fungi may be associated with mycorrhizae on one plant. Each combination may have a different effect on plant growth. In commercial forestry it is common practice to ***inoculate tree seedlings*** with an appropriate mycorrhizal fungus before planting out. Growth of some trees may improve by up to ***40%***. ***Ectomycorrhizae*** attach themselves to ***outer surfaces*** of roots, which are usually swollen and may be more forked than non-mycorrhizal roots (Fig. 218). Inside the root the fungus only grows around the cortical cells. Formed primarily on forest trees mostly by ***mushrooms and puffballs*** (Basidiomycetes) and some Ascomycetes.

Spores are produced above ground and are wind spread. Mycorrhizae grow upright into small cavities in soil, compacted soil may be lacking in these cavities. *Pisolithus tinctorius* (MycorTree™) may be injected into the root zone of some mature and newly planted trees. ***Endomycorrhizae*** roots look similar to ***non-mycorrhizal roots*** in shape and colour, but inside the root the fungus grows into cortical cells, forming special feeding hyphae (arbuscles and vesicles). There is only loose mycelium on the root surface on which spores are produced underground. Different groups of fungi may produce endomycorrhizae. They are produced by most cultivated plants and on some forest trees. ***Ectendomycorrhizae*** are intermediate between the other two. The fungus grows into and around the cortical cells of roots and may or may not have a fungus mantle on the surface of the feeder roots. Fungi may be of unknown identity. See Eucalypt K 65.

Sooty mould (various fungi) grows on ***honeydew*** excreted by ***some sap sucking insects***, eg aphids, leafhoppers, lerps, mealybugs, soft scales and whiteflies. It attracts ***ants***. Extensive or persistent sooty mould reduces photosynthesis and inhibits normal colouring of leaves. It will disappear only if the insects producing the honeydew are controlled. Sooty mould will then dry and flake off, hosing may assist removal. See Citrus F 41.

Others: ***Projectile fungus*** (*Sphaerobolus stellatus*) fruiting bodies ***disfigure*** plant surfaces but are of little importance. See Potting mix N 64.

Environment: ***Autumn colours*** and leaf spot patterns may be produced under high humidity. Premature development of autumn leaf colours may indicate water stress and low temperatures. ***During cold winter weather*** leaves of some plants develop reddish circles, eg light green camellias, or general reddish pigments, eg euonymus. Pigmentation disappears with warmer weather. Tropical plant leaves may blacken, leaves may roll under, eg rhododendron. ***Late spring frosts*** can injure new growth of frost-sensitive plants. In areas where frost occurs, do not fertilise young plants in autumn and protect with some sort of shade. Plants may be sprayed with ***water*** near sunrise to avoid damage from rapid thawing which occurs when sun strikes frozen tissue. ***Bacterial sprays*** also offer protection. ***Hail*** may damage leaves, fruit, green shoots (which later callus and become canker-like), injured areas may be invaded by bacterial or fungal diseases. Damage may not be obvious until flowers are formed and fruits ripen. Large concentrations of hail may suddenly chill, check growth and cause green leaves to fall. ***Lightning*** may split trees. ***Excessive exposure to sun*** may scorch leaves, flowers, fruit, limbs, trunks, exposed sides of plants show more severe symptoms. ***Leaves*** may yellow. Severe damage results in brown patches ***within leaf margins*** which may later be colonised by leaf spotting fungi, eg *Pestalotiopsis*. Yellow sections of ***variegated leaves*** may brown. Leaves of ***shade loving*** plants may scorch easily. Scorching can also occur when protection is suddenly removed (pruning, storms, wind). Drying effect of sun is exaggerated by hot winds and lack of water. ***Buds or flowers*** of white and pale pink varieties, which are wet with dew or frost in the morning, may brown if exposed to direct sun. ***Bark*** on ***trunks*** exposed to sun due to defoliation (water stress, storm damage, wind, disease or insect attack) may peel and split and be invaded by wood rot fungi. Patches of bark may brown or redden. Bark may be killed on species with thin bark. Protect by white washing. ***Wind and rain*** can cause browning of flower petals, particularly white and pale coloured varieties. Wind may tatter or scorch leaves of soft new growth, chill plants preventing growth and blow over waterlogged trees in shallow soil. ***Drought or inadequate irrigation*** may cause brittle marginal scorching of leaves. Hot, windy weather, fungal attack on the roots, construction damage, waterlogging or a combination of these, may aggravate the problem. Recently planted, root-injured or insect-infested trees, may die. ***Excessive soil moisture*** may be due to leaking taps or irrigation systems, drainage patterns or poor drainage, excessive rain or irrigation. ***Waterlogging*** occurs when water replaces the air in the soil pores for long periods, eg in low lying areas or in heavy soils when roots cannot extract sufficient oxygen for normal growth. Leaves may die, branches may die back. Some plants die rapidly, others over a long period of time. Waterlogging can be complicated by other factors. Very few plants can survive waterlogging and *Phytophthora*. During certain weather some ornamental trees may ***flower out-of-season*** (in autumn as well as in spring), eg Manchurian pear and crab apple. ***Snow*** may damage trees by its weight and cause chilling injury and sweating if it lies on plants for long periods. ***High humidities:*** ***Continuous fogs*** may cause leaves to blacken and fall ***(sweating)***. Sweating is worse in plants with a compact habit and hairy leaves. If fogs last 2-4 days or longer, fineleaved hairy species may be severely damaged. ***Oedema*** may affect camellia and other plants. It is caused by abnormal water relations within the plant, when roots absorb more water than leaves can transpire. Small masses of tissue expand and break out on ***leaf undersurfaces*** causing small watery swellings or galls. When these burst they harden into variously shaped ***small corky scabs***. See Camellia K 40.

Genetic problems: ***Fasciation*** is where upper parts of stems become flattened and have multiple leaves and ridges, stems look as if joined together. Commonly occurs on ash, casuarina, daphne, euonymus, wattle. See Daphne K 53. ***Sports*** are a genetic change and are common; variegated forms produce green shoots. Variegated leaves and flowers may be confused with virus and deficiency symptoms on some hosts. ***Unusual bark features*** occur naturally on some trees, eg liquidamber. ***Variation of tree performance*** within a species is common and results in variable flowering, autumn colours, growth rates etc. Source of planting materials, eg the ***provenance of eucalypts*** (place of natural geographic origin), is very important (Eldridge et al. 1993).

Insects: ***Ants*** (Formicidae) are attracted to ***honeydew*** produced by some sap-sucking insects, eg aphids. Some species nest in trees. Ants may also nibble edges of young citrus ***leaves*** which become cupped as they grow. Injury is minor but it can reduce vigour of young trees. ***Control ants*** when they are observed on trees. Trees should be ***pruned*** (skirt is at least 0.5 m off the ground) to reduce access by ants via weeds and lower canopy. ***Destroy nests*** and if necessary treat lower trunks and under canopies. Sticky bands around the base of the trunk may stop ants. See Turfgrasses L 8. Some insects associated with trees are ***pests of other plants***, eg European earwig (*Forficula auricularia*) shelters under bark. ***Beneficial insects*** are associated with trees. Moths feed on trunk exudations, honeybees and other insects feed on nectar.

Nutrient deficiencies, toxicities

Trees may suffer from deficiencies and toxicities in the same way as other plants (Handreck 1994). Only a few examples are described. If large plantings are planned, obtain a ***soil analysis*** before planting susceptible species and if deficiencies or toxicities occur, confirm them by ***tissue analysis.*** Fertilisers may be ***applied*** to the soil around the trees, to the foliage or by trunk injection. ***Iron deficiency*** (chlorosis) affects ***ornamentals***, eg azalea, camellia, cyclamen, eriostemon, gardenia, gerbera, grevillea, hydrangea, magnolia, rose, gloxinia, *Crowea*, *Dampiera*, eucalypt, wattle, ***fruit***, eg blueberry, citrus. ***Symptoms*** appear initially on new leaves, veins are green against a background of creamy yellow. If severe, whole plants yellow, leaf size is reduced, shoots shorten, leaf edges may brown, new growth is poor or dies back, flowering is reduced. ***Favoured*** by insufficient available iron for chlorophyll formation, usually occurs in alkaline soil. Grow azaleas in soils with a pH < 6. May also develop in acid soils resulting from an accumulation of heavy metals, eg copper, relative to the amount of iron present. Iron may be unavailable because of high levels of other nutrients, eg nitrate nitrogen, phosphate. Overwatering of plants (poor aeration), high or low temperatures, root damage may also ***contribute to symptoms***. Check soil pH before planting susceptible species. Do not plant beside cement brick walls or apply alkaline fertilisers, eg lime, superphosphate or wood ash. Commercial fertilisers are available for acid-loving plants, blood and bone and sulphate of ammonia can also be used. If iron deficiency should occur, iron chelates or other fertilisers specially prepared for these plants, may be applied either to the soil or to the foliage when the plant is growing. ***Magnesium deficiency*** may cause green or yellow V-shaped patterns on older leaves. ***Nitrogen deficiency:*** Trees commonly affected include citrus, daphne, camellia. Older leaves are affected first, eventually all leaves become creamy yellow. The plant appears to be lacking vigour and may be woody. Apply a complete fertiliser in spring and autumn. ***Boron deficiency*** occurs on radiata pine, grape (hen and chickens), apple and pear (cork), cabbage, cauliflower and celery (hollow heart), turnip, beetroot (brown heart), lucerne, some wattles, eg *A. adunca*, *A. spectabilis*. Symptoms vary depending on the species. Wilting and defoliation of the upper parts of shoots occurs followed by death of the terminal bud and dieback of the shoots. Leaves may become thickened and lateral buds develop. Only small amounts are required by plants and excessive quantities are very toxic. See Fruit 14. ***Phosphorus deficiency*** is rare in Australian plants except perhaps in rainforest situations. Specialised root systems, eg ***proteoid roots,*** play a part in the uptake of phosphorus. See Trees K 18. ***Phosphorus toxicity:*** Levels normal for other plants may be toxic to some container-grown ***Proteaceae***, eg some species of banksia, grevillea and hakea, where soil is not used (in garden-grown plants the phosphorus is rendered immobile by soil). Some Fabaceae and Mimosaceae which grow naturally on sandplains and heathland may also be sensitive, eg *A. suaveolens*, *Brachysema* spp. Youngest leaves may yellow, leaves may blacken, oldest leaves may die, and the whole plant may die. Do a ***soil/mix analysis*** prior to potting up and a ***leaf analysis*** to confirm phosphorus toxicity. Phosphorus toxicity arising from the use of superphosphate and blood and bone, which contain high levels of phosphorus, is difficult to correct. Toxic effects of excess phosphorus may be offset by addition of some other elements, eg iron, but advice should be obtained. ***Salt toxicity:*** Excessive use of chemical fertilisers may cause total soluble salts to accumulate over time damaging some ***ornamental plants***, eg azalea, camellia, gardenia, ***most fruits***, eg grape, ***vegetables***, eg carrots, radish, celery, ***field crops***, eg most clovers. ***Leaves*** may have a marginal scorch and later fall, but often they blacken and soften. Apply only recommended rates of fertilisers. Where salt toxicity has occurred, excess salts may be washed out by leaching (repeated irrigation); good drainage is essential for this to be successful, if this is not possible, plant salt tolerant trees, eg varieties of casuarina, eucalypt, wattle. ***Soil salt:*** If the water table rises near enough to the soil surface for evaporation to occur by capillary action, salt will build up and vegetation growth and leaf size will be reduced, and dieback occurs. Soil water does not need to appear ***on the surface*** for salting to occur. Salting may occur in low lying areas where drainage water collects. Water is continually evaporating during warm weather and dissolved salts become concentrated. Salting is common in hilly country which has been extensively cleared of vegetation. In severe cases salt may appear as a white encrustation on the surface. ***Windborne salt*** is picked up from the sea and transported inland by onshore winds. Leaves may blacken and brown with papery patches, new growth withers and dies, leaves may fall. Symptoms vary greatly with the species. Only plant ***salt tolerant plants***. See Citrus F 43, Soil N 81.

People-pressure diseases *(PPD)*

Animals chew or scratch bark, dig up roots, birds scratch around the base of shallow-rooted shrubs, rodents and possums eat buds. ***Bare-rooted*** and containerised nursery stock must be cared for prior to planting, and planted in the correct manner at the appropriate time of year. ***Bark splitting*** may be caused by lightning or growth stresses. ***Buildings*** may cause trees to lean outwards. ***Land clearing*** caused by agriculture, mining, forestry or urbanisation may reduce tree numbers. Flooding and inappropriate irrigation may kill trees. ***Mechanical injury*** by cars, stays, vandalism, balled roots, construction damage, removal or addition of surrounding soil or lawn mowers may damage trees. ***Girdling of roots*** in containers (Fig. 219) prior to planting out may shorten tree life by constricting the vascular system and nutrient movement and by not adequately anchoring trees. Containers are available which reduce/avoid this problem. ***Pruning*** removes dying and dead tissues, but if done improperly can predispose tree to disease or decay. Prune at branch collars, do not leave stubs. ***Soil compaction*** by vehicles, play areas and on paths decreases oxygen and free water and allows buildup of carbon dioxide and other gases, which may ***smother roots***; there may be few spaces for mycorrhizae to grow in. Barriers around trees prevent parking. Mulches help to cushion the effect of foot traffic. ***Vandalism*** includes stealing and breaking tops of young trees.

Pesticide injury:

Many broadleaved plants are susceptible to ***hormone-type herbicides***, eg 2,4-D, dicamba, resulting in cupped, twisted or malformed leaves. Herbicide injury often follows ***spray drift*** (wind, volatility) of hormone-type herbicides used to control broadleaved weeds in lawns. Trees may also absorb herbicides via their roots, especially if heavy rainfall follows application in adjacent areas, causing washing over the ground surface or leaching through soil. Grass clippings and bark chips from treated lawns and other areas can carry herbicides.

Recent plantings are very susceptible to injury. ***Simazine*** may induce symptoms similar to those caused by water stress. ***Sulphur*** may scorch leaves, especially at temperatures > 28^{o}C. ***Petroleum oils*** may damage deciduous and evergreen trees, especially under stress. Too many applications during dormancy may injure bark and > than label rates during summer may damage many species. Oil may remove the bluish colour of blue spruce, which may not return for months. ***To avoid injury*** to trees from pesticides and anti-transpirants, strictly adhere to label directions relating to dosage, plant species and cultivar, manner of applications and weather. ***Substances injected into trunks*** eg fungicides, insecticides, fertilisers, herbicides, vitamins and tree growth regulators (Yau 1994) may cause bark blowout, splitting, weeping or bleeding. Only tree-inject strong compartmentalisers, eg most eucalypts and non-weepers, and only when there is transpiration pull and trees are not under stress from drought or injury. Re-examine injected trees after 12 months to assess hole closure. If they are not closing then do not perform any more tree injections. Allow 3-4 years between injections. See Plane tree K 115.

Pollution: ***Natural gas*** is not directly toxic to plants, but underground leaking gas pipes deprive roots of oxygen. Trees die slowly, leaf tips and margins are scorched, centres often remain green. Leaves may cup, wilt and fall prematurely. After repairing the leak do not replant for at least 12 months to allow oxygen levels to rise, then loosen and aerate the soil. ***Gaseous air pollutants*** come from smoke stacks or burning areas. ***Oxidants*** are formed in the atmosphere from industrial and auto emissions and are common components of ***smog***, which occurs to some extent around all large cities. Pollution-sensitive natives may be used to measure smog. ***Symptoms*** include bleached, water soaked areas and brown spots especially on ***leaf uppersurfaces***. Affected leaves may fall early. Young and very mature leaves appear to be more resistant. Most serious forms of air pollution can only be prevented by ***environmental protection agencies***. Select trees that are ***tolerant*** to air pollutants in a given area. ***Very sensitive species*** include silver banksia. ***Some species***, eg eucalypt, oak, weeping willow, produce high levels of hydrocarbons (terpenes and isoprenes) that react with nitrogen oxide and contribute to smog. Ash is a low-emitting species.

Potential weeds: Many ***exotic trees***, eg hawthorn, may become urban weeds. Many ***native plants***, eg some hakeas, become weeds overseas. See Urban bushland N 86.

Unwanted roots, suckers and trees

Unwanted invasive roots may cause building, landscape and sewer/drainage damage, soil heave and sucker problems. Root grafts may spread vascular wilt and virus diseases (uncommon). Although trees which do not produce invasive roots may be selected, when water becomes scarce, roots seek it out. ***Prevent*** problems by providing sufficient ***space*** for roots, constructing root-resistant foundations, pavements and pipes, containing roots within a given area while providing room for growth. Problem tree roots should be identified. ***After establishment***, trees may be trenched and underground ***mechanical barriers*** to deflect roots and withstand the pressure of growing roots, eg impervious fabrics, or mesh, reinforced concrete, steel or fibre sheeting, soft plastic sheeting, syfra root deflection barriers put in place.

Chemical root barriers (barriers containing herbicide) at least 1 m deep, may be placed as close to the item to be protected and as far from the tree root system as possible; ensure roots do not grow over the top of barriers (Anon. cur. edn.).

Suckers damage pavements, underground services and are undesirable near buildings or desired trees. Use ***rootstocks*** that will not sucker. Herbicides applied to suckers ***attached*** to the parent tree may be translocated to it and damage or kill it. Check that the herbicide to be used in that situation is suitable. ***Unattached suckers*** can be sprayed if < 0.5 m high, or cut off at ground level and the cut surface painted with herbicide. Home gardeners can dig suckers out.

Unwanted trees: Trees are removed because of age, size, diseases, pests, nuisance roots, suckers and thinning in forests. Some trees, eg pines, which do not sucker can be killed by cutting off the trunk below the bottom branch. ***Trees that sucker or coppice*** from stumps and/or root systems, eg elms, eucalypts and poplars, can be poisoned in spring, summer and autumn when sap is flowing, then cut down when dead. ***To kill individual trees***, either drill holes in or frill the trunk with an axe immediately prior to applying the herbicide. Stem injection equipment is used for thinning young eucalypt forests and removing unwanted woody weed species in urban bushland.

Others: ***Allelopathy*** is the release by one species into the environment of chemicals which interfere with surrounding plants. See Eucalypt K 65. ***Senescence:*** Do not confuse ***natural senescence*** of leaves and twigs with serious tree problems. ***Leaves*** on evergreen trees do not last forever, but yellow and fall after a certain length of time. Intermittent yellowing of older leaves occurs at the base of each stem of some plants, eg daphne, camellia. ***Twigs*** and ***branches*** within older tree canopies may die.

WEEDS

Problem weeds around young trees include annual and perennial grasses and broadleaved weeds. ***Landscape design*** should minimise difficult weed control situations. Weed control requirements change with ***time***. Preferably ***pre-plant*** control weeds by cultivation or herbicides, etc. ***Post-plant*** weed control is essential. Around ***newly planted trees*** by ***cultivation*** (keep to a minimum within the drip line as it may injure shallow roots), by ***mulches*** of various types, by ***weed mat*** laid on top of dripline and held in place by metal pegs (may last 4-10 years depending on sun, etc), or by ***post and pre-emergence herbicides***. Some herbicides should not be applied around newly planted trees. Rows between trees may be mowed. Preferably control weeds around ***older trees*** by ***permanent ground cover, mulches or by cover cropping***, to stabilise soil, prevent erosion and act as a buffer against high soil temperatures and heavy rain. ***Spot spraying*** emerged weeds and the application of pre-emergence herbicides is useful amongst ornamental trees, but ***constant herbicide use*** may ***bare soil***. As trees age, they provide shade for areas around the trunk reducing weed growth. Weed control on ***sloping areas*** ought to be continually revised to avoid the exposure of roots due to lack of weeds to hold the soil around tree roots. Some trees and shrubs have become ***woody weeds***, pyracantha, wattle. See Trees K 21, Urban bushland N 86.

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Tree Guards, Tree Roots, Building & Sewers
Tree Injection for Insect Control
Tree Poisoning
Weed Control for Trees
NSW Agfacts
Black Heart of Apricots
Dodders
Iron Chlorosis in Ornamentals
Nectar Scarabs
Wood Rots of Fruit Trees and Other Plants
NSW Forest Protection Series
Borers and Termites in Trees
Leafeating Insects
Sap-sucking Insects
Qld Farmnotes
Pests of Young Trees (WA Farmnote)
Phytophthora Root and Collar Rot (NT Agnote)
Vic Agnotes
Armillaria Root Parasite of Plants
Eriophyid Mites
Phosphorus Toxicity & Native Trees & Proteaceae Plants
Root Rot Diseases of Ornamentals and Fruit Trees
Silver-leaf disease of Fruit Trees
Transplanting Ornamental Trees and Shrubs
Verticillium Wilt of Deciduous Fruit Trees
Wood-rotting Fungi of Fruit and Nut Trees

Associations, Journals etc.
Arboricultural Association
Arboriculture Journal (International J. of Urban Forestry)
Arborist News
Australasian Tree Seed Centre (TREDAT database)
Australian Forestry
Australian Horticulture (Trees and Shrubs Features)
Australian Parks and Recreation
Forestry Commissions (states/territories pub. lists)
Greening Australia
Grounds Maintenance
GrowerTalks
GrowSearch (database Qld DPI)
International Society of Arboriculture Plant Health Care
Journal of Arboriculture (Compendia)
Landscape Australia
Landscape Contractors Associations
National Arborists Association of Australia (NAAA)
NIAPR titles
NZ Turf Management
Ornamentals Update
PLANTGRO (CSIRO database)
Shrub and Tree Growers Associations
Tree Seed News

See Australian native plants N 9, Preface xii

Remember, always check for recent references

MANAGEMENT

Nearly all local authorities have tree protection orders, guidelines for tree selection for homes, parks and street trees, root and weed control programs. There are legislative requirements for various plantings, eg trees under powerlines, and Australian standards for trees. Local communities may be involved with school plantings, nature parks and landcare groups. Nursery Accreditation Schemes and Forest Codes of Practice for Nurseries control diseases and pests in nurseries, etc.

Selection

Horticultural requirements: Match local climate, site and tree. ***Trees are grown*** for ***shelter***, ***aesthetics***, ***food***, ***timber***, ***landscape requirements***, ***special locations***, eg rural, industrial or saline areas, to combat soil and water erosion, lowering water tables. ***General characteristics*** include growth rate, ultimate size and lifespan, deciduous/evergreen and native/exotic, hardiness, crown shape, foliage, density, rooting habits, suckers, ***flowers,*** availability and price. ***Unfavourable characteristics*** include health problems (allergies), poisonous nature, falling fruit, thorns. ***Outstanding characteristics*** include fast growth, autumn colours, flowers, scent, shape. ***High or low maintenance***, eg need for ***pruning***, irrigation, ***litter*** removal (bark, fruit, limbs). Systematic ***tree replacement programs*** for ageing landscapes must be prepared. ***Provenance*** is the name given to different geographic origins of a species (Lehane 1996). Correct provenance is as important as species selection and can result in success or complete failure of a species.

Resistant varieties: Select trees and hedges which are either problem-free or have some resistance or tolerance to ***parasitic pests and diseases*** present locally and overseas, and ***non-parasitic local problems***, eg poor drainage, salinity, exposed slopes, pollution. Avoid large plantings of susceptible trees.

Plant quarantine: Propagation material, scions, pollen, seeds, freshly cut foliage and flowers, logs, timber, wooden packing material and wooden articles ***entering Australia*** are subject to quarantine requirements (Com. of Aust. 1992). Contingency plans have been developed for exotic pests and diseases of living trees. ***Interstate*** and ***regional quarantine regulations*** affect some tree pests, eg elm leaf beetle. Nursery accreditation schemes prevent spread of diseases, eg *Phytophthora*, and soil pests, eg garden weevils, black vine weevil, etc. in containers.

Disease-free planting material: Select plants propagated from quality parent stock (colour, flowers, etc) which are free from pests, eg scales, and diseases, eg viruses, *Phytophthora*.

Establishment

Propagation: By seed, cuttings, grafting, lignotubers, tissue culture. ***Instant landscapes*** may be created by transplanting advanced and mature trees. Trees can be transplanted to nurseries, regenerated and relocated. ***Nursery stock*** must have straight main stems free from scars, be young and well grown, but not root bound. Trees of the same species grown from ***seed*** tend to be more variable than those propagated vegetatively. Propagation material of the ***same species*** derived from different parent stock or different locations (see above), may vary markedly (Eldridge et al. 1993). For some features, eg autumn colours, select trees in autumn especially if grown from seed.

Cultural methods: ***Design landscapes*** aesthetically and with other considerations, eg street corners, school and shopping centre exits not obscured by hedges or trees. Avoid planting ***susceptible trees*** in ***sites contaminated*** with pests or diseases, eg *Phytophthora*. Plant when trees can establish before being subject to drought, heat, cold or wind. ***Protect when young*** from drying winds, animals, cars, children, lawn mowers and other damage with tree guards, stakes, fencing, watering, mulching and if necessary, pruning. Only water in first 2 years. Plant as recommended without damaging roots.

Sanitation: Avoid contaminating equipment, soil. Avoid contaminated soil or compost; remove dead or dying trees, prune when foliage is dry. Hand removal of some insects found on young trees is a viable option.

Biological control programs for trees tend towards ***maintaining the natural enemies*** of diseases and pests rather than ***applying or releasing*** biological control agents. Exceptions include *Agrobacterium* (Nogall®) which is applied to seeds/rootstocks to control crown gall (*Agrobacterium* sp.) on *Prunus* spp.

Weeds should be controlled around young trees for a distance of 0.5 m from the trunk either by hand removal, cultivation, cutting, mulching or by post- or pre-emergence herbicides. Do not damage roots or young stems.

Pesticides: ***Growth regulators*** are used on cuttings. ***Herbicides*** are used for weed control. ***Insecticides and fungicides*** are used on nursery stock, and may have a role in the management of new tree plantings to maximise growth rates and survival, providing they comply with safety guidelines. However, species ***should*** be able to grow satisfactorily thereafter without the need for pesticide applications either to the foliage or soil.

Maintenance

Monitor potential diseases, pests and predators, and crown density, weather. The International Society of Arboriculture (Matheny et al. 1994) and other organisations produce ***visual tree hazard evaluation forms*** for trees in urban areas. Equipment is being developed to ***detect and evaluate incipient decay*** in trees (Anon. 1996, Bethge et al. 1996).

Cultural methods: Maintenance changes as trees get older, eg weed control and tree surgery will change. ***Prune*** and ***fertilise*** appropriately, ***water*** older plants thoroughly only if showing signs of stress during a drought.

Biological control: Encourage ***passive natural controls***, eg weather extremes, predators, parasites and diseases by keeping trees healthy. A degree of damage has to be accepted. There is a lag between the outbreak of a pest and its control by natural agencies. Insects of low densities on trees do not cause tree death, most trees recover from defoliation quickly. The wide variety of insects on trees is an essential source of food for birds and other predators and parasites of insect pests of trees, pastures and crops. Insect populations fluctuate.

Physical and mechanical methods: ***Tree surgery*** is used to repair wood rot or borer damage, storm and construction damage. Laboratory assistance may be required to ***diagnose or confirm*** diseases or insects.

Pesticides: ***Pesticides*** have a limited role in management of mature trees, and have environmental and economic costs. Only trees < 3 m may be sprayed with low hazard products, eg white oil; there is community resistance to such spraying in public areas. Only local councils and similar organisations have the ***necessary equipment*** to spray large highly valued or heritage trees. ***Tree injection*** does not affect parasites and predators, but may physically damage trees and provide entry points for wood rot fungi and predispose trees to borers. New tree injection techniques may reduce or eliminate these problems. Tree injection should give control for 6-8 weeks and much longer if isolated trees are treated. Soil applications of systemic insecticides to control foliage feeding insects is being researched. ***Growth regulators*** control hedge growth.

Postharvest

Trees may be ***harvested*** for timber, timber products, cut flowers and foliage. Woody-stemmed material for cut flowers or foliage is more prone to bacterial infection than soft-stemmed flowers. Cut stems on an angle with a sharp knife, change vase solution every 2 days. Flowers with woody stems are thirsty, so place in deep water and top up regularly; warm water eases water flow up stems. Most flowering shrubs do well in preservative solution; many, eg *Prunus*, can be forced; some produce easily bruised flowers with a short life. Handle with care and keep cool. Spraying ***berries*** with hair spray or clear fixative may prevent shrivelling (Jones and Moody 1993); remove leaves to see berries.

Table 3. Insect and mite leaf damage

Sucking pests	Upper leaf surface	Lower leaf surface
Greenhouse thrips	Silvering	Thrips, dots of tarry excreta
Greenhouse whitefly	Speckling	Adults, scale-like nymphs, honeydew, sooty mould
Lace bugs[a]	Speckling of leaf	Adults, nymphs, nymph skins, dots of tarry excreta
Leafhopper	Speckled feeding patterns	Nothing, sometimes nymph skins
Twospotted mite	Speckling	Mites, webbing

[a] Limited host range eg azaleas, rhododendrons, olive

Table 4. Leaf browning on azaleas

Scorched or dead leaves	Symptoms
Azalea leaf miner[a]	Dead patches appear on leaves, often bounded by ***leaf veins***. Leaf tips may be ***rolled under***
Phytophthora root rot	Leaves and later the whole plant dies. ***Disease test*** is necessary.
Phytophthora shoot blight	Buds and shoot tips brown and blacken. ***Disease test*** is necessary
Rhizoctonia web blight	New growth of azaleas blighted and webbed
Sunscorch	Yellow or brown areas ***within*** leaf margin
Drought (too little soil water)	***Brittle*** brown leaf tips and margins
Waterlogging (too much soil water)	***Soft brown*** dead areas at tips and around margins
Salt toxicity	***Soft brown/black*** dead areas at tips and around margins

[a] Azaleas only

Abutilon

Chinese lantern

Abutilon spp.
Family Malvaceae (mallow family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Abutilon mosaic virus
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf spot
- **Nematode diseases**
- **Insects and allied pests**

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Abutilon mosaic virus occurs naturally in Brazil, Puerto Rico, India and probably Trinidad. It has been sent all over the world in variegated *Abutilon* species grown as ornamental plants. There are probably several strains. *Abutilon megapotamicum* is the only known host in Australia, overseas also other ***Malvaceae***, eg cotton, hibiscus, *Malva, Sida*. The attractive bright yellow and green variegation of *Abutilon* ***leaves*** is the main reason for its propagation as an ornamental plant. Mottling tends to disappear if plants are grown in darkness or subdued light. Symptoms shown by naturally infected plants vary seasonally, depending on the light intensity. ***Spread*** by grafting, by propagation from infected plants, by the introduction of infected plants, by cotton whitefly (*Bemisia tabaci*) in northern Australia, not by contact between plants, not by seed. Any shoots reverting to green may be cut out from the base. See Trees K 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) has been reported as occurring on native *Abutilon* spp. See Stone fruits F 125.

FUNGAL DISEASES

Fungal leaf spot (*Ascochyta abutilonis*) attacks *Abutilon* spp. See Annuals A 5.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne hapla*) has been reported on native *Abutilon* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

*Abutilon tend to be attacked by the same pests that infest **other Malvaceae**, eg hibiscus, hollyhock, cotton, mallow weed.*

Bugs (Hemiptera), eg ***coon bug*** (*Oxycarensis arctatus*), ***cotton harlequin bug*** (*Tectocoris diophthalmus*), ***cotton seed bug*** (*O. luctuosus*) and ***harlequin bug*** (*Dindymus versicolor*), suck sap from ***shoots*** causing wilting. See Hibiscus K 82, Vegetables M 12.

Caterpillars (Lepidoptera) of several moths, eg ***castor oil looper*** (*Achaea janata*), feed on ***foliage***. Caterpillars of ***cotton tipworm*** (*Crocidosema plebejana*) burrow into ***tips***. ***Rough bollworm*** (*Earias* sp.) feeds on ***young shoots, flowers and seed capsules***. Caterpillars of a ***small moth*** (*Phyllonorycter stephanota,* Gracillariidae) may ***mine in leaves***. See Hibiscus K 82.

Mealybugs (Pseudococcidae), eg ***hibiscus mealybug*** (*Maconellicoccus hirsutus*) and ***longtailed mealybug*** (*Pseudococcus longispinus*), infest *Abutilon*. See Greenhouses N 25.

Metallic flea beetles (*Altica* spp.) are small shiny, metallic looking and about ***3 mm*** long. They chew ***tiny holes*** of irregular shapes in ***young leaves and buds***, as the leaves grow the holes enlarge. See Hibiscus K 82.

Soft scales (Coccidae), eg ***black scale*** (*Saissetia oleae*) and ***white wax scale*** (*Ceroplastes destructor*), disfigure plants. See Citrus F 41.

Whiteflies (Aleyrodidae), eg ***greenhouse whitefly*** (*Trialeurodes vaporariorum*) and ***cotton whitefly*** (*Bemesia tabaci*), mainly infest ***leaf undersurfaces***. See Greenhouses N 24.

Others: Fuller's rose weevil (*Asynonychus cervinus*) may feed on *Abutilon* leaves overseas, larva feed on roots, leaves may yellow. See Rose J 6.

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See Hibiscus K 83, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Abutilon may not be grown in the coldest districts, as some species, eg *Abutilon* Saritzii, are sensitive to ***frost***. Some species, eg weeping Chinese lantern (*A. megapotamicum*), make attractive ***hanging baskets***. Plants should be well established in pots prior to sale and kept well illuminated. In winter, they should be kept cool at 8-12^{o}C, in summer they require frequent regular watering. ***Ethylene*** causes bud and flower drop; growers sometimes spray plants with anti-ethylene agents prior to sale (Nowak and Rudnicki 1990).

Ash

Fraxinus spp.
Family Oleaceae (olive family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Ash yellows (phytoplasma) may cause a ***decline*** in *Fraxinus* overseas. ***Spread*** by grafting, by leafhoppers (Gleason and Sinclair 1996). See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots: ***Leaf spots*** (*Gloeosporium* unconfirmed) are usually light brown. See Annuals A 5.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*), ***phytophthora root rot*** (*Phytophthora* sp.). See Trees K 4, K 6.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne halpa*) and ***dagger nematode*** (*Xiphinema italiae*) have been recorded on *Fraxinus* sp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae): ***Cotton aphid,*** melon aphid (*Aphis gossypii*) may infest ***new shoots***. See Cucurbits M 53, Roses J 4.

Borers: ***Various species*** may infest branches or trunks, particularly if damaged by ***sunburn*** or ***lack of water***. Many borer species occur overseas causing significant damage to ash. See Trees K 11. ***Secondary wood rot fungi***, eg ***yellow heart rot*** (*Schizophyllum commune),* may infect damaged areas.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Apple mussel scale*** (*Lepidosaphes ulmi*). Masses of brown bodies shaped like ***oyster shells*** and about ***8 mm*** long cover twigs and branches. The scales overwinter in the egg stage under the scales. Young crawlers appear in spring. See Citrus F 39, Pome fruits F 116.

Soft scales (Coccidae): ***Black scale*** (*Saissetia oleae*) is a ***serious pest*** affecting ash trees and is difficult to control on large trees. Severely infested young trees may be stunted. See Citrus F 41.

See Citrus F 39, F 41.

Others: An ***exotic psyllid*** (*Psyllopsis fraxinicola,* Psyllidae, Hemiptera) feeds on *Fraxinus* in Tasmania.

VERTEBRATE PESTS

Birds may feed on seed and break off new shoots. See Fruit F 13.

Non-parasitic

Environment: Excessive crown thinning may result in ***sunburn*** injury to the thin bark of *Fraxinus*. ***Drought*** conditions may adversely affect *Fraxinus* spp.

Genetic: Some ***claret ash trees*** seem to lack vigour and have a tendency to die back as they age (the cause is unconfirmed). ***Fasciation*** is a genetic abnormality occasionally observed on ash ***stems***. Nothing can be done except to remove affected parts but it is likely that the same tree will produce further fasciated parts. Do not propagate from affected trees. See Daphne K 53.

Salt injury: Some *Fraxinus* spp. are sensitive to ***excess fertilisers*** and may suffer from browning of leave edges due to salt injury. See Trees K 20.

Sooty mould: Ash trees (leaves and trunk and branches), infested with soft scales or aphids become covered with ***honeydew*** and associated ***sooty mould***. ***Ants*** are attracted to the honeydew. See Trees K 19.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Ashes are deciduous trees, preferring full or half sun. Some species, eg claret ash (*Fraxinus* Raywood) and golden ash (*F. excelsior* Aura), produce ***brilliant autumn foliage*** in cool temperate and cold climates. Choose species and varieties to ***suit the site***, eg desert ash (*Fraxinus oxycarpa*) is frost hardy, tolerant to hot and dry conditions; golden ash requires summer irrigation especially during the early years to avoid scorching of foliage. *Fraxinus* may be ***propagated*** by seed and by grafting.

Azalea and Rhododendron

Rhododendron spp.
Family Ericaceae (heath family)

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Azalea leaf gall

Scientific name: Agaricales, Basidiomycetes: Azalea leaf gall (*Exobasidium vaccinii*)

Host range: Azalea, rhododendron, blueberry.

Symptoms: Minor, unsightly disease. In spring, ***new leaves*** become ***thickened*** and ***fleshy***, white, pinkish or greenish. ***Flowers*** and ***seed pods*** may also be affected. Galls wither, become brown and fall to the ground. See Bonsai N 15 (Fig. 393).

Overwintering: In dead galls on the host or on the ground.

Spread: Spores (basidiospores) produced on the surface of galls, on the host, or the ground are spread by wind. By movement of infected plants.

Conditions favouring: Wet weather in spring. Outdoor plantings where galls from previous seasons accumulate on the ground.

Control:
Sanitation: Hand pick and destroy galls in spring as soon as they appear, before spores form.
Resistant varieties: Hexe, Advent Bells and Phoebus are more susceptible than others.
Disease-free planting material: Only plant gall-free plants.
Pesticides: Apply ***fungicides*** to new growth in spring before new leaves unfold. Before spraying, remove galls already present.

Fungal leaf spots (*Cercospora*, *Septoria*, *Cylindrocladium*, *Pestalotiopsis*, *Phyllosticta*, other species) may cause leaf spotting and leaf fall, especially on older leaves. ***Septoria leaf spots*** are initially yellowish red with brown centres and purplish margins. They may develop into large reddish-brown, angular blotches covering most of the leaf. See Trees K 2 (Fig. 199). ***Cercospora leaf spots*** are usually smaller and less sharply defined. See Annuals A 5.

Ovulinia petal blight

Scientific name: Ascomycetes
Ovulinia petal blight (*Ovulinia azalea*)
Grey mould (*Botrytis cinerea*), which can attack a wide range of plants, may also cause petal blight.

Host range: Evergreen azaleas, eg Kurume, Indica, deciduous azaleas, other *Rhododendron* sp. and hybrids, mountain laurel (*Kalmia latifolia*).

Symptoms: ***Flowers*** can be ***ruined*** in rainy weather. Small circular spots appear on ***petals***. ***White spots*** develop on ***dark coloured petals*** (Fig. 221), brown spots on pale coloured petals. In humid weather, flowers collapse, but remain attached to the plant for several months whereas uninfected flowers fall soon after fading. Small black resting bodies ***(sclerotia)*** develop on diseased petals. Flower stalks and calices of flowers may be infected. ***Grey mould*** (*Botrytis cinerea*) is a ***serious disease*** of azaleas in mild, humid climates. Initially symptoms on petals are similar to those of *O. azaleae*. If damp weather continues a grey furry mould develops on flowers. See Greenhouses N 22.

Spread: Sclerotia on the ground produce spores (ascospores) the following spring, which are spread by wind and infect flowers. These infected flowers produce more spores (conidia), which are also spread by wind and infect other flowers. By movement of infected plants and infested soil.

Conditions favouring: Mild, damp weather.

Control:
Cultural methods: Avoid overhead irrigation during flowering
Sanitation: In small plantings, infected flowers may be promptly and persistently picked off.
Pesticides: Systemic foliage ***fungicides*** have been developed especially to control petal blight. Plants may be sprayed as a preventative treatment as soon as flower buds begin to open.

Powdery mildew (*Oidium* spp.) occurs commonly on ***deciduous azaleas and some native rhododendrons*** during warm, humid conditions in late autumn. White powdery spores cover large areas of young stems and leaves, new leaves may be distorted and reduced in size. On some native *Rhododendron* spp., infected leaves develop a ***pinkish colouration***. Severe, prolonged, untreated infections reduce flowering and plant vigour. If the disease occurs late in autumn on deciduous species it may not be necessary to spray. Varieties vary in ***resistance***. See Annuals A 6.

Root diseases cause yellowing of foliage, defoliation, dieback of branches and shoots and often ***death of the plant***.

Armillaria root rot (*Armillaria luteobubalina*) produces cream, fan-shaped fungal threads under the outer bark of ***large roots***. See Trees K 4.
Damping off, eg ***rhizoctonia web blight*** (*Rhizoctonia solani*), is mainly found on azalea ***cuttings*** propagated under mist in warm, humid conditions, but may also occur on ***container-grown*** azaleas. Young leaf growth becomes webbed and blighted. Grey fungal threads develop during moist humid conditions, leaves brown and fall. Leaves close to the soil surface are usually first to be affected. ***Others:*** *Cylindrocladium scoparium*, *Phytophthora* spp., *Pythium* spp. See Seedlings N 66.
Phytophthora root rot (*Phytophthora* spp.) and *Pythium* spp. may cause ***serious root rotting*** on azaleas and rhododendrons. If bark is removed at ground level, tissue is brown; roots are dead and decayed. Composition of media affects severity of disease. *Phytophthora* is least severe in pine bark and mixes of pine bark and sand. See Trees K 6, K 24 (Table 4).

Rust (*Chrysomyxa ledi* var. *rhododendri*) is uncommon on azalea and rhododendron. Brown and yellow pustules develop on ***leaf undersurfaces*** during warm, moist weather. See Annuals A 7.

Others: ***Shoot dieback*** (various fungi) infects new growth, wounds; stems die (Bodman et al. 1996).

NEMATODE DISEASES

In Qld, ***root knot*** (*Meloidogyne* spp.), *Aglenchus agricola*, *Helicotylenchus dihystera*, *Scutellonema brachyurum*, *Tylenchorynchus* spp. and *Xiphinema americanum* have been recorded feeding on roots of *Rhododendron indicum*. *Morulaimus* and *Paratrichodorus* spp. have been recorded feeding on *Rhododendron* sp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Azalea lace bug

Scientific name: Tingidae, Hemiptera:
Azalea lace bug (*Stephanitis pyrioides*)

Host range: Azaleas and rhododendrons.

Description and damage: Plants are ***severely affected***. ***Adult bugs*** are small, about 3 mm long, sluggish, brown with lacy wings. ***Nymphs*** are spiny. Nymphs and adults suck plant sap from ***leaf undersurfaces*** causing a greyish white flecking of uppersurfaces. Adult bugs, spiny nymphs, nymph skins and tarry excreta may all be found on leaf undersurfaces. See Trees K 24 (Table 3).

Pest cycle: Gradual metamorphosis (egg, nymph, adult). Each egg laid on leaf undersurfaces is covered with dark sticky excreta.

Overwintering: As eggs on infested leaves.

Spread: By adults flying assisted by wind, movement of infested plants.

Conditions favouring: Sunny exposed sites. New growth in spring may be rapidly infested.

Control: Lace bug is a serious pest of azaleas.
Biological control: Overseas an ***egg parasite*** (*Anagrus* sp.) assists chemical control. ***Minimise infestation*** by planting in semi-shade with mixed vegetation that shelter natural enemies.
Resistant varieties: Broad-leaved azaleas are most susceptible and may be ***seriously affected***.
Pesticides: Apply insecticides early in spring ***to prevent*** lace bug damage to new leaves.

Azalea leafminer

Scientific name: Gracillariidae, Lepidoptera:
Azalea leafminer (*Caloptilia azaleella*)

Host range: Azalea, rarely rhododendron.

Description and damage: ***Moths*** are only 6 mm long and difficult to find. ***Caterpillars*** are up to 10 mm long, yellow and difficult to find; they mine inside ***leaves***. Initially, mined areas appear green but later become brown. If there are several mines per leaf the whole leaf may shrivel. Tips of infested leaves are rolled under (Fig. 222). Plants become unsightly. All leaves may be infested.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with several generations each year. Female moths lay eggs on the leaf undersurface, caterpillars immediately burrow into the leaf. When fully fed they leave the mine, roll the tip of the leaf under and pupate within the rolled tip. Later the moth emerges.

Overwintering: As late larval stages in the curled leaf tips.

Spread: By moths flying (to adjacent plants only as they can fly only a few metres), wind may assist them. By movement of infested plants.

Conditions favouring: Hot, summer weather.

Control:
Sanitation: Hand pick and destroy affected leaves in spring. However, by the time damage is noticed, damage is usually quite extensive.
Biological control: A ***small wasp*** which parasitises the caterpillar, and a ***small spider*** which eats the caterpillars in the rolled tips leaving large amounts of frass, provide some control, but do not prevent economic damage.
Plant quarantine: Moths do not fly far, so isolate plantings by keeping new plants separate until their freedom from infestation is ensured.
Pesticides: ***Insecticides*** prevent damage to new leaves. Commence applications in spring.

Caterpillars (Lepidoptera)

Leafrolling moth (Tortricidae) caterpillars commonly ***bind leaves together***. Susceptible varieties include Pink Dream and Dr Arnold. See Pome fruits F 112.
Leaf case moth (*Hyalarcta huebneri*) caterpillars feed on leaves. Initially they skeletonise small round areas, later they eat whole leaves. See Trees K 13.

See Annuals A 8, Trees K 13.

Mites (Acarina)

Cyclamen mite (*Steneotarsonemus pallidus*) may cause leaf curling. See Cyclamen C 16.
Twospotted mite (*Tetranychus urticae*) sucks sap from ***leaves*** giving them a sandy mottled or bronzed appearance. In severe infestation, leaves may yellow

and fall. They produce ***webbing*** on which they crawl around and to which they attach their eggs. See Beans (French) M 29, Trees K 24 (Table 3).
Others: Privet mite (*Brevipalus* sp.).

Thrips (Thripidae, Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) suck sap from ***leaf undersurfaces*** causing silvery leaves. Thrips produce black dots of ***excreta***. In severe infestations, thrips may feed from upper surfaces as well. See Greenhouses N 24, Trees K 24 (Table 3).
Onion thrips (*Thrips tabaci*) is thought to cause similar damage. See Onion M 68.

Weevils (Curculionidae, Coleoptera)

Apple weevil (*Otiorhynchus cribricollis*) chew edges of ***leaves*** at night giving them a saw-toothed appearance. See Pome fruits F 116.
Black vine weevil (*Otiorhynchus sulcatus*) feeds on ***leaves*** at night, cutting holes along the margin and sometimes devouring whole leaves leaving only midribs and large veins. ***Larvae*** are ***root feeders***, often destroying so many roots that they may nearly kill azaleas especially if collar is bare and stems girdled. See Grapevine F 63.
Fuller's rose weevils (*Asynonychus cervinus*) chew large pieces around ***leaf margins*** giving them a ragged, saw-edged appearance. Possible root damage by larvae is not well documented. See Roses J 6.
Garden weevil (*Phlyctinus callosus*) chews scalloped holes in the centres and from margins of ***leaves***. See Trees K 17.

See Trees K 17.

Whiteflies (Aleyrodidae, Hemiptera)

Azalea whitefly (*Pealius azaleae*) infests azalea, rhododendron, overseas also mountain laurel and andromeda. The pest cycle is similar to greenhouse whitefly.
Greenhouse whitefly (*Trialeurodes vaporarium*).

Nymphs and adults of both whiteflies suck sap from ***leaf undersurfaces***. ***Sooty mould*** develops on the ***honeydew*** secreted by the nymphal stages, coating leaves and stems. See Greenhouse N 24, Trees K 24 (Table 3).

Others: ***Leafhoppers*** (Cicadellidae) suck plant sap causing ***speckled leaves***. Each speck represents a feeding site as the insect walks across the leaf surface. See Trees K 24 (Table 3). Damage is not noticed until the insects have left. ***Longicorn beetles*** (Cerambycidae) may bore in trunks of old rhododendron, exit holes are seen. ***Mealybugs*** (Pseudococcidae, Hemiptera) may infest plants in warm climates. ***Oleander scale*** (*Aspidiotus nerii*) is usually only found on the bark and leaves of neglected plants.

Non-parasitic

Environment: Several agencies may cause scorched leaves, plants may die. See Trees K 24 (Table 4). Damage may not appear until 2-3 weeks later. Azaleas have shallow roots and wilt readily during hot, windy weather, but recover on being ***watered***. Plant in areas sheltered from hot winds and water regularly during summer especially during hot windy weather. Roots should be mulched to keep cool and moist. Initially leaf tips and margins become brown and brittle, eventually leaves may brown. ***Waterlogging*** damage is similar to that caused by lack of water except that ***leaf tissue is soft instead of brittle***. Provide good drainage. ***Sunscorch*** causes dead brown areas ***within the leaf margin***, later whole leaves may brown. Avoid sites with excessive exposure to sun and/or high temperatures, eg avoid heat reflection from brick walls, black plastic, weed mats, pine and other chip mulches. ***During cold weather***, new rhododendron leaves may roll tightly under. If there is late frost, developing new leaves may be reduced in size and have light green markings on them. In late winter ***senescing*** azalea leaves may yellow and redden.

Nutrient deficiencies: ***Iron deficiency*** (chlorosis) symptoms appear initially on new ***leaves***. Leaves yellow but veins remain green. In severe cases the whole plant may yellow, leaf size is reduced, shoots shorten, leaf edges scorch and new growth may die back. Flowering is affected in severe chlorosis. Check ***soil pH*** before planting, it should be < 6.0. ***Do not plant*** beside cement brick walls or apply alkaline fertilisers such as lime, superphosphate or wood ash. Use blood and bone and sulphate of ammonia or fertilisers available for acid-loving plants. ***If iron deficiency occurs***, apply iron chelates or azalea fertilisers during spring. See Trees K 20. ***Salt toxicity:*** Excessive application of ***chemical fertilisers*** causes soft, blackened leaf tips and margins. Whole leaves are eventually affected. If damage has already occurred, excess fertiliser may be leached out (repeated waterings), good drainage is essential. See Trees K 20, K 24 (Table 4).

Others: Overseas, rhododendrons planted near ***large black walnut trees*** may suddenly wilt and die. Roots of walnuts seem to secrete ***toxins***. The only solution is to move the walnut trees or move the rhododendrons. Azaleas have ***brittle stems*** and are easily damaged by hoses, dogs and children. Occasional twigs of some rhododendron varieties, eg White Bourke, produce several short curved shoots rather like a witches' broom which usually die. It is thought that this may be a type of varietal ***degeneration***, but a parasitic organism may be involved. All parts of the ***azalea plant*** are considered to be ***poisonous***. There are >500-1,000 natural species of *Rhododendron* and several thousand hybrids and cultivars, many contain in their flowers (including nectar), fruit, leaves and shoots, toxic compounds (Frohne and Pfander 1983). Some varieties of rhododendron have rusty red hairs ***(pubescence)*** on leaf undersurfaces which may be mistaken for rust. New leaves develop after flowering in spring, some older leaves yellow, colour and fall ***(senescence)***, causing concern to new growers. Azalea leaves have a life of several years on the plant. Some varieties of rhododendrons, eg Mrs Charles Wilson and Mrs Percival, have ***sticky buds***, others, eg Schryderi and Mauve Schryderi, have sticky leaves and attract insects. Tiny black fruiting bodies of the ***projectile firing fungus*** (*Sphaerobolus* sp.) adhere to and disfigure azalea leaves. See Potting mix N 64.

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State/Territory Departments of Agriculture/Primary Industry eg

Azalea Leafminer (NSW Insect Pest Bull. 133, 1968)
Diseases of Azaleas and Rhododendrons (Vic Agnote)
Rhododendrons and Azaleas (SA ABG leaflet)

Associations, Journals etc.

Local Rhododendron Socs.

See Trees, shrubs and climbers K 22

MANAGEMENT

Evergreen or semi-deciduous azaleas and rhododendron are ***spring flowering shrubs*** widely grown outdoors in the ground and in containers. Evergreens will grow in almost any climate except the tropics, but deciduous cultivars prefer cooler conditions. Only grow varieties recommended for a particular district. If there is a particular problem, consider selecting ***resistant or tolerant varieties.*** Plant ***disease and pest-free plants***, avoid rootbound or weakened plants. ***Propagated*** by cuttings. ***Prepare a monthly care guide*** which should include all activities, eg planting, fertilising, pesticide applications. Grow in a well drained acid soil (pH 4.5 to 6), sheltered from hot, drying winds. ***Provide partial shade*** such as light overhead leaf cover, 3-4 hours direct sun per day is sufficient for flowering. ***Provide adequate water supply***, particularly during summer. Roots are shallow so they benefit from a cool, moist and shaded root run. ***Fertilise*** regularly when recommended with an appropriate fertiliser. ***Growth regulators*** may be used to induce flowering and promote compactness. ***Control weeds*** but do not cultivate close to plants. There should be a minimum cultivation within the drip line. Azaleas will die if roots are disturbed. ***Pre-emergence herbicides*** are registered for use. ***New growth*** may be protected from azalea lace bug, azalea leaf miner and thrips damage in late winter and spring with ***insecticides***. In areas where petal blight occurs, protect flowers with ***fungicides***. ***Diagnose and monitor*** any problem accurately. ***Examine leaf undersurfaces*** and other plant parts for pests and diseases regularly at least once per week, if in doubt seek expert advice. ***Potted azaleas*** should be sold when 1/4 to 1/3 flowers open (Nell 1993). Plants grow best at 15-18^{o}C and should be kept moist and well illuminated with indirect light. They are sensitive to drafts of hot or cold air. ***Ethylene*** causes rapid leaf and flower drop and growers sometimes apply anti-ethylene compounds. ***For cut flowers,*** cut stems on an angle with a sharp knife, place in deep water and change vase water every few days, top up water regularly. Handle blooms as little as possible.

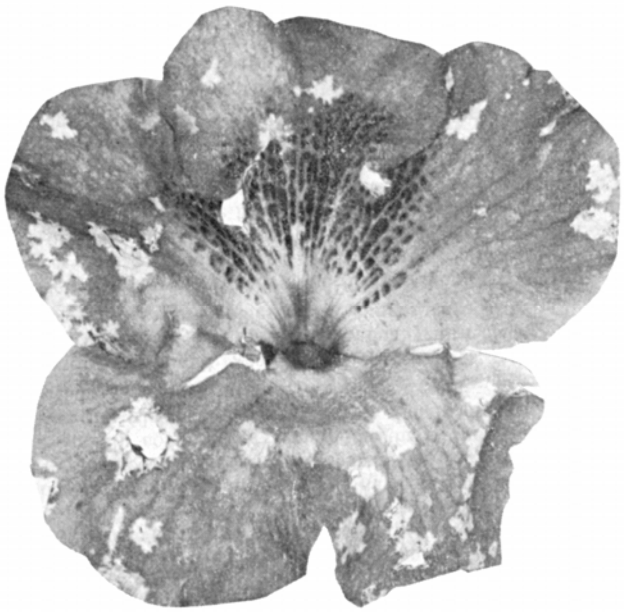

Fig. 221. White spots on dark petals caused by ovulinia petal blight (*Ovulinia azalea*). Dept. of Agric., NSW.

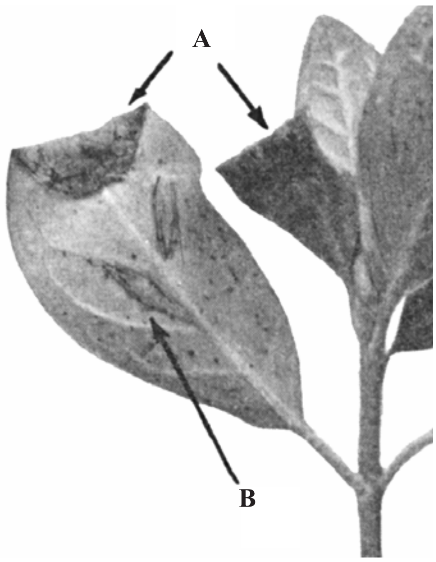

Fig. 222. Azalea leaf miner (*Caloptilia azaleella*) damage. **A** : Leaf mines are pale green initially then later brown. **B :** Leaf tips turned under. Dept. of Agric., NSW.

Banksia

Banksia spp.
Family Proteaceae (waratah family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Cankers
  - Fungal leaf spots
  - Root and stem rots
  - Wood rots
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Mites
  - Ross's black scale

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Cankers: In WA diffuse cankers caused by ***Cryptodiaporthe*** (= *Diplodina*) which is possibly endemic, may kill *B. coccinea*, *B. grandis* and *Dryandra sessilis*. ***Zythiostroma*** causes stem cankers on *B. baxteri*. ***Botryosphaeria ribis*** which occurs worldwide, and is possibly introduced, debilitates *B. speciosa* in association with climatic stress (Shearer 1994). ***Plectronidium australiense*** occurs on dead banksia branches. Affected branches should be pruned out well below cankered areas (Sutton and Pascoe 1986). See Trees K 5.

Fungal leaf spots: *Asterina systema-solare* (= *Seynesiae banksiae*), *Episphaerella banksiae* (= *Parodiella banksiae*), *Lineostroma banksiae* (= *Didymosphaeria banksiae*) and *Vizella banksiae* (Walker 1994). See Annuals A 5, Trees K 6.

Root and stem rots

Phytophthora* root rots** (*Phytophthora* spp., eg *P. cinnamomi*, *P. cryptogea*, *P. drechsleri* and *P. nicotianae* var. *parasitica*). ***P. cinnamomi* (Pc)** has been blamed for ***most deaths of banksias in cultivation. *B. grandis* in the jarrah forest in WA, has been used as an indicator plant for the presence of ***Pc.*** ***Resistant species*** include hill banksia (*B. collina*), *B. caleyi*, *B. integrifolia*, swamp banksia (*B. robur*), *B. spinulosa*. ***Susceptible species*** include bull banksia (*B. grandis*), *B. ashbyi*, *B. brownii*, *B. coccinea*, *B. hookeriana*, *B. lehmanninana*, *B. media*, *B. occidentalis*, *B. speciosa*, *B. victoriae* (Cho 1983). ***Susceptible species***, eg *B. grandis*, may be ***grafted on to resistant rootstock***, eg *B. integrifolia* var. *integrifolia*. See Trees K 6.
***Others:* *Armillaria* root rot** (*Armillaria luteobubalina*), ***pythium* root rot** (*Pythium* spp., *P. debraryanum*, *P. ultimum*), ***rhizoctonia* collar rot** (*Rhizoctonia solani*). See Trees K 7.

Wood rots: ***Common honeycomb*** (*Osmoporus gunnii*), ***tinder punk*** (*Phellinus robustus*, *P. setulosus*), ***wood rots*** (*Pycnoporus sanguineus*, *Perenniporia medulla-panis*). See Trees K 8.

NEMATODE DISEASES

More than 40 species have been identified in association with banksia, eg ***burrowing nematode*** (*Radolpholus* sp.), ***dagger nematode*** (*Xiphinema* sp.), ***root knot nematodes*** (*Meloidogyne* spp.), ***spiral nematodes*** (*Helicotylenchus*, *Rotylenchus*), ***ring nematode*** (*Criconema* spp.), ***root lesion nematode*** (*Pratylenchus* sp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Banksia longicorn (*Paroplites australis*) attacks banksia especially ***mature specimens*** of old man banksia (*B. serrulata*). See Trees K 11.
Others:* *Banksia jewel beetle (*Cyria imperialis*), ***elephant weevil*** (*Orthorhinus cylindrirostris*), ***fruit-tree borer*** (*Maroga melanostigma,* Oecophoridae). See Trees K 11, K 12.

Caterpillars (Lepidoptera) of > 20 species of moths and at least one butterfly feed on banksias.

Banksia moth (*Danima banksiae,* Notodontidae) caterpillars feed on ***Proteaceae***, eg banksia, dryandra, grevillea, hakea. ***Moths*** are up to 80 mm across and are grey with black and white markings and an orange body. ***Caterpillars*** are handsome, about ***50 mm*** long and brown with circular bands, end parts are mauve. When irritated, they throw back their heads and shoot out a ***purple bifid organ*** which secretes formic acid and probably repels natural enemies.
Doubleheaded hawk moth, banksia hawk moth (*Coequosa triangularis*, Sphingidae) caterpillars feed on leaves of ***Proteaceae***, eg banksia, grevillea, hakea, *Persoonia*. ***Moths*** are beautiful, usually deep yellow/ brown, with a dark brown triangle on the front of each forewing, wingspan is about 150 mm. ***Caterpillars*** are ***large***, about ***120 mm*** long, green and seem to have a head at each end of the body. They lack the abdominal spine which most hawk moth caterpillars have and are covered with short stiff bristles. Relatively rare, solitary caterpillars, pupate in soil. Control is rarely necessary. See Hakea K 78 (Fig 257).
Leafminers: ***Leafcutter moth*** (Incurvariidae) caterpillars mine in leaves of banksia, eg *B. serrata,* and later cut out oval or irregular, flattened cases in which they pupate or which they use as shelters while they feed within new mines. Moths are tiny. See Eucalypt K 62. ***Stegommata sulfuratella*** (Lyonetiidae) caterpillars produce ***blotch mines*** in young leaves of *B. integrifolia.* See Hakea K 78.
Leafroller moths (Tortricidae): ***Arotrophora arcuatalis*** caterpillars tunnel in ***flower spikes*** and are a ***major pest*** of plantation banksia in WA. Their feeding kills individual florets and distorts blooms. ***Native wasps*** (*Trichogrammatoidea*, *Trichogramma*) parasitise caterpillars but ***insecticides*** are usually still required (Rohl and Woods 1994). ***Lightbrown apple moth*** (*Epiphyas postvittana*) may roll leaves together. See Pome fruits F 112.

Macadamia twig-girdler (*Xylorycta luteotactella*) caterpillars lives in small tunnels in a ***branch*** or woody ***fruit***, covering the entrance with a web of silk and faeces, or in a silk gallery spun amongst the ***foliage*** incorporating webbing and faeces. They feed on bark and leaves and bore into ***flower spikes*** or ***cones***. See Macadamia F 77. Also ***X. strigata. Chalarotona intabescens*** and ***Scieropepla*** caterpillars also tunnel in ***flower spikes***.

Others: ***Fiery jewel*** (*Hypochrysops ignitus ignitus*, Lycaenidae) and ***grevillea looper*** (*Oenochroma vinaria*) caterpillars feed on leaves. ***Painted apple moth*** (*Teia anartoides*) caterpillars may skeletonise leaves. Annuals A 8, Trees K 13.

Mites (Acarina)

Eriophyid mites (Eriophyidae): ***One species*** sucks sap from leaf undersurfaces of fine-leafed banksias, eg *B. ericifolia;* ***leaves roll inwards***. ***Another species*** causes grotesque ***galls*** on banksia ***fruit***. Mites feed and shelter among the deformed tissue. Early removal and burning of deformed fruit reduces infestation. See Grapevine F 62.

Spider mites (Tetranychidae): ***Broad mite*** (*Polyphagotarsonemus latus*), ***twospotted mite*** (*Tetranychus urticae*). See Beans (French) M 29.

Ross's black scale (*Lindingaspis rossi,* Diaspididae, Hemiptera) infests banksia and olive in sheltered situations. ***Female scales*** are ***blackish***, flat, circular, about 2 mm across and stick tightly to leaves. The female body, eggs and nymphs are purple. ***Male scales*** are oval, smaller and dark brown. The body of the male is orange. Nymphs and adults suck from ***leaf undersurfaces***, leaves may yellow and fall in severe infestations. No honey dew is produced. ***Overwinters*** on host plants. ***Spread*** by vegetative propagation, infested plants, winged adult males flying and by nymphs crawling. See Citrus F 39.

Others: A ***lerp insect*** (*Cecidopsylla putealis*) forms ***pit galls*** on leaves. A yellow-brown ***wasp*** (*Megastigmus*, Torymidae) may emerge from ***stems, leaves and flowers*** of banksia, eucalypt, hakea, wattle, citrus, *Helichrysum*. ***A sucking insect*** (*Frenchia banksiae*, Asterlecaniidae, Hemiptera) may cause unusual ***galls*** on banksia, casuarina. ***Banksia whitefly*** (*Aleurocanthus banksiae*) feeds on leaves and shoots (Jones and Elliot 1986). ***Coconut whitefly*** (*Aleurodicus destructor,* Aleyrodidae) may be a ***pest*** of banksia, coconut, other plants. Also ***flea beetles*** (Galerucinae, Chrysomelidae).

Non-parasitic

Environment: All eastern species of *Banksia* except the northern *B. dentata*, are ***frost hardy***.

Nutrient deficiencies, toxicities: ***Iron deficiency*** commonly occurs on banksia, ***new leaves*** yellow between the veins. See Azalea K 29, Citrus F 43. ***Phosphorus toxicity:*** Some banksia, eg *B. ericifolia,* may be damaged by normal amounts of phosphorus in media. Usually tips and margins are discoloured or brown. Banksia have ***proteiod roots***. See Trees K 18.

Others: ***Birds*** may damage flowers when seeking nectar. ***Fungi:*** *Argopericonia* and *Tryssglobulus* occur amongst leaf hairs on healthy leaves of *B. marginata*. (Sutton and Pascoe 1987).

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State/Territory Departments of Agriculture/Primary Industry eg

Banksia (SA ABG Leaflet)

Banksias for Cut-flower Production (SA Fact Sheet)

See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

More than 60 species of *Banksia* are endemic and are a symbol of the Australian bush (Wrigley and Fagg 1989). An overview of the industry has been outlined by Coombs (1995). Most banksias need a sunny position and slightly acid or gravelly soil which provides excellent drainage. They may be watered in dry weather. A few species prefer ***different conditions***, eg swamp banksia (*B. robur*), prefers a moister soil. Readily ***propagated*** from seed, also by cuttings and tissue culture. Banksias are marketed fresh, dried, sulphur treated or dyed. ***Harvest flowers*** when the collar around the base of the flower head is open and flower is dry, during a cool time of day, shake off excess nectar, place in water with preservative; the foliage may be stripped from the lower 100 mm and sometimes from around the flower. When ***storing***, some species, eg *B. speciosa* and *B. burdetti*, are best kept out of water, lying flat in a covered box in a cool room. ***Recut stems***, use a commercial preservative and do not mist (Jones and Moody 1993).

Birch

Betula spp.
Family Betulaceae (birch family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Several viruses have been associated with ***foliage*** line patterns, ringspotting and veinbanding overseas (Cooper 1993). See Trees K 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) has been recorded on birch. See Stone fruits F 125.

FUNGAL DISEASES

Rust (*Melampsoridium betulinum*) infects ***silver birch*** (*B. pendula*). Overseas also other *Betula* spp. Rust is only a problem on ***nursery stock***, causing ***severe defoliation***, seedlings may die back and even ***die***. Small, circular, orange fruiting bodies (uredia) develop on ***leaf undersurfaces*** towards the end of summer. As cool weather sets in, dark brown fruiting bodies (telia) appear in the uredia. In nurseries where severe damage is expected, ***avoid overhead irrigation*** and apply ***fungicides*** at the first sign of disease. On mature trees damage is sporadic and control is not attempted (Marks et al. 1982). See Annuals A 7.

Others: ***Fungal leaf spots*** (various species), overseas also *Cylindrosporium*, *Gloeosporium*. ***Root rots***, eg ***armillaria root rot*** (*Armillaria luteobubalina*) and ***phytophthora root rot*** (*Phytophthora* spp., *P. cinnamomi*). ***Wood rots***, eg ***silver leaf*** (*Stereum purpureum*), ***yellow heart rot*** (*Schizophyllum commune*). ***Canker*** (*Botryosphaeria*).

PARASITIC PLANTS

Mistletoe (Loranthaceae) may infest the branches of birch trees. See Trees K 9.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Birch aphid (*Calaphis flava*)
European aphid (*Euceraphis betulae*)
In cold climates, these exotic aphids overwinter as eggs on their deciduous hosts. Winged aphids fly to other birch trees. See Roses J 4.

Borers

Fruit-tree borers (*Cryptophasa albacosta*, *Maroga melanostigma*, Oecophoridae): ***Caterpillars*** make short vertical tunnels often in a ***branch fork*** and feed on the bark around the tunnel entrance, trees may be ***ringbarked***. See Fruit F 10, Trees K 12.

Silverbirch branchcutter (*Strongylurus cretifer,* Cerambycidae, Coleoptera) is a ***longicorn beetle***, the larvae of which feeds in the ***branches*** of birch. Branches and trunks may ***break***. See Trees K 11.

Emperor moths (*Opodiphthera eucalypti* and *O. helena,* Saturniidae, Lepidoptera) ***caterpillars*** are predominantly green and feed on the ***foliage*** of birch. Both species spin tough oval cocoons incorporating fragments of the ***bark*** of the tree on which the cocoon is spun. See Eucalypt K 60.

Oak leafminer (*Phyllonorycter messaniella*) may mine in birch ***leaves*** (Elliot and deLittle 1984). See Oak K 101.

Scale (Hemiptera) on ***young tips*** may cause ***dieback*** on young trees. See Citrus F 39, Trees K 16.

Non-parasitic

Birches are deciduous tree adapted to ***cool temperate*** and cold climates. They prefer full sun or half shade and ***irrigation*** during dry summers, otherwise they may die back from the tops.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

PLANT MANAGEMENT

Birches are slender with graceful foliage and brilliant autumn foliage. They are adapted to cool temperate and cold climates but require irrigation during dry seasons.

Boronia

Boronia spp.
Family Rutaceae (citrus family)

PESTS AND DISEASES
Parasitic
Fungal diseases
Powdery mildew
Root rots
Rust
Wood rots
Nematode diseases
Root knot nematodes
Insects and allied pests
Black citrus aphid
Boronia psyllid
Caterpillars
Citrus mealybug
Greenhouse whitefly
Scales
Slugs and snails
Non-parasitic
Environment

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Powdery mildew (*Oidium* sp.) has been recorded on ***brown boronia*** (*Boronia megastigma*). See Annuals A 6.

Root rots

Damping off (*Phytophthora* spp., *Pythium* spp.). See Seedlings N 66.
Phytophthora root and collar rots (*Phytophthora cinnamomi, P. cryptogea*) affect *Boronia* spp. causing them to be short-lived. See Trees K 6.
Others: Armillaria root rot (*Armillaria luteobubalina*). See Trees K 4.

Rust (*Puccinia boroniae*) pustules develop on leaves of ***brown boronia*** (*B. megastigma*) and *B. pilosa*. See Annuals A 7.

Wood rots: ***Ring-barking fuscoporia*** (*Fuscoporia laevigata*) may affect brown boronia (*B. megastigma*). The fruit body forms a rust-coloured, pore-bearing sheath on the ***collar of saplings***. The fungus appears to ***ringbark*** and ***kill saplings*** rapidly. It produces a white, sapwood rot (Marks et al. 1982). See Trees K 8.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) have been recorded on ***brown boronia*** (*B. megastigma*) and *B. malloyae* (*B. elatior*). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Black citrus aphid (*Toxoptera citricidus*) may infest ***new growth***. See Citrus F 35, Roses J 4.

Boronia psyllid (*Ctenarytaina thysanura,* Psyllidae, Hemiptera) feeds and develops upon ***young leaves*** of boronia and is found in alpine, mountain or cool to cold temperate areas. There may be many generations each year in cool damp areas in mid-summer. See Eucalypt K 62.

Caterpillars (Lepidoptera)

Butterfly (*Adaluma urumelia,* Lycaenidae) caterpillars may feed on ***mature leaves*** of *B. lanceolata*) in the NT and are attended by ***small black ants*** (*Monomorium* sp.). This genus should perhaps be merged with *Nesolycaena* (Common and Waterhouse 1981).
Lightbrown apple moth (*Epiphyas postvittana*) caterpillars ***web leaves and shoots*** of boronia. See Pome fruits F 112.
Satin blue (*Nesolycaena alboservicea,* Lycaenidae): The first 2 caterpillar instars of this butterfly feed on ***flowers*** of *B. glabra* and *B. obovata*, but later instars feed on ***older leaves*** closer to the ground, frequently consuming the whole leaf. Rare, found on Fraser Island and Stradbrooke areas of Qld.

See Annuals A 8, Trees K 13.

Citrus mealybug (*Planococcus citri*) feeds on ***Rutaceae***, eg boronia, citrus, *Eriostemon*. See Citrus F 38, Greenhouses N 25.

Greenhouse whitefly (*Trialeurodes vaporariorum*) is small, white and moth-like, usually 1-2 mm long. Wings are folded when at rest. Nymphs are translucent, greenish and scale-like. Nymphs and adults suck sap from ***new shoots and leaf undersurfaces***. Sooty mould grows on the honeydew they secrete. See Greenhouses N 24.

Scales (Hemiptera)

Soft scales (Coccidae)
Black scale (*Saissetia oleae*)
Chinese wax scale (*Ceroplastes sinensis*)
White wax scale (*C. destructor*)
Soft scales secrete honeydew.
Scale (*Cochaspis angraeci,* Conchaspididae) occurs on *Boronia* spp. in WA. Females produce a white, usually circular and conical scale covering, sometimes resembling ***armoured scales***.

See Citrus F 39, F 41, Trees K 16.

SNAILS AND SLUGS

Various species damage boronia. See Seedlings N 70.

Non-parasitic

Environment: The ***roots*** of boronias in containers or in the field should not be allowed to ***dry out***. Boronias are not suitable for tropical or highland areas.

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State/Territory Departments of Agriculture/Primary Industry eg

Growing Native Plants (ANBG booklet No.12)

Associations, Journals etc.

GrowSearch (database Qld DPI)

See Australian native plants N 9, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: Boronias grown for cut flowers can be separated into those grown for ***fragrance*** and those grown for their ***coloured flowers***. ***Brown boronia*** (*B. megastigma*) is grown for the spicy scent from its flowers in early spring and the essential oils for the manufacture of perfume. ***B. heterophyllla*** is grown for its rose-carmine bell-shaped flowers. It is possible that other species, eg *B. denticulata*, will prove suitable for the same purpose. Boronia shrubs are not suited for tropical or highland areas.

Resistant varieties*:** Boronia is susceptible to ***phytophthora root and collar rot (*P. cinnamomi*) and may be short-lived. *B. clavata* is probably the hardiest boronia and may be suitable as a rootstock.

Disease-free planting material: Obtain quality cuttings from plants of the desired horticultural quality which are ***free from*** *Phytophthora*, rust and other diseases and pests.

Establishment and Maintenance

Propagation: All species grow readily from cuttings in summer which may be treated with ***growth regulators***. Some, particularly the WA species, germinate readily from seed, the eastern species require seed treatment prior to sowing (Wrigley 1988).

Cultural methods: For cut flowers, plants are regularly ***replaced*** every 3 years, growing them preferably in partial shade in moist or peaty soil (Salinger 1985). Most need a light well drained soil and if this is not provided they may succumb to *Phytophthora*. In nature most species occur in heaths and dry sclerophyll forests, where vegetation is thick and some shade is provided, where leaf litter is also thick and the surface soil temperature varies little. Some species occur in very deep shade in gullies. These points should be borne in mind when positioning *Boronia* spp. They require good drainage, a sandy soil with heavy mulch of leaf litter under which surface roots can remain cool (Wrigley 1988). Mulch must not be too close to the collar, or rot may result. ***As a generalisation*** boronias grow best in sheltered sites, with some shade during the day, protection from hot drying wind and a cool root area. Roots should never be allowed to dry out or get very hot, but do need perfect drainage. ***Fertilise*** as recommended. All boronias respond well to ***pruning*** after flowering.

Pesticides: Shape and flowering may be manipulated with environmental treatments and/or growth regulators (Day 1993, 1994).

Postharvest

Harvest so that branches with about 50% of flowers open are received by the retailer (Jones and Moody 1993). Flowers must be fresh and undamaged, branches must ***not be dry and curled***. They must be ***handled carefully*** as florets drop easily. Avoid ethylene contamination. Long shoots are cut and bunched into fives or decs, preferably placed in sleeves after standing in water (Salinger 1985).

Vase life: Recut 20 mm from stems, strip foliage which would be underwater and place in a commercial preservative. Flowers can be misted (Jones and Moody 1993).

Bottlebrush

Callistemon spp.
Family Myrtaceae (eucalypt family, myrtle family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Damping off
  - Fungal leaf spots
  - Root rots
  - Wood rots
- **Parasitic plants**
  - Mistletoe
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Bugs
  - Callistemon sawfly
  - Caterpillars
  - Leafminers
  - Leafrolling thrips
  - Lilly pilly psyllid
  - Scales
  - Tip borers

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Damping off: ***Grey mould*** (*Botrytis cinerea*) attacks young shoots and stems in nurseries, especially *C. citrinus*. ***Others:*** *Cylindrocladium scoparium, Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani*. See Seedlings N 66.

Fungal leaf spots mainly cause ***serious damage*** during wet conditions. Several species have been identified (Walker 1994).

Cylindrocladium scoparium may cause ***severe damage*** to bottlebrush, melaleuca and related plants. Dead areas on leaves are often surrounded by a ***purple margin***. Affected leaves tend to fall readily from the plant.
Tar spot (*Phyllachora callistemonis)* mainly attacks *C. speciosa* and *C. Gawler* Hybrid. Small, hard, irregularly-shaped, ***black fruiting bodies*** develop on the leaves and are often arranged in a more or less ***circular pattern***. They resemble blobs of tar (Fig. 223) and are often mistaken for scale insects. Severely affected leaves look unsightly, yellow and fall. Tar spot is usually found in subtropical areas but may be found in sheltered areas in cooler regions.
Others:* *Dark mildew leaf spot (*Meliola queenslandica*), *Seimatosporium dilophosporum.* ***Leptosphaerulina trifollii*** may cause leaf spotting on *C. viminalis* Profile.

See Annuals A 5.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*). ***Phytophthora root rot*** (*Phytophthora cinnamomi*, *P. cryptogea*) attacks bottlebrush on poorly drained sites. See Trees K 7.

Wood rots: ***Tinder punk*** (*Phellinus* spp.) and other species, may attack bottlebrush. ***Large pruning*** cuts facilitate entry. See Trees K 8.

PARASITIC PLANTS

Mistletoe (Loranthaceae) may infest bottlebrush. See Trees K 10.

NEMATODE DISEASES

Nematodes associated with *Callistemon* spp. in Qld and SA include ***burrowing nematode*** (*Radolpholus magniglans*), ***dagger nematode*** (*Xiphinema elongatum*), ***sheath nematode*** (*Hemicycliophora natalensis*) ***spiral nematode*** (*Helicotylenchus*) and *Hemicriconemoides* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Common splendid ghost moth (*Aenetus lignerven*) caterpillars tunnel in ***living trees*** after they have fed amongst litter or under decaying logs on the ground. If the stem is slender it may be ***ringbarked*** and plants may die. See Trees K 12.
Fruit-tree borer (*Cryptophasa melanostigma*) caterpillars live in short tunnels often at ***branch forks*** and feed on ***bark***. Entrances are covered with ***chewed wood and frass***. See Fruit F 10, Trees K 12.
Ring-barking weevils (Curculionidae), eg *Aterpus griseatus*, feed on ***twigs*** of bottlebrush, melaleuca and related shrubs. Larvae may ***ringbark stems*** below ground level (Hockings 1980). Soil at the base may be treated. See Geraldton wax K 73.
Longicorn borer, callistemon trunkborer, (*Platyomopsis armatula*) causes serious damage to bottlebrush, also eucalypt, *Leptospermum*, melaleuca. ***Adults*** are stout, grey-brown beetles about 20 mm long. Wing covers have lumps and roughened projections, antennae are 20 mm long. ***Larvae*** are fleshy, legless, cream and 15 mm long. They ***tunnel under the bark***, feeding on sapwood, ***ringbarking*** small and large branches causing them to die. Branches may break off in a storm. Tropical and subtropical regions. See Trees K 11.

Bugs (Hemiptera)

A bug (*Crompus* spp., Lygaeidae) may suck sap from bottlebrush, *Leptospermum*, *Metrosideros*. Bugs are about ***5 mm*** long, small, ovoid with short sericeous hairs. Lygaeidae bugs mostly feed on ***seeds***.
Callistemon tip bug (*Pomponatius typica,* Coreidae) infests bottlebrush, broadleaved melaleuca, other native plants. ***Adults*** are up to ***20 mm*** long, solitary, elongate, with ***strong repellent odours***, slow-moving and look like dead leaves (camouflage). ***Nymphs*** are similar to adults but smaller. Both suck sap from ***new shoot tips*** causing them to wither and die. Close examination of the stem will reveal the feeding holes. ***Control*** is not usually warranted. Bugs may be collected periodically and destroyed.

Leafspotting mirid bug, myrtle mirid bug (*Eucerocoris suspectus,* Miridae) is a ***serious pest*** of bottlebrush, especially *C. polandii*. ***Adults*** are delicate, hard to find, up to ***10 mm*** long, orange with black legs, long black antennae and gauzy wings. ***Nymphs*** are oval, orange with bands on legs and antennae. Both suck sap and secrete saliva during feeding damaging ***new shoots and young leaves***. Spots of dead tissue develop everywhere the insects have pierced the leaf surface. See Melaleuca K 98.

Callistemon sawfly (*Lophyrotoma* sp., Pergidae, Hymenoptera)

Callistemon sawfly larvae may ***seriously damage*** bottlebrush, eg red bottlebrush (*C. citrinus*), *C. salignus* and *C. viminalis*. ***Adult sawflies*** are robust, wasp-like insects about 23 mm long. ***Larvae*** are up to ***20 mm*** long, caterpillar-like with thoracic and abdominal legs, brown with a sword-like appendage on the tip of the abdomen (Fig. 224). The body tapers off towards the end. When disturbed, they bend their heads and tails over their backs and regurgitate. Young larvae feed side by side, and quickly ***skeletonise leaves***. Older larvae may feed individually and eat entire leaves. Shrubs can be defoliated, branches may die, changing the growth habit of the plant and upsetting flowering. Whole hedges may be ***defoliated***. There are ***several generations*** each season. Fully fed larvae may leave host plants and wander singly for some distance to pupate but they may pupate on the host plant. ***Overwinters*** as larvae in cocoons. ***Control*** should be directed towards the 1st generation, later generations are then not such a problem. Larvae may be removed by ***hand***, or infested shoots pruned off and destroyed. Regurgitation by the larvae repels birds and other natural enemies. If infestations are severe and extensive in spring, shrubs may be sprayed with an ***insecticide*** when larvae are first observed. Wetting agents will increase the effectiveness of insecticides. See Eucalypt K 63.

Caterpillars (Lepidoptera)

More than 10 species may infest bottlebrush.

Bizarre looper, zigzag looper (*Anisozyga pieroides*) caterpillars are ***25 mm***, brown and like a twisted dead leaf (excellent camouflage). Control is not necessary. See Wattle K 133.

Capsule moth (*Bathrotoma constricta,* Tortricidae) is not a pest. Tiny caterpillars eat the contents of immature callistemon capsules and join ***2 capsules together*** to make a portable case for themselves (Fig. 225). Caterpillars graze on leaf surfaces leaving small areas of dead tissue. ***Spread*** by moths flying, movement of infested plants.

Case moths, bagworms (Psychidae): ***Saunders's case moth*** (*Oiketicus elongatus*) caterpillars chew large lumps out of ***leaves*** of bottlebrush, *Epacris*, eucalypt and other species. See Trees K 13.

Cup moths (Limacodidae): ***Chinese junks*** (*Doratifera* spp.) are flattish, fleshy, ***slug-like caterpillars*** about ***40 mm*** long with brown or yellow retractable stinging hairs. See Eucalypt K 60, Trees K 13.

Painted apple moth (*Teia anartoides*) caterpillars are sporadic ***destructive pests*** with solitary habits. ***Orgyia athlophora*** occurs in south-western WA. See Pome fruits F 113.

Web moths (Pyralidae) caterpillars ***web leaves*** together. See Teatree K 124.

See Annuals A 8, Trees K 13.

Leafminers (Lepidoptera)

Leafmining moth (*Heliozela* sp., Heliozelidae) has metallic scales, is 2 mm long, flies in sunshine and rests on flowers. ***Caterpillars*** mine between leaf surfaces. ***Leaves*** may look reddish and fall. If leaves are examined closely, mines can be seen. There is a ***complete metamorphosis*** (egg, caterpillar, pupa, adult) with probably several generations each year. When caterpillars in mines are fully fed, they ***cut flat oval cases*** from the mine which drop to the ground, attach to the host or elsewhere, before pupation. Pupae are ***parasitised*** by a wasp. ***In nurseries***, new growth may be protected with insecticides.

Leafmining moth (*Pectinivalva* spp., Nepticulidae) caterpillars tunnel in leaves of ***Myrtaceae***, eg bottlebrush, eucalypt, *Leptospermum, Lophostemon*. ***Moths*** are tiny. ***Caterpillars*** form ***slender tortuous mines*** which later expand gradually or abruptly into irregular blotch mines (Fig. 226).

See Azalea K 28, Trees K 15.

Leafrolling thrips

Leafrolling thrips, leaf distortion thrips (*Teuchothrips* sp., Phlaeothripidae, Thysanoptera) is a ***sporadic pest*** of bottlebrush and melaleuca. Different species infest pittosporum and probably *Ficus*. ***Adults*** are black, 1-2 mm long. ***Nymphs*** are pale orange, smaller and wingless. Nymphs and adults feed on ***young leaves*** causing them to roll and redden but not fall (Fig. 227). A temperate to tropical pest. ***Control*** measures may not be necessary. Infested shoots may be ***pruned off*** and destroyed. ***Susceptible species*** include *C. citrinus* and *C. viminalis*. Where infestations occur every season, insecticide may be applied to new leaves in spring, at the first sign of infestation. As sprays do not kill the eggs within the leaf, apply 2 sprays about 10 days apart. See Greenhouses N 24.

Lilly pilly psyllid

Lilly pilly psyllid, pimple gall (*Trioza eugeniae,* Psyllidae) causes pimples on ***new leaves*** and shoots (Fig. 228). Control is not usually necessary. See Lilly-pilly K 95. ***Other psyllids*** may infest bottlebrush, eg psyllids that secrete wax. A tiny orange species may suck sap from ***young shoots*** causing distortion. See Eucalypt K 62, Trees K 15.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Circular black scale*** (*Chrysomphalus aonidum*) is a sporadic pest of leaves which may fall. Susceptible species include broadleaved forms of *C. viminalis*. ***Mussel scales*** (*Lepidosaphes* spp.) may infest bottlebrush and melaleuca. Adult females are white and about 1.7 mm long, males are winged. Leaves often tolerate infestation. ***Red scale*** (*Aonidiella aurantii*) may infest all aboveground plant parts. See Citrus F 39.

Soft scales (Coccidae): ***Nigra scale*** (*Parasaissetia nigra*) is smooth, dark, broadly-oval, about 5 mm long. Nymphs lodge on adult coverings, and settle on young shoots and along leaf midribs. Honeydew attracts ants and encourages sooty mould. See Custard apple F 52. ***Tessellated scale*** (*Eucalymnatus tessellatus*) is a sporadic minor pest. ***Adults*** are light to dark brown, very flat, closely appressed to the leaf surface and about 5 mm long. ***Nymphs*** are wrinkled. Both feed on leaves causing premature yellowing. Tropical and subtropical regions. See Citrus F 41.

See Citrus F 39, Trees K 16.

Tip borers: ***Callistemon tip borer***

(Lepidoptera) is a ***persistent minor pest*** of melaeuca and bottlebrush. ***Moths*** are about 3 mm long and hard to find. ***Caterpillars*** are about 10 mm long, creamy and tunnel down centres of ***young shoots***. Tips die back for about 100 mm. A light attack has a beneficial tip pruning effect, persistent attacks may stunt plants and affect appearance. ***Do not confuse*** tip borer damage with frost damage to young growth. A ***complete metamorphosis*** (egg, caterpillar, pupa, adult) with several generations each season. Female moths lay eggs on young shoots, caterpillars pupate in hollowed out shoots. Emerging moths cut small exit holes. ***Overwinters*** as caterpillars in cocoons in shoots. ***Spread*** by moths flying, by the movement of infested plants. ***Start control*** in spring to prevent population buildup. Dead tips may be pruned off and burnt. In ***susceptible*** varieties, if ***persistent and severe,*** protect new growth with insecticides.

Others: ***Spine-tailed froghopper***

(*Machaerota finitima*). ***Wasp galls*** (Hymenoptera) are found on the stems of young *C. salignus*.

Non-parasitic

Environment: ***Full sun*** is required for maximum flower production. Most are native to areas with damp soils. Many will tolerate ***light frost*** when established and will grow in a range of climates.

Others: ***Fasciation*** which is a genetic defect is not uncommon on callistemon. ***Lichens*** often occur on older plants. Occasionally new leaves are sharply ***wrinkled,*** the cause of which is unknown.

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See Australian native plants N 9, Melaleuca K 99, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Bottlebrushes are attractive woody shrubs and small trees and are amongst the ***hardiest*** of plants. There is a wide range of flower colour and some species will flower twice a year if conditions are good. Some new cultivars may be more ***susceptible*** to pests and diseases. Only plant ***disease-free planting material*** which is free from *Phytophthora*, fungal leaf spots, scales and other pests. ***Propagated*** by seed collected near the bottom of the shrub to make sure that it is mature. Most species strike readily from cuttings and cultivars must be propagated in this way to ensure retention of clonal properties (Wrigley 1988). ***Soil conditions*** matter little as most species will tolerate badly drained soils. A position in ***full sun*** is necessary for maximum flower production. ***Prune*** to remove spent flowers as they fade. ***Severe pruning*** of old bushes may kill them.

Fig. 223. Tar spot (*Phyllachora callistemonis*).

Fig. 224. Callistemon sawfly (*Lophyrotoma* sp.) larvae.

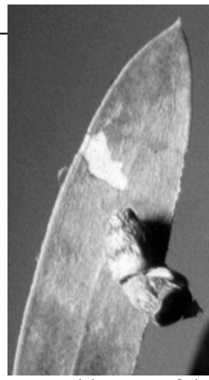

Fig. 225. Portable case of the capsule moth (*Bathrotoma constricta*).

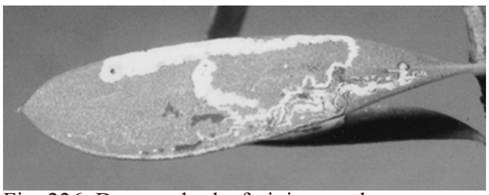

Fig. 226. Damage by leafmining moth (*Pectinivalva* sp.). (unconfirmed).

Fig. 227. Leafrolling thrips (*Teuchothrips* sp.)damage.

Fig. 228. Pimples on leaves caused by lillypilly psyllid (*Trioza eugeniae*).

Camellia

Camellia spp
Family Theaceae (tea family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Camellia yellow mottle virus
- **Fungal diseases**
  - Camellia leaf gall
  - Canker
  - Fungal leaf spots
  - Petal blights
  - Root rots
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Mites
  - Scales
  - Thrips
  - Weevils

Non-parasitic
- Bud drop
- Environment
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Camellia yellow mottle virus affects camellias especially *C. sasanqua, C. japonica*, also *C. reticulata*. 10% of camellias are thought to be affected. Usually only a ***few young leaves*** on a twig or branch develop a yellow mottle which may be marginal, irregularly blotched or speckled. See Trees K 1 (Fig. 196). ***Flowers*** may be mottled and marbled but the relationship of foliage mottling to flower breaking is not definite. Infected plants thrive and bloom. ***Do not confuse virus symptoms*** with varieties which have mottled leaves and flowers, deficiencies (iron and nitrogen) or senescence patterns after flowering. ***Overwinters*** in infected host plants. ***Spread*** by vegetative propagation and grafting, not by insects, not by sap on hands and tools. Its natural method of spread is not known. ***There is no cure*** for infected plants. Commercial growers should discard plants known or suspected of being infected. ***Plant virus-tested stock***. Do not propagate from plants which have at any time shown symptoms of virus infection. See Trees K 4.

Other viruses (undetermined) are considered to cause bright yellow or green ***ringspots*** on new leaves of some japonicas.

FUNGAL DISEASES

Camellia leaf gall (*Exobasidium camelliae*) is a minor disease of camellias during cool, wet weather in spring and is more common on sasanquas than japonicas. ***Leaves and shoots*** become thick, fleshy, distorted and enlarged. Leaf uppersurfaces look normal but ***undersurfaces*** are white, cracked and peel in strips, exposing spores. There is usually only one diseased shoot on a stem and only a few on a plant. Galls wither and fall to the ground. See Azalea K 27.

Canker, camellia dieback (*Glomerella cingulata*). Cankers may girdle ***stems and twigs***, branches ***die***. Fungi invade ***wounds*** including leaf scars. Cultivars with large leaf scars, eg Donation, are ***more susceptible*** than those with small leaf scars. See Trees K 5.

Fungal leaf spots: ***Pestalotiopsis spp.*** colonises ***leaves*** damaged by sunscorch or drought. Papery, greyish-white areas or irregular spots develop on leaves. Small black specks (fruiting bodies) which produce spores develop in these spots. Leaves may generally yellow and fall. Other fungi, eg *Alternaria*, may also colonise. ***Citrus black spot*** (*Guignardia citricarpa*): Brown, circular leaf spots of dead tissue 1-2 mm across. Black dots (fruiting bodies or pycnidia) occur in leaf spots. ***Others***: *Cercosporella*, *Septoria*. See Annuals A 5, Trees K 6.

Petal blights: ***Camellia petal blight*** (*Ciborina camelliae*, Ascomycetes) can be ***devastating*** in NZ and other countries (Stovoid 1994) but is not known to occur in Australia. ***Flowers*** may collapse within 3 days if humidity is high and temperatures mild. ***Overwinters*** as resistant sclerotia in soil until the next flowering season, when they produce spores. ***Spread*** by windborne spores, by the movement of nursery stock, on flowers for show purposes, possibly on shoes. All species and varieties are ***susceptible*** and ***fungicides*** have not given satisfactory control. There are strict ***quarantine*** restrictions on the importation of camellias into Australia. ***Grey mould*** (*Botrytis cinerea*) may damage buds and flowers especially after frost. See Azalea K 27, Greenhouses N 22.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*) may attack mature camellias. See Trees K 4. ***Phytophthora root rot*** (*Phytophthora cinnamomi*) affects japonicas in poorly drained soils; sasanquas are rarely affected. Some japonica plants are ***grafted*** on to sasanquas. See Trees K 6.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) and *Paratrichodorus* sp. have been recorded on camellia in Australia, but camellias are reputed to be ***unusually resistant***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Black citrus aphid (*Toxoptera citricidus*)
Cotton aphid, melon aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Aphids suck sap from ***new shoots***, distorting new growth of ***nursery stock***. Honeydew and nymph skins cause further disfigurement. See Rose J 4.

Caterpillars (Lepidoptera): ***Noctuids*** (Noctuidae), eg ***budworms*** (*Helicoverpa* spp.) may feed inside buds, ***looper caterpillars*** (*Chrysodeixis* spp.) may chew leaves. ***Cup moth*** (*Anaxidia lozogramma*) caterpillars also chew leaves. ***Fiery jewel*** (*Hypochrysops ignitus ignitus*, Lycaenidae) caterpillars feed on leaves of banksia, camellia, plum, wattle and other plants (Common and Waterhouse 1981). ***Leafrolling moths*** (Tortricidae), eg ***orange fruitborer*** (*Isotenes miserana*) caterpillars bind new leaves together to form a shelter, from which they chew holes in leaves. See Citrus F 37, Trees K 13.

Mites (Acarina)

Eriophyid mites (Eriophyidae) are microscopic, elongated with small legs grouped at the head end. They suck plant sap. ***Camellia bud mite*** (*Cosetacus camelliae*) feeds in buds, especially ***flower buds*** on japonicas and may cause premature flower ***bud drop***. ***Camellia rust mite*** (*Acaphylla steinwedeni*) feeds on protected humid ***leaf undersurfaces*** of japonicas. Leaves develop brown, circular discoloured patches. In heavy infestations leaf undersurfaces may turn a rusty brown colour, ***uppersurfaces curl downwards*** and white cast skins are seen. Mite populations fluctuate from season to season, shrubs heavily infested one season may be free of mites in later years. ***Ribbed tea mite*** (*Calacarus carinatus*) is deep purplish and feeds mainly on ***uppersurfaces*** of more mature leaves of japonicas during dry weather. Rain destroys large numbers. Leaves may become bronzed and dusty due to cast skins and mite wax. See Grapevine F 62.

Spider mites (Tetranychidae): ***Tea red spider mite*** (*Oligonychus coffeae*) during hot weather causes midribs and veins and eventually whole leaves to become reddish-brown. ***Twospotted mite*** (*Tetranychus urticae*) causes leaf speckling, webbing may be present. See Beans (French) M 29.

Tarsonemid mites (Tarsonemidae): ***Broad mite*** (*Polyphagotarsonemus latus*) ***distorts*** new growth. Miticides may be applied, commencing when damage is first observed. See Greenhouses N 26.

Scales (Hemiptera) infest leaves and stems.

Armoured scales (Diaspididae)
- Camellia scale (*Lepidosaphes camelliae*)
- Fiorina scale (*Fiorina fiorinae*)
- Greedy scale (*Hemiberlasia rapax*)
- Oleander scale (*Aspidiotus nerii*)
- Purple scale, mussel scale (*L. beckii*)

Soft scales (Coccidae)
- Black scale (*Saissetia oleae*)
- Hydrangea scale (*Pulvinaria hydrangeae*)
- Soft brown scale (*Coccus hesperidum*)

Soft scales excrete honeydew which attracts ants and on which sooty mould grows.

See Citrus F 39, F 41, Trees K 16.

Thrips (Thripidae, Thysanoptera)

Greenhouse thrips (*Heliothrips haemorrhoidalis*) feed on ***leaf undersurfaces***. Tarry black spots of ***excreta*** help to identify the problem. Leaves become silvered. See Greenhouses N 24.

Plague thrips (*Thrips imaginis*) cause ***flowers*** to brown and wither, buds become distorted or discoloured and fail to open. See Roses J 6.

Weevils (Curculionidae, Coleoptera)
Black vine weevil (*Otiorhynchus sulcatus*)
Fuller's rose weevil (*Asynonychus cervinus*)
Garden weevil (*Phlyctinus callosus*)
Weevils chew ***leaf edges*** giving them a ragged scalloped appearance. Older weevils attack stems and other plant parts. ***Larvae*** may attack ***roots***, fully grown larvae may girdle stems just below ground level causing dieback. See Trees K 17.

Others: ***European earwig*** (*Forficula auricularia*) may chew flowers, ***greenhouse whitefly*** (*Trialeurodes vaporariorum*) feeds on leaf undersurfaces. ***Mealybugs*** (Pseudococcidae) feed at the junctions of leaves and stems.

Non-parasitic

Bud drop, balling, blasting: Some camellias (and other plants, eg gardenia) set more flower buds than they can carry. A natural thinning takes place and a good crop of flowers is still obtained. ***Bud drop, where no or few flowers*** are obtained, however, is of concern. Buds may form normally, be green and healthy or their tips may turn brown and decay prior to dropping. This type of mass bud drop may have many causes. ***Bull-heading:*** The petals are so tightly packed together that they cannot slide over one another to open. Buds develop up to the time they should open, then rot and eventually drop. Some varieties have a tendency to bull-head. ***Camellia bud mite*** may also cause premature bud drop but this is not common. ***Favourable environment:*** Over or irregular watering, poor drainage, insufficient water during late summer/autumn, unseasonably high or low temperatures, sunburnt flower buds with morning dew on them (the calyx becomes damaged and will not open properly), wide sudden drop in temperature, wind, heavy rain, too heavy shade, poor nutrition, pot bound. ***Varietal:*** Some varieties drop buds abnormally for no apparent reason despite excellent care. ***Determine the cause of the bud drop and correct it***. Replace varieties which, despite good care, continue to drop buds excessively with more reliable cultivars.

Environment: ***Drought:*** Camellias have shallow roots, insufficient soil moisture during hot, dry, windy weather in summer/autumn may not be obvious for several months. Leaf tips and margins may later brown, bud drop may occur the ***following spring***. Camellias do not tolerate ***waterlogging***. ***Oedema, corky scab*** may affect camellia, begonia, pelargonium, *Brassaia* and other plants and is caused by abnormal water relations within the plant, ie roots absorb more water than leaves can transpire. Oedema is ***favoured*** by over or irregular watering of soil during extended periods of cloudy weather, high humidity or low light intensity (stomates may not open and transpiration is reduced) and over-fertilisation. Also by high humidities, as in glasshouses, accompanied with poor drainage. Small masses of tissue expand and break out on ***leaf undersurfaces*** causing small watery swellings or galls. When these burst they harden into variously shaped ***small corky scabs***. Often the scabs become rusty or grey and may be mistaken for rust. Leaves closest to ground are mostly affected. ***Adjust watering and fertilising***

regimes. Outdoors, camellia may be replanted in a more open location. In glasshouses, plants can be relocated away from humidifiers. Camellias with large root systems and sparse foliage are most susceptible, eg reticulatas and some japonicas. ***Excessive exposure to sun*** may cause leaf yellowing. Severe damage results in brown patches within the leaf margins, which may be later colonised by fungi, eg *Pestalotiopsis*. Buds or flowers of white and pale pink varieties, wet with dew or frost in the morning, may brown due to scalding if exposed to direct sun. Exposed sides of plants show more severe symptoms. Sasanqua grow well in full sun in a temperate climate, but reticulatas and japonicas need to be shaded for at least half of the day during summer. ***Wind and rain*** can cause browning of flower petals, particularly white and pale coloured varieties. When siting plants, consider minimising these possible problems. ***Deep red circles of anthocyanin pigment*** may develop on leaves of susceptible camellias, especially lighter green varieties, during cold winter weather. These disappear with the onset of warmer weather.

Nutrient deficiencies, toxicities: ***Iron deficiency*** (chlorosis) causes mild to severe yellowing, initially of new leaves. Except in the most severe cases, ***veins remain green***. The pH should not be > 6.0. See Azalea K 29, Trees K 20. ***Nitrogen deficiency*** eventually causes all leaves to yellow, older leaves are affected first. Plants lack vigour and may be woody. Apply a complete fertiliser in spring and autumn. ***Salt toxicity*** is caused by repeated excessive use of chemical fertilisers. Leaves initially develop a marginal scorch. Later they may blacken and feel soft to handle and may fall. See Trees K 20.

Others: ***Genetic variegations:*** Occasionally a twig has leaves lacking or partially lacking in chlorophyll ***(sport).*** Some varieties, eg Hi Jinks, have ***variegated leaves***. Do not confuse these with viral disease or senescence. Yellow areas are ***susceptible to sunburn*** and may be removed as they can be colonised by secondary fungi. ***Senescing leaves:*** Camellia leaves have an average life of up to ***3 years***. Old leaves fall after flowering, new growth and foliage appears during the following weeks. Leaf patterns on senescing leaves may be confused with virus or deficiency symptoms. ***White slime moulds*** (Myxomycetes) may develop on lower leaves, they disappear without causing damage in a few weeks. ***Sooty mould*** (*Capnodium* spp.) grows on honeydew secreted by aphids, soft scales, mealybugs and whitefly. ***Some varieties do not flower*** for 2-3 years after planting, older plants which have been moved may take several years to reach their previous flowering capabilities. ***Leafcutting bees*** (*Megachile* spp.) may cut neat scallops from leaf edges.

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State/Territory Departments of Agriculture/Primary Industry eg

Camellias (ABG Leaflet, Adelaide)
Camellias in the Garden (NSW Agfact)
Diseases of Camellias (Vic Agnote)
Diseases and Physiological Disorders of Camellias (Vic Agnote)

Associations and Journals eg

American Camellia Soc.
Australian Camellia Soc. and state branches
GrowSearch (database Qld DPI)
The International Camellia Journal

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Camellia are popular evergreen shrubs, tub specimens and hedge plants. They need cool, humid climates. The main problems affecting camellias are ***non-parasitic***. Select species suited to the site to be planted and the purpose for which they are being grown. Varieties differ in their ***susceptibility*** to *Phytophthora* root rot. Camellias forced in greenhouses for cut flowers are more susceptible to canker and oedema. Only propagate from plants that are ***free from virus, other diseases and pests***, eg scale. ***Propagated*** by terminal or leaf bud cuttings, also by seeds, grafting and air layering, by tissue culture. Plants from seed do not grow true to type. Seedling camellias are often used as rootstocks for slow growing cultivars. ***Sun*** is required for flowering. Sasanquas will grow well in full sun, but reticulatas and japonicas should be shaded for part of the day in summer. Provide acid soil (pH 5.0 to 5.5), high in organic matter, adequate irrigation and good drainage. To obtain larger flowers, only 1 flower is allowed to mature on each stem. Camellias require ***minimal pruning.*** ***Collect and burn*** diseased leaves, dead flowers, cut out cankers. ***Quarantine*** regulates camellia propagation material and ***tea plants*** (*C. sinensis*) entering Australia, to prevent entry of camellia petal blight and other diseases and pests. ***Growth regulators*** are used for cuttings and to promote compactness. ***Fungicides and insecticides*** are registered for use on camellias if considered necessary. ***Flowers and foliage (C. japonica): Harvest*** when flowers are fully open and leaves are mature. Cut stem on an angle with a sharp knife. ***Vase life*** for flowers may be 1-4 weeks, spray flowers once or twice a day with water (Nowak and Rudnicki 1990). Change vase preservative solution every 2 days, place in deep water and top up regularly (Jones and Moody 1993). ***Potted camellia plants:*** ***Sell plants*** when 2-3 years old and 1/3 to 1/2 buds are open. Plants need bright light, moist soil, temperatures < 20°C. Ethylene hastens flower bud abscission. ***Store and transport*** for a maximum of 1-2 days in darkness at 5-8°C at high humidities (Nowak and Rudnicki 1990).

Casuarina

She-oak

Allocasuarina spp., *Casuarina* spp.
Family Casuarinaceae

Casuarina has few diseases and pests.

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Root rots: ***Armillaria rot*** (*Armillaria luteobubalina*), ***phytophthora root rot*** (*Phytophthora* spp., *P. cinnamomi*). See Trees K 4, K 6.

Wood rots

Cramp ball (*Daldinia concentrica,* Ascomycetes) ***fruiting bodies*** develop in dense clusters on ***trunks and branches*** of casuarina. They are ***10-15 mm*** across, oval to nearly spherical, shiny black to chocolate-coloured and appear between June and January. A white rot develops.

Tinder punk (*Phellinus badius*) affects casuarina. The fruiting body is ***large and hard*** and survives for up to ***20 years*** (each year adding new growth). Its uppersurface is rough, often cracked and slopes downwards to the horizontal undersurface that bears fine, matt brown to dark rust-coloured pores which release spores. The fruiting body is about 100 mm thick and up to 100 mm wide. It is well hidden in ***crevices*** in the ***tree trunk***. The fungus rapidly decays heartwood producing a white, pocket rot that is sometimes indistinct.

See Trees K 8.

PARASITIC PLANTS

Mistletoe (Loranthaceae) may infest casuarina. See Trees K 10.

NEMATODE DISEASES

More than 40 species of nematodes have been recorded in association with *Allocasuarina* and *Casuarina*, eg ***burrowing nematode*** (*Radopholus*), ***cyst nematode*** (*Heterodera*), ***dagger nematode*** (*Xiphinema*), ***root knot nematode*** (*Meloidogyne*), ***sheath nematode*** (*Hemicycliophora*), ***spiral nematodes*** (*Helicotylenchus*, *Rotylenchus*) (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers may attack casuarina.

Beetle borers (Coleoptera) include ***twig girdling longicorn beetles*** (Cerambycidae) and ***jewel beetles*** (Buprestidae). Some bore in ***roots***. See Trees K 11.

Ghost moths (Hepialidae, Lepidoptera): ***Common splendid ghost moth*** (*Aenetus ligniveren*) and *A. lewini.* See Trees K 12.

Oecophorid borers (Oecophoridae, Lepidoptera): ***Fruit-tree borer*** (*Maroga melanostigma*) caterpillars bore into the ***trunk*** producing galleries in the bark, covered with a strong dark brown webbing of silk, faecal pellets and detritus, often completely ***ringbarking*** the tree. ***Cryptophasa irrorata*** is common from Cape York to Victoria. Caterpillars bore in the ***branches*** of casuarina and feed on the branchlets which they cut off and attach to the entrance of the tunnel. See Fruit F 10, Trees K 12.

See Trees K 11.

Caterpillars (Lepidoptera):

Caterpillars of more than 14 species of moths and at least 1 species of butterfly may attack casuarina.

Silkworm moths (Bombycidae): ***Casuarina moth*** (*Pernattia exposita*) caterpillars are ***destructive pests*** of casuarina, eg *A. littoralis, A. stricta, C. cunninghamiana, C. glauca, C. equisetifolia.* ***Moths*** are stout bodied, females are large and sluggish compared to the smaller and faster males. ***Caterpillars*** are up to ***25 mm*** long, ***hairy and slender*** with a relatively large head. Caterpillars feed on ***leaf scales and stems*** and may ***ringbark branches***. Severe infestations during dry periods or on weakened trees may cause trees to ***die***. Caterpillars pupate in oval parchment-like cocoons spun on branchlets. As caterpillars drop to the ground if disturbed, the branches can be beaten with sticks and the caterpillars collected on plastic sheets spread on the ground and then destroyed (Jones and Elliot 1986). Caterpillars of ***Porela spp.*** also feed on casuarina. See Mulberry F 85.

Noctuids (Noctuidae): Caterpillars of ***Cynosargo ornata*** feed on *C. littoralis* and caterpillars of ***Epicoma constristis*** on *C. muelliana*, *Eucalyptus* and *Leptospermum*.

Others: Caterpillars of ***Mimoscopa ochetaula*** (Tineidae) live in shelters formed by joining with silk the still green branchlets of casuarina. Also ***Catorycytis subparallela*** (Gelechiidae), a ***jewel butterfly*** (*Hypochrysops piceatus,* Lycaenidae) and ***Munychryia spp.*** (Anthelidae).

See Annuals A 8, Trees K 13.

Mites (Acarina): ***Eriophyid mites*** (Eriophyidae) infest *C. cunninghamiana* causing deformation of the ***tips*** of ***small shoots*** and rolling them into ***tiny bunches***. See Grapevine F 62.

Scales (Hemiptera)

Asterolecarids (Asterolecaniidae): ***Casuarina scale*** (*Frenchia* spp.) cause unusual ***galls*** on banksia and casuarina. Swellings develop around the point of attachment which becomes woody and gall-like. In severe attack trees become weak and may ***die***.

Eriococcids (Eriococcidae): ***Coccid galls*** (*Cylindrococcus* spp.) are remarkable in that they mimic the ***fruiting capsules*** of casuarina even the overlapping scales. The insects feed inside the galls. Other species may also infest twigs and bark of casuarina. See Eucalypt K 63, Trees K 14.

Soft scales (Coccidae): ***Nigra scale*** (*Parasaissetia nigra*) is leathery, oval, raised, black waxy scale about ***5 mm*** long. Young scales are light brown and soft. Mature females are dark and have masses of eggs underneath their bodies. Copious amounts of honeydew, which attracts ants and encourages the growth of sooty mould, is produced. Nymphs settle on ***young shoots*** and along ***leaf midribs***. See Citrus F 41, Custard apple F 52, Trees K 16.

Thrips (Thysanoptera)

Phlaeothripidae: *Casuarina* spp. support a large number of thrips species, some of which cause ***galls***.

Ensiferothrips primus (Thripidae) which has remarkably broad wing hairs, feeds on casuarina ***leaves***. See Greenhouses N 24.

Wasp galls: ***Bootanelleus orientalis*** (Torymidae) develop in ***seeds*** of casuarina. ***Ditropinotella*** (Pteromalidae) are associated with ***galls*** on casuarina, Myrtaceae, Poaceae and wattle. See Eucalypt K 61, Trees K 14.

Others: Many sucking insects (Hemiptera) other than scales also feed on casuarina.

Casuarina mealybug (*Pseudoripersia turgipes*). See Greenhouses N 25.

Froghoppers and spittle bugs: Philagra parva has a long, narrow head and is associated with casuarinas and wattles. Nymphs live in the ***spittle***. ***Spine-tailed froghopper*** (*Machaerota finitima*) may also infest casuarina. Control is not necessary as they are minor pests and kept in check by natural controls. See Trees K 14.

Lace bugs (Tingidae): Little is known about Australian species. Endemic species have been captured on many Australian native plants including casuarina. See Azalea K 28.

Leafhoppers (Cicadellidae): *Occinivana eborea* feeds on casuarina in WA. See Vegetables M 15.

Psyllids (*Acanthocnema* spp., Triozidae) occur on casuarina. Nymphs of *A. casuarinae* are elongate, flattened and live almost stationary, curved around a ***casuarina leaf***. See Eucalypt K 62, Trees K 15.

Squash bugs (Coreidae): *Tylocryptus egenus* has a slender abdomen and strongly resembles the casuarina branchlets on which it lives. It emits a strong ***repellent odour***.

Treehoppers (Eurymelidae), which are readily recognised by their ***widely flattened face***, feed on casuarina. Nymphs are gregarious but do not jump if disturbed. They are always attended by ***ants***. See Eucalypt K 61, Trees K 15.

Non-parasitic

Fasciation occasionally causes ***curved flattened stems***. See Australian native plants N 12 (Fig. 391), Daphne K 53.

Nitrogen-fixation: ***Frankia*** (Actinomycete or filamentous bacterium) forms a ***symbiotic*** or mutually beneficial relationship, with casuarina roots. *Frankia* grows on the fine roots of casuarina causing the roots to swell and form ***nodules***. Within the nodule, *Frankia* converts ***atmospheric nitrogen*** to a form useable by the plant. There is no growth response to inoculation with *Frankia* unless phosphorus is applied. See Trees K 19.

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Casuarina for Farm Planting (NSW Forestry Com.)

Increasing Casuarina Growth Through Nitrogen Fixation for Land Reclamation (CSIRO Div. Soils)

See Australian native plants N 9, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Casuarina are trees or shrubs and are hardy plants. They are used for park planting, shade trees, windbreaks and shelter belts and most produce high quality fuel wood. Male and female flowers are produced on the same, or different plants, depending on the species. The ***fruits*** produced on the female plants are an attractive part of the plant. Casuarinas will grow in most soils provided there is good drainage. They prefer full sun. ***Black sheoak*** (*A. littoralis*) is tolerant of frost, saline and moderately limey soils, and once established will withstand a low water regimes. ***Propagated*** by seed (14-21 days to germinate), not by cuttings. The ability to grow on ***infertile soils*** is in part due to the symbiotic association with *Frankia*.

Christmas bush

Ceratopetalum gummiferum
Family Cunoniaceae

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Root rots
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Greenhouse whitefly
  - Psyllids
  - Scales
  - Thrips

Non-parasitic
- Environment
- Genetic

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Root rots: ***Damping off*** (*Phytophthora*, *Rhizoctonia solani*) and ***phytophthora root rot*** (*Phytophthora* spp., *P. cinnamomi*). See Trees K 7.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) has been recorded on *C. gummiferum*. ***Other nematodes*** have also been found associated with *C. apetalum*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Fruit-tree borer (Oecophoridae, Lepidoptera) caterpillars produce ***webbing and frass*** (sawdust) at junctions of ***twigs or branches***. See Fruit F 10.
Longicorn beetle (Cerambycidae, Coleoptera) larvae may tunnel in ***trees*** which are ***weakened*** by regular and severe pruning. See Trees K 11.

See Trees K 11.

Caterpillars (Lepidoptera) of a ***pencilled blue butterfly*** (*Candalides consimilis*, Lycaenidae) may occasionally feed on ***foliage*** (Common and Waterhouse 1981). See Trees K 13.

Greenhouse whitefly (*Trialeurodes vaporariorum*) may feed on ***leaf undersurfaces*** of ***nursery stock.*** See Greenhouses N 24.

Psyllids (Psyllidae, Hemiptera) may damage ***new leaves*** of nursery and mature plants. Leaves roll inwards. ***Insecticides*** may be applied when new growth is appearing. See Trees K 15.

Scales (Hemiptera) may infest leaves and stems.

Armoured scales (Diaspididae):
White palm scale (*Phenacaspis eugeniae*)
Soft scales (Coccidae):
Black scale (*Saissetia oleae*),
Soft brown scale (*Coccus hesperidum*).

See Citrus F 39, F 41, Trees K 16.

Thrips (Thripidae, Thysanoptera): ***Plague thrips*** (*Thrips imaginis*) suck sap from ***calyces*** which brown and fall preventing the development of the attractive red bracts. See Roses J 6.

Non-parasitic

Environment: ***Frost*** and ***hot, strong winds*** may damage Christmas bush. ***Lack of water*** may cause blossom fall during spring; if weather is hot and dry, water plants regularly.

Genetic: Some plants produce ***white/pink flowers*** instead of the high demand, deep red.

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State/Territory Departments of Agriculture/Primary Industry eg
The Christmas Bush in the Garden (NSW Agfact)
See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Christmas bush is evergreen, the red flowers are actually their enlarged calyces. ***Select*** cultivated varieties which give superior colours and vase life. Christmas bush ***grows well*** in a range of climates but not in tropical or frosty areas. ***For good flowering*** it requires full sunlight, well drained mulched soil, protection from strong, hot or salty winds, and regular watering from spring onwards. Christmas bush only needs ***pruning for shaping*** after flowering. Remove 1/3rd previous season's growth and cut away undesirable growth. If flowering branches are cut for flowers, this is sufficient pruning apart from shortening any very long branches and general tidying up. ***Propagation*** is usually by seed but also by cuttings. Seedlings and cuttings should be hardened off. ***Harvest*** cut flowers early in the morning when plants are cool. ***Mist*** or dunk heads in water or leave for a good soak. Christmas bush appears to ***absorb water*** better through ***leaves and flowers*** than through stems. Wrap in wet bags or boxes with wet paper. Keep cool, out of sunlight and draughts. Recut stems, use a preservative in vase water, top up regularly (flowers are thirsty), and mist regularly (Jones and Moody 1993).

Conifers

Order Coniferales

Conifers generally are relatively free from pests and diseases (there are exceptions).

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas, soilborne viruses have been detected in conifer roots, but none in the foliage, eg ***tobacco necrosis virus*** in *Pinus sylvestris*, ***tomato blackring virus*** in *P. sitchensis*, ***arabis mosaic virus*** in *Chamaecyparis lawsoniana* and ***tomato ringspot virus*** in *Cupressus arizonica* (Cooper 1993). ***Tomato mosaic virus*** has been isolated from red spruce (*Picea rubens*) and cypress (*Cupressus* spp.) (Jacobi 1992). See Trees K 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) on *Cupressus*. See Stone fruits F 125.

FUNGAL DISEASES

Cankers

Cypress canker, branch canker (*Seiridium* spp. = *Monochaetia* spp.) affects false cypress (*Chamaecyparis* spp.) and cypress (*Cupressus* spp.) The cambium tissue is attacked, producing cankers on the ***branches and trunk***. Brown powdery material is present in the depressed patches or splits in the ***bark*** and ***resin*** may ooze from branches or the trunk. As the infection spreads, branches are frequently ***girdled*** and the tree acquires a ragged appearance with dead and dying limbs. Trees are rarely killed but infected hedges and windbreaks are ***unsightly***. ***Overwinters*** in cankers. ***Spread*** by airborne spores that might alight in cracks and fissures in the bark, germinate and proceed to attack the phloem and secondary cortical tissue of the branches. ***Favoured*** by injury caused by insects or mechanical damage. Maintain ***vigorous tree growth***. Remove affected trees, especially if the more susceptible species are attacked, and replant with a different species. ***Species with some resistance*** include Arizona cypress (*Cupressus glabra*), Bhutan cypress (*C. torulosa*) and Mexican cypress (*C. lusitanica*). ***Susceptible species*** include Lambert's cypress (*Cupressus lambertiana*), Monterey cypress (*C. macrocarpa*), Roman cypress (*C. sempervirens*), Lawson's cypress (*Chamaecyparis lawsoniana*) (McMaugh 1994).

Others: ***Dieback*** (*Diplodia pinea*) causes shoot dieback on blue spruce (*Picea pungens* var. *glauca*) and may defoliate radiata pine (*P. radiata*). ***Canker and dieback*** (*Phomopsis* sp.) occurs on spruce (*Picea* spp.), *Phomopsis occulta* occurs on Colorado spruce (*P. pungens*) overseas on young tissue and root-pruned seedlings in nurseries (Igoe et al. 1995).

See Trees K 5.

Needle cast and blight diseases

Scientific name/host range: Several Ascomycete fungi may cause ***needles to fall*** prematurely and slow growth, eg ***diplodia canker and shoot blight*** (*Diplodia pinea*) occurs on pines, ***dothistroma needle blight*** (*Dothistroma septospora*) on radiata pine (*P. radiata*), ***lophodermium needle casts*** (*Lophodermium* spp.) on *Pinus* spp., ***naemacyclus needle casts*** (*Naemacyclus* spp.) on radiata pine (*P. radiata*), ***Swiss needle cast*** (*Phaeocryptopus gaeumannii* = *Adelopus gaeumannii*) on Douglas fir (*Pseudotsuga* sp.).

Description and damage: Needle cast and blight diseases of conifers have common characteristics although each differs from all others in some respects (Agrios 1988). The needle-like leaves of conifers are infected by spores (conidia or occasionally ascospores) at some time during the growing season. The ***fungus enters the needle*** and usually a light green to yellow spot that later turns brown or red ***encircles the needle*** and kills the part of the needle beyond the spot (Fig. 229). The fungus may spread into the needle or separate new infections may develop. ***Entire needles may be killed***, and either cling to the tree giving the tree a brown burned appearance for a while, or shed. Needle casts and blights can be destructive on ***mature trees***, especially in plantations of a ***single species***, which can ***die*** following ***repeated defoliation***. ***Young trees*** in ***nurseries*** or ***after planting out***, can be ***severely damaged***.

Overwintering: In most instances, as spores in dead needles on the tree or on the ground, some as infected, but still living needles, on the tree.

Spread: Spores produced on infected needles on the tree or on the ground, are either released into the air, or exuded during wet weather and washed down or splashed by rain, onto other needles and trees.

Conditions favouring: Wet, humid weather. Environmental stress.

Control: The damage caused to individual trees in home gardens and parks is not serious enough to warrant control measures. In ***plantations***, effects of needle cast diseases can be reduced considerably by appropriate site selection, tree spacing, regular thinning and fertilisation. In ***nurseries***, fungicides may be applied at regular intervals.

Root rots, damping off

Damping off: Some fungi cause damping off diseases in nurseries and later root rots of more mature trees. ***Nursery hygiene*** is therefore important in preventing spread. ***Fungi include*** *Botryodiplodia theobromae, Colletotrichum acutatum, Cylindrocladium scoparium, Dothiorella pinea, Fusarium* sp., *Helicobasidium coonampactum, Phytophthora, Pythium, Rhizoctonia solani, Sclerotium rolfsii* (Marks et al. 1982). ***Grey mould***, shoot death, needle blight (*Botrytis cinerea*) may be a serious disease of Sitka spruce (*Picea sitchensis*) and other conifers, eg cypress (*Cupressus*), pines (*Pinus* spp.), Douglas fir (*Pseudostuga* spp.). A sparse ***web forms on young shoots and leaves***. When shoot tips are infected, they wilt and die. In densely crowded seedling beds infection usually begins on the lower leaves or needles and slowly spreads upwards. Stems are girdled, shoots killed. See Greenhouses N 22, Nurseries N 51, Seedlings N 66.

Armillaria root rot (*Armillaria* sp.) causes minor losses to some conifers, eg cypress (*Cupressus* spp.), Lawson's cypress (*Chamaecyparis lawsoniana*). See Trees K 4.

Fusarium rots (*Fusarium* spp.): ***F. acuminatum*** occurs on Norfolk Island pine (*Araucaria heterophylla*) and ***F. solani*** on *Araucaria* spp., *Pinus* spp., eg Aleppo pine, Canary Island pine, maritime pine, radiata pine. See Vegetables M 7.

Phytophthora root rots (*Phytophthora* spp., *P. cinnamomi, P. cryptogea, P. nicotianae*). ***Susceptible conifers*** include Lawson cypress (*Chamaecyparis lawsonia* Allumii and Filiformis), *Araucaria* spp., firs (*Abies* spp.), juniper (*Juniperus* spp.). Conifers with ***some resistance*** include some cypresses (*Cupressus* spp.) and radiata pine (*P. radiata*). It seems that when *Phytophthora* has caused disease of other crops prior to planting, there may still be potential for serious disease, or if trees are planted in wet, coarse-textured, infertile soil. Also there is considerable ***variation in resistance within a species*** from tree to tree. See Trees K 6.

Woody root rots (Basidiomycetes): ***Tinder punk*** (*Phellinus noxius*) and *Poria vincta* are ***important woody root rots*** in subtropical and tropical conifer plantations in Qld. *P. noxius* may kill hoop pine (*A. cunninghamii*) in all age and vigour classes, and cause butt rot in older trees. See Trees K 8.

Other root rots: ***Ashy stem blight***, charcoal rot (*Macrophomina phaseolina*), ***dieback*** (*Botryodiplodia theobromae*), ***sclerotium collar rot*** (*Sclerotium rolfsii*), ***thielaviopsis black root rot*** (*Thielaviopsis basicola*), also *Cylindrocarpon* sp., *Heterobasidium annosum*.

See Trees K 7, Vegetables M 7.

Wood rots

Ring-barking fuscoporia (*Fuscoporia laevigata*) affects cypress pine (*Callitris* spp.), possibly other conifers, and other trees and shrubs. The fruit body forms a ***rusty-brown sheath*** on the collar of ***saplings***. The fungus appears to ring-bark and kill saplings rapidly. It produces a white, sapwood rot. It is found in most forests in Victoria. See Trees K 8.

Tinder punk (*Phellinus* spp., Basidiomycetes) attacks *Araucaria* spp., cypress (*Cupressus*), cypress pine (*Callitris*) and other trees. The fruit body is ***large*** (about 100 mm thick and up to 100 mm wide), heavy and hard and survives for up to ***20 years***, each year adding new growth. It is hidden in splits and crevices in the trunk. The fungus rapidly decays heartwood, producing a white, pocket rot that is sometimes indistinct. It may also cause a ***root and butt rot*** of hoop pine (*Araucaria cunninghamii*). See above.

Others: Many other fungi cause trunk, butt and root rots, some are weak pathogens, eg ***root and butt rot*** (*Chaetoporus radulosus*) on *Araucaria*. Also ***yellow heart rot*** (*Schizophyllum commune*), *Coriolus* spp. *Cryptoderma bibulosa, Daedala sanguinea, Fomes mastoporus, Ganoderma applanatum, Lenzites* spp., *L. strigosus, Meripilus talpae, Polyporus verecundus, Poria* spp., *Pycnosporus* sp.

See Trees K 8.

Wood-stains, sap-stains

Several Ascomycetes and Imperfect Fungi cause unsightly ***discolouration*** of wood, reducing its ***quality*** but not its ***strength***. Some fungi can attack several species, others are host specific.

Surface moulds usually grow on the ***freshly cut surfaces of wood*** and impart to the wood the colour of their spores, eg *Aspergillus* (black or green), *Fusarium* (red), *Penicillium* (green or yellow), *Rhizopus* (grey).

Sap-stain or blue-stain fungi discolour sapwood by producing ***pigmented hyphae*** that grow mainly in the ray parenchyma, but can spread throughout the sapwood and cause lines of discolouration. Sap-stain fungi include *Ceratocystis, Cladosporium, Diplodia, Graphium, Hypoxylon, Xylaria*. Also ***blue-stain*** (*Diplodia pinea*), ***brown-stain*** (*Gibberella fujikoroi*) and ***sap-stain*** (*Trichoderma viride*) affect *Araucaria.*

See Trees K 9.

NEMATODE DISEASES

More than 30 species of nematodes have been associated with conifers including ***burrowing nematode*** (*Radopholus* spp.), ***citrus nematode*** (*Tylenchus*), ***dagger nematode*** (*Xiphinema*), ***foliar nematode*** (*Aphelenchoides*), ***ring nematode*** (*Criconema*), ***root knot nematode*** (*Meloidogyne*), ***root lesion nematode*** (*Pratylenchus*), ***sheath nematode*** (*Hemicycliophora*), ***spiral nematodes*** (*Rotylenchus, Helicotylenchus*). ***stunt nematode*** (*Tylenchorhynchus*), also *Boleodorus, Cephalenchus, Hemicriconemoides Macroposthania, Morulaimus, Neodolichodorus, Paralongidorus, Paratrichodorus, Scutellonema, Tylenchus, Tylodorus, Xenocriconemella.* ***Pine wood nematode*** (*Bursaphelenchus xylophilus*) is not known to occur in Australia (Com. of Aust. 1987). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Hemiptera)

Aphids (Aphididae) may cause foliage to brown and die. Nymphs and adults feed on ***young shoots*** and produce copious amounts of ***honeydew*** which attracts ants and encourages the growth of ***black sooty mould***. In severe infestations, the honeydew makes trees ***glisten*** in the sun, and the ground beneath trees, ***shiny*** and ***sticky***. ***Cypress pine aphid*** (*Cinara tujafilina*) affects cypress pine (*Callitris* spp.), cypress (*Cupressus* spp.). ***Adult aphids*** are plump, soft, dark brown, hairy and about ***2-4 mm*** long. Winged adults are only found late in the season. A sporadic pest which can disfigure ***native pines***. Infestation may reduce their value as specimen trees in public parks. Occurs in temperate and subtropical regions, mainly inland. ***Usually controlled by natural enemies***, eg predators such as birds, lizards, spiders and insects, ladybird adults and larvae, scale-eating caterpillars, parasitic wasps and flies. Wind, heavy rain and frost will also destroy large numbers. Insecticides may be used on small trees in nurseries. ***Cypress pine aphid*** (*C. cupressi*) may heavily infest cypress pines (*Callitris* spp.). This is a large brown aphid with short cornicles. A related species (*C. thujufolia*) attacks other pine and is similar in appearance. Also ***cypress aphid*** (*C. fresai*). ***Juniper aphid*** (*C. juniperi*) infests cypress (*Cupressus* spp.) and juniper (*Juniperus* spp.). Adult aphids are ***large*** (3-5 mm long), grey and congregate on the main trunk during the day (Fig. 230) and feed on the foliage at night. Foliage may brown and die. ***Spruce aphid*** (*Elatobium abietinum*) infests Douglas fir (*Pseudotsuga* spp.), spruce (*Picea* spp.). Initially causes needles to develop a pale mottled colour and heavy feeding results in needle fall.

Pine aphids (Adelgidae) are large aphids which affect conifers. The ***primary host*** is spruce (*Picea* spp.), and the ***secondary hosts*** are fir (*Abies*), larch (*Larix*), Douglas fir (*Pseudostuga*) and pine (*Pinus*). True galls form on the primary host (spruce). ***An adelgid*** (*Adelges* sp.) feeds on spruce (*Picea* spp.) and Douglas fir (*Pseudostuga* spp.). ***Pine adelgid***, woolly pine aphid (*Pineus pini*) feeds on radiata pine (*P. radiata*). See Bonsai N 15 (Fig. 394), Pine K 108.

See Trees K 10, Roses J 4.

Bark beetles and weevils
(Curculionidae, Coleoptera)

Pine bark beetles are serious pests of pines:
Black pine bark beetle (*Hylastes ater*)
Fivespined bark beetle (*Ips grandicollis)*
Goldenhaired bark beetle (*Hylurgus ligniperda*)
See Pine K 109.

Pine bark weevil (*Aesiotes notabilis*) is a ***serious pest*** of conifers in plantations, natural stands and trees growing in parkland. It infests *Agathis* spp. and *Araucaria* spp., other conifers. ***Weevils*** are dull grey, about ***15 mm*** long, with numerous conspicuous bumps and protuberances on wing covers. ***Larvae*** are fleshy, white and legless. Larvae enter through deep wounds in ***bark*** and feed actively around their point of entry. Attacks persist, and secondary pests can enter damaged areas; trees may be ***ringbarked*** and ***die***. Occurs in tropical and subtropical climates. Insecticides are sometimes applied.

Cypress bark beetle (*Phloeosinus cupressi*) can kill or ***severely damage*** cypress (*Cupressus* spp.) under stress, especially ornamental trees. ***Beetles*** are ***2.5 mm*** long. ***Larvae*** are ***3 mm*** long. Trees die from the top, hence the common name ***'dead top'***. Found all months of the year. Remove the tree unless attack is only slight and offending sections can be removed. Fertilise tree if retained. ***Susceptible species*** include Monterey cypress (*C. macrocarpa*) and Bhutan cypress (*C. torulosa*).

Cypress bark weevil, mottled pine bark weevil (*Aesiotes leucurus*) attacks cypress (*Cupressus* spp.), radiata pine (*P. radiata*), Aleppo pine (*P. halepensis*). ***Weevils*** are ***15-20 mm*** long, dull black or brown and mottled with fine, white markings on the head and legs, with white-tipped wing covers (Fig. 231). There are 2 pairs of blunt spines towards the end of the wing covers. The first sign of adult feeding is ***dead tips*** on the ends of ***branchlets***. Female weevils lay their eggs on or just under the bark surface. ***Larvae*** are cream, legless and ***15-20 mm*** long. They damage the ***inner bark*** and in large numbers kill trees by ***ringbarking.*** Exit holes are round and about 6-8 mm across. There may be resin bleed and later, patches of dead bark. Pupae are whitish, and about 12 mm long. If dead bark is removed, the tunnels are seen (Fig. 231). ***Favoured*** by stress following prolonged dry periods, irregular rainfall, closely planted trees in windbreaks, poor soils. Weevils are found from September-March, among foliage or resting on trunks and limbs of trees where they are difficult to see. ***Damage*** may be found all the year round. Under normal seasonal conditions, the ***strong resin flow*** produced by the tree, traps larvae before serious damage or trees die. Regular watering and fertilising will assist in building up resin which will kill larvae, and help the trees to resist further attack, but it is better to plant ***less susceptible species***, eg Bhutan cypress (*C. torulosa*), Brunning's golden cypress (*C. macrocarpa* Brunniana Aurea).

Others: ***Hoop-pine bark beetle*** (*Hylurdrectonus piniarius*) on *Araucaria*.

See Trees K 10.

Borers

Ambrosia beetles: ***Large ambrosia beetle*** (*Platypus froggatti*) on *Araucaria* spp., ***platypus beetle,*** mountain pinhole borer (*P. subgranosus*). See Trees K 10.

Jewel beetles (Buprestidae, Coleoptera): ***Cypress jewel beetles***, Murray pine borers (*Diadoxus* spp.) are probably the ***most important pest*** of cypress (*Cupressus* spp.), cypress pine (*Callitris* spp.) especially white cypress pine (*C. columellaris*). ***Small cypress jewel beetle*** (*D. erythrurus*) is about ***15 mm*** long, black, yellow and green coloured, it flies readily. They emerge from trees from November-January. ***Larvae*** are thickset, legless, whitish and ***40-50 mm*** long, typically 'cobra-headed' with their thoracic segments flattened and wider than the rest. Exit holes on the ***trunk*** are oval and 6-8 mm across. ***Cypress jewel beetle*** (*D. scalaris*) may damage cultivated pines. ***Hoop-pine jewel beetle*** (*Prospheres aurantiopictus*) is a ***serious pest*** of hoop pine. ***Beetles*** are handsome, slender, shiny, about ***20 mm*** long with 8 prominent golden blotches on wing covers. ***P. moesta*** is shiny black and also attacks hoop pine. See Trees K 11.

Longicorns (Cerambycidae, Coleoptera):
Cypress longicorn (*Tritocosmia latecostata*)
Hoop-pine branchcutter (*Strongylurus decoratus*)
Hoop-pine longicorn (*Diotimana undulata*)
Pine witchetygrub (*Cacodacnus planicollis*)
White cypress longicorn (*Uracanthus pallens*)
See Trees K 11.
Weevils (Curculionidae, Coleoptera): ***Giant pine weevil*** (*Eurhamphus fasciculatus*) damages *Agathis* spp. hoop, bunya and kauri pines. ***Weevils*** are large about ***60 mm*** long, brown and white with a long snout and tufts of hair on the wing covers. ***Larvae*** are large, fleshy, white and legless. Larvae bore large circular tunnels deep into the wood. Also ***hoop-pine stitch beetle*** (*Hyleops glabratus*), ***hoop-pine borers*** (*Pachycotes australis*, *P. clavatus*), ***pine stump weevil*** (*Mitrastethus australiae*) on pine, ***radiata pine shoot weevil*** (*Merimnetes oblongus*). See Conifers K 47, Trees K 12.
Wood wasps (Siricidae): ***Sirex wasp*** (*Sirex noctilio*) on pines especially ***radiata pine***. See Pine K 109, Trees K 12.

See Trees K 11.

Caterpillars (Lepidoptera)

Case moths (Psychidae) commonly occur on conifers. ***Leaf case moth*** (*Hyalarcta huebneri*) occurs on radiata pine (*P. radiata*), patula pine (*P. patula*) and other trees, also ***Lepidoscia arctiella***. ***Faggot case moth*** (*Clania ignobilis*) infests conifers, eg cypress pine (*Callitris* spp.), pines. See Trees K 13.
Cutworms (Noctuidae): ***Bogong moth*** (*Agrotis infusa*) caterpillars and other species may damage pines in ***nurseries***. See Seedlings N 68.
Hoop-pine seed moth (*Hieromantis ephodophora*, Oecophoridae) infest *Araucaria*.
Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars may defoliate radiata pine. See Pome fruits F 112.
Orange fruitborer (*Isotenes miserana*) caterpillars are green initially, later cream with reddish-brown bands along the body. The head is dark brown. They feed on ***young foliage*** of golden Brunning cypress (*Cupressus macrocarpa* Brunniana). See Citrus F 37.
Pine loopers (*Chlenias* spp., Geometridae) attack cypresses (*Cupressus* spp.) especially Monterey cypress (*C. macrocarpa*), also pines (*Pinus* spp.). A ***pine looper*** (*Parathemis lyciaria*) and ***twig looper*** (*Ectropis excursia*) infests radiata pine (*P. radiata*). See Avocado F 19.
Tussock moths (Lymantriidae): ***Omnivorous tussock moth*** (*Acyphas leucomelas*) caterpillars infest false cypress (*Chamaecyparis lawsoniana*). ***Painted apple moth*** (*Teia anartoides*) and ***painted pine moth*** (*Orgyia australis*). See Pome fruits F 113.
Web moths (Pyralidae) affects false cypress (*Chamaecyparis lawsoniana*). ***Tree lucerne moth*** (*Uresiphita ornithopteralis*) caterpillars infest tree lucerne (*Cytisus proliferus*), broom and other plants (Elliott and deLittle 1984). See Tea-tree K 124.

See Trees K 13.

Cypress pine sawfly, callitris sawfly, pine sawfly (*Zenarge turneri,* Argidae, Hymenoptera)

larvae infest ***cypress pines*** (*Callitris* spp.), especially white cypress pine (*C. columellaris*) and ***cypress*** (*Cupressus* spp.), especially Brunning's golden cypress (*C. macrocarpa* Brunniana Aurea). ***Sawflies*** are slender, black, mottled with yellow in the front of the head and about 25 mm across their outspread wings. ***Larvae*** are up to ***25 mm*** long, translucent green and difficult to see (Fig. 232). They feed during the ***day***. Trees can be quickly ***defoliated***. Tips of shoots wither and may fall. When fully grown, larvae pupate in the soil. Most common in dry inland areas in south-east Australia, but also occurs at the coast. It is a ***sporadic pest*** found from February to April. Light infestations on small trees may be hand picked and destroyed. ***Predators***, eg birds, lizards and insects, ***parasitic wasps and flies***, bacterial and fungal diseases kill many. ***Insecticides*** may be applied to ***nursery stock*** when larvae are first observed. See Eucalypt K 63.

Golden mealybug, yellow-banded mealybug

(*Nipaecoccus aurilanatus***,** Pseudococcidae, Hemiptera) is usually only a problem in spring on ***nursery stock*** of ***Norfolk Island pine*** (*Araucaria heterophylla*) and sometimes ***bunya pine*** (*A. bidwilli*). They cause little damage to trees. ***Mealybugs*** are covered with white mealy secretion (Fig. 233). They are up to ***4 mm*** long, roundish, black and banded with ***bright yellow wax*** around the edge of their bodies. They suck sap from ***stems*** and occasionally from ***needles***. Mealybugs produce ***honeydew***, and sooty mould growing on it makes trees look dirty. Tree growth rate may be reduced and needles may be discoloured. Usually ***controlled naturally*** by the predatory ***mealybug ladybird*** (*Cryptolaemus montrouzieri*), the larva of which also covers itself with a white, mealy material, do not confuse it with the golden mealybug itself (Fig. 233). Larvae of mealybug ladybirds are much more agile than golden mealybugs and move quickly up and down stems. ***Insecticides***, applied to ***nursery stock*** when predators are present, will prolong and may accentuate mealybug problems; only apply if damage is serious and ladybirds are absent. Use a wetting agent. See Greenhouses N 25.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Juniper scale*** (*Carulaspis juniperi*) infests juniper (*Juniperus* spp.) and cypress (*Cupressus* spp.), especially Lambert's cypress (*C. lambertiana*). ***Mauve pittosporum scale***, pine parlatoria scale (*Parlatoria pittospori*) infests pine (*Pinus* spp.).
Eriococcid scales (Eriococcidae): ***Felted pine coccid*** (*Eriococcus araucariae*).
Margarodid scales (Margarodidae): ***Kauri coccid*** (*Conifericoccus agathidis*).
Soft scales (Coccidae): ***Soft brown scale*** (*Coccus hesperidum*) infests spruce (*Picea* spp.).

See Citrus F 39, F 41, Trees K 16.

Scarab beetles (Scarabaeidae, Coleoptera):

Green scarab beetle (*Diphucephala colaspidoides*) and other species, may feed on conifers. See Eucalypt K 61, Trees K 16, Turfgrasses L 11.

Sirex wasp

(*Sirex noctilio*) may be a ***serious pest*** of pines in a weakened condition, eg those planted in unsuitable areas with poor soils and low erratic rainfall. See Pine K 109.

Spider mites (Tetranychidae, Acarina)

Spruce spider mite (*Oligonychus ununguis*) during hot dry seasons may infest conifers including firs, junipers, pines, spruce. ***Adult females*** are smaller than twospotted mites and orange to greenish-black. Large populations can build up before the problem is noticed. ***Nymphs*** are pale green. Nymphs and adults feed on ***needles*** by sucking and may turn them ***yellow, grey, brown or even nearly white***. Plants may take on a bronze colour and needles are often ***shed***. Foliage eventually dies. If infestation is ***severe***, a very ***fine webbing*** will be formed between leaves and branches. Large trees are damaged more on the lower branches. Seedlings and small trees may be killed if an infestation is severe. ***Overwinters*** in cool areas as eggs deposited near the base of the needles and other protected areas, but not on needles themselves. ***Spread*** by movement of infested plants, mites crawling, wind, etc. ***Irrigate*** infested trees appropriately. ***Insecticides*** may be applied to ***nursery stock*** as soon as infestation is noticed.

Twospotted mite (*Tetranychus urticae*) infests juniper (*Juniperus* spp.) and can ruin the ***appearance*** of spruce (*Picea* spp.) in one season. Even if controlled, damage remains ***for several seasons***. Needles become whitish. See Beans (French) M 29.

Termites (various species, Isoptera): Some conifers, eg radiata pine (*P. radiata*), are ***very susceptible*** to termite damage, others, eg cypress pine (*Callitris* spp.), are reputed to be ***resistant***. See Trees K 17.

Others: ***Bugs*** (Hemiptera), eg ***small light brown tortoise-like bugs*** (*Lestonia haustorifera* and *L. grossi*, Lestoniidae) have been collected from the growing tips of native cypress (*Callitris*). ***A shield bug*** (*Piezodorus hybneri,* Pentatomidae) feeds extensively on *Callitris*. ***Callitris fly gall*** (*Diplosis frenelae*, Diptera) affects cypress pines (*Callitris* spp.) causing large, rounded, woody galls about 20 mm across. It splits into 6 sections when old, ***mimicking*** a ripe cypress pine cone. Maggots feed within the gall. Found in temperate and subtropical regions, mainly inland. ***Severe infestations*** are very difficult to control. Watering during dry periods, fertilising and mulching are beneficial. ***Prune out*** and destroy small infestations when first observed, preferably before adults have emerged. This helps to reduce buildup of the pest. Trees that are consistently and severely attacked may be removed. ***Tiny wasps*** may parasitise the maggots within the galls. Even systemic sprays are generally ineffective because the maggots are encased within the gall. Once emergence holes of the adult flies can be seen on the galls it is too late to start control measures. ***Grasshoppers, locusts*** (Orthoptera), eg wingless grasshopper (*Phaulacridium vittatum*) and yellow-winged locust (*Gastrimargus muscicus*). ***Thrips*** (Thripidae), eg ***greenhouse thrips*** (*Heliothrips haemorrhoidalis*) may infest ***indoor conifers***, eg Norfolk Island pine (*Araucaria heterophylla*) causing them to become sticky with insect excreta; also ***kauri thrips*** (*Oxythrips agathidis*). ***A weevil*** (*Car*) has been associated with *Callitris* spp.

VERTEBRATE PESTS

Birds, especially cockatoos, feed on new shoots and cones. ***Rabbits*** dig in the soil around newly planted *Callitris* trees and gnaw the roots, causing severe damage and often death. See Fruit F 13.

Non-parasitic

Environment: ***Wind, frost, moisture:*** Some conifers, eg radiata pine (*P. radiata*), cypress pine (*Callitris* spp.), can withstand strong wind, frost and dry conditions. Many conifers when first planted in home gardens ***die*** during their ***first year*** due to lack of irrigation or natural rain. ***Variegated conifers*** may require shade from hot direct sun. Conifers do not re-shoot after ***fire damage***.

Fungi: ***Mycorrhizae:*** Coniferous ***nursery stock*** benefit from inoculation with mycorrhizal fungi. See Trees K 18. ***Sooty moulds*** (various species) may grow on honeydew secreted by aphids and other sucking insects. Needles and twigs have a black sooty appearance. See Trees K 19.

Nutrient deficiencies, toxicities: Conifers suffer from various ***nutrient problems***. Radiata pine (*P. radiata*) may produce short, tufted or rossetted needles due to ***boron deficiency***.

Pesticide injury: ***Oil sprays*** make foliage look dark and unattractive. ***Systemic insecticides*** used for tree injection are toxic to some cypresses, eg Bhutan cypress (*Cupressus torulosa*).

Pollution: Norfolk Island pine (*Araucaria heterophylla*) withstands ***frost and salt spray***. Death on beach fronts is thought to be due to surfactants from detergents, from sewage outlets, which are blown on to the trees with the salt spray. In other areas near the sea these trees grow well. Conifers ***accumulate*** pollutants on their leaves, ***deciduous trees*** are better for polluted areas.

Others: ***Large falling fruit:*** Bunya pines are not suitable for parks and gardens because their large fruit may fall. ***Mechanical injury*** may be caused by landscaping, sprinkler damage or fire. ***Senescence:*** Some of the book leaf conifers naturally develop dead foliage in the centre as they age, it can be removed by hand. ***After the needles of many confers die*** it may take 6 months for them to brown. Small conifers that die in summer from lack of water may not brown until the middle of the following winter. ***Birds***, eg starlings and Indian myna, nest in some of the columnar conifers, creating a nuisance. Some conifers, eg swamp cypress (*Taxodium distichum*), are ***deciduous***. Conifers must be ***pruned*** carefully, they do not re-shoot. Many ***nuisance insects***, eg spiders, make their homes within the protective shelter of dense branches of conifers.

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State/Territory Departments of Agriculture/Primary Industry eg
Armillaria Root Rot (NSW Agfact)
Borers and Termites (NSW For. Prot. Series 4)
Leaf Eating Insects (NSW For. Prot. Series 3)
Sap Sucking Insects (NSW For. Prot. Series 2)
Sirex Wood Wasp (NSW For. Prot. Series 1)
Phytophthora root rot
Wood rot (NSW Agfact)

Associations, Journals etc.
The Forest & Forest Products Pest & Disease Committee

See Pine K 110,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Conifers are grown for timber, ornamental plantings, windbreaks, bonsai and florist's foliage. Generally they are considered to be relatively disease and pest free. ***Resistant varieties:*** Choose species with tolerance to local conditions, eg salt-laden areas. Swamp cypress (*Taxodium distichum*) will thrive in waterlogged soil and *Callitris* will grow well in sandy soils in dry areas (McMaugh 1994). ***Disease-free planting material:*** Only plant disease and pest-free nursery stock in disease and pest-free soil in appropriate sites. ***Propagation*** usually by seed, also by cuttings and micropropagation. ***Cultural methods:*** Generally conifers require fertile, well drained soils in cool temperature and highland areas. Avoid very hot sites. Although full sun is generally recommended for conifers, the white or yellow flecks of variegated conifers are likely to brown in hot sunny sites. If roots are allowed to become too hot and dry, or if dry hot winds prevail, foliage will appear dull and lifeless and may brown at the tips. Young trees especially may suffer from insufficient soil moisture during hot, dry windy weather in summer, the needles turning brown several months later. ***Sanitation:*** Care must be taken when ***pruning*** conifers otherwise the shape is ruined. ***Pesticides*** should only be applied in nurseries. ***Harvest*** healthy unwilted foliage for florist's foliage. Many have woody stems which should be recut cleanly. Most are heavy drinkers, always keep in water, replenish and change water regularly, use standard preservatives. Most like to be kept cool and in high humidity. Many florists soak green foliage or wilted foliage for 2-12 hours prior to use in arrangements. Do not soak yellow or grey foliage which browns if soaked in cold water, hold in a cool position, foliage may be misted (Jones and Moody 1993).

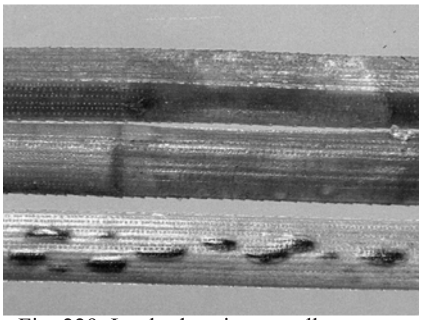

Fig. 229. Lophodermium needle cast (*Lophodermium* sp.) on *P. ponderosa*. Fruiting bodies n lowest needle. B. A. Fuhrer.

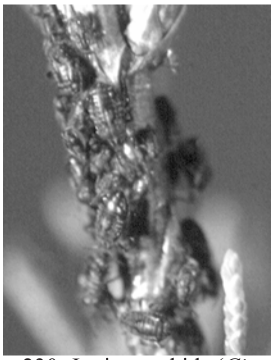

Fig. 230. Juniper aphids (*Cinara juniperi*) (3-5 mm long) on *J. virginiana* Sky Rocket**.**

Fig. 231. Cypress bark weevil (*Aesiotes leucurus*). ***Upper :*** Adult (15-20 mm long). ***Lower :*** Infested pine wood. Dept. of Agric., NSW.

Fig. 232. Cypress pine sawfly (*Zenarge turneri*) larva up to 25 mm long**.**

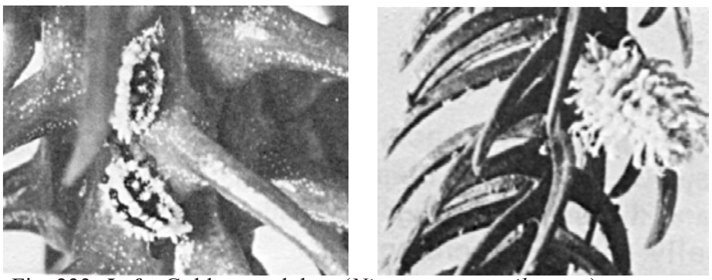

Fig. 233. ***Left :*** Golden mealybug (*Nipaecoccus aurilanatus*) up to 4 mm long. ***Right :*** Larva (up to 13 mm long) of a predatory ladybird (Coccinellidae). For. Com., NSW.

Correea

Native fuchsia

Correa spp.
Family Rutaceae (citrus family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Fungal leaf spots
  - Phytophthora root rot
  - Rust
- **Insects and allied pests**
  - Leafmining moth
  - Lightbrown apple moth
  - Scales

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots

Halo spot (*Pseudocercospora correae*) affects almost all *Correa* spp. causing ***red-brown dead spots*** with broad reddish margins, ***8-15 mm*** across. Brown masses of spores develop on ***leaf uppersurfaces***. Halo spot is a ***severe disease*** both in cultivation and in natural habitats.

Red blotch (*Pseudocercospora correicola*) affects *C. reflexa* and *C. lawrenciana*. Faint reddish blotches ***5-10 mm*** across develop on ***leaf uppersurfaces***, corresponding grey-brown areas of fungal sporing structures develop among hairs on ***leaf under surfaces*** (Pascoe and Sutton 1987).

Others: Various species including *Acremonium, Asterina, Hansfordia.*

See Annuals A 5, Trees K 6.

Phytophthora root rot (*Phytophthora cinnamomi*, *P. nicotianae* var. *parasitica*). See Trees K 6.

Rust (*Puccinia correae*) was recorded on *Correa* spp. at the beginning of this century but there does not appear to be any recent records. See Annuals A 7.

INSECTS AND ALLIED PESTS

Leafmining moth (*Stigmella leucarhyra,* Nepticulidae, Lepidoptera) caterpillars infest *Correa reflexa* and *C. alba*. ***Moths*** have a brownish head, white eye-caps and dark bronze forewings with a yellow transverse band. Adults have a wingspan of about 3-6 mm. ***Caterpillars*** produce narrow linear mines on ***leaf uppersurfaces*** in coastal NSW and spin their cocoons in August and early September. The early part of the mine is often in the form of a spiral, and later this area turns brown. After leaving the spiral, the ***mine is tortuous***, gradually expanding, but does ***not become a blotch***. Faecal material is deposited in a thin central line throughout the length of the mine, except for the last few millimetres before the caterpillar leaves it to pupate in oval silken cocoons, usually in the leaf litter or soil. Pupal remains protrude from the cocoon after the moth merges (Common 1990). See Trees K 15.

Lightbrown apple moth (*Epiphyas postvittana*) caterpillars ***tie leaves and shoots*** and may damage ***fruits***, especially those touching affected leaves. See Pome fruits F 112, Trees K 13.

Scales (Hemiptera)
Black scale (*Saissetia oleae,* Coccidae)
See Citrus F 41, Trees K 16.

Others: ***Mites*** (Acarina) feed amongst ***leaf galls*** on leaves of *Correa* sp. in coastal areas. ***Weevils*** (Curculionidae) chew ***leaves*** in established gardens. See Trees K 17.

Non-parasitic

Environment: Leaves of *Correa* Dusky bells may become ***sunscorched***.

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See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Correa are woody shrubs which flower in ***winter*** and tend to attract birds to the garden. All species are ***frost hardy***. *Correa alba*, *C. backhousiana*, *C. reflexa* have some ***resistance*** to ***salt laden winds***. For healthy growth and flowering, plant in sun or semi-shade, in well drained soil with friable rich compost used as a mulch, or lightly forked into the soil around the plant's root zone. Fertilise in early autumn and spring, and regularly deep water during the growing season. Regular ***tip pruning*** after the main flowering period, encourages the development of a well branched compact shrub and better flowering the following season. Some species are pruned to keep bushy and prevent spread. ***Propagation*** is easiest from cuttings taken in late summer and early autumn. Dip the base of cuttings in a rooting hormone. As roots develop, pot in individual containers and liquid fertilise. Some growers manipulate hybrids and germinate seed. Seed is explosive and ripens in early summer over 1-2 weeks.

Daphne

Daphne spp.
Family Thymelaeaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Scientific name: Virus diseases are ***the most serious problem*** affecting daphne. More than 10 virus diseases have been found in *D. odora*, often a single plant may be infected with several of these.

Alfalfa mosaic virus	Daphne latent ringspot
Arabis mosaic virus	Daphne virus S
Carnation mottle virus	Daphne virus X
Cucumber mosaic virus	Daphne virus Y
Daphne-tobacco mosaic virus	
Tobacco ringspot virus	

Host range: Some viruses only affect daphne, others, eg cucumber mosaic virus, affect many plants.

Symptoms: Symptoms caused by individual viruses on daphne have not been well documented. ***Leaves*** may show pale green or yellowish flecks, streaks, mottles and rings (Fig. 234). Leaves may also be small, thin, leathery, slightly curled and fall excessively during autumn and winter. In severe infections, branches or whole plants may die. ***Flower*** colour may be uneven or reduced, actual flowering may be delayed and buds may fail to open. Plants grown in the shade may not display such severe virus symptoms, but this does not mean they are not infected. Virus-infected plants are less attractive and therefore less saleable.

Overwintering: Infected host plants.

Spread: All viruses are spread by ***vegetative propagation*** from infected plants. Some, eg alfalfa mosaic virus, cucumber mosaic virus, daphne virus S and daphne virus Y, are also spread by ***aphids***, eg green peach aphid (*Myzus persicae*). Some, eg arabis mosaic virus, tobacco ringspot virus and daphne latent ringspot, are also spread by ***nematodes*** (but these viruses are not a problem in Australia due to the absence or small distribution of the nematode vectors). Some, eg carnation mottle virus, daphne-tobacco mosaic virus and daphne virus X are spread by sap via cutting implements, cultivation tools and by ***contact***.

Control: Once a plant is infected little can be done. ***Home gardeners*** may restore severely affected plants to better health by regular foliage or soil applications of fertilisers. ***Commercial producers*** of nursery stock should use virus-tested parent stock in conjunction with management practices outlined below and train staff in nursery hygiene.

Sanitation: Rogue and destroy, or remove from the nursery, all plants showing symptoms of virus infection. Maintain strict hygiene. All cutting implements should be sterilised before use. Wash hands before working with virus-tested stock. See Nursery Hygiene N 51.

Plant quarantine: Never place newly purchased virus-tested daphne plants beside older ones which may be infected with virus. Keep old infected stock separate from new virus-tested stock.

Disease-free planting material: Do not propagate from virus-infected plants. Plant ***virus-tested planting material*** of *D. odora*. Although some daphne viruses are spread by ***aphids***, these viruses are ***not*** the most commonly present in daphne in Australia.

Pesticides: Use suitable ***insecticides*** for the control of aphids in ***nurseries*** where virus-free plants are propagated. See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots (*Marssonina daphnes,* other species) causes small, thick brown spots to develop on ***both sides of leaves*** which yellow and die. See Annuals A 5, Trees K 6.

Grey mould (*Botrytis cinerea*) may cause a petal blight of ***flowers***. See Greenhouses N 22.

Powdery mildew (*Oidium* spp.) may develop on the ***foliage***. Plants grown in very protected sites, with little air movement and low levels of light, are very susceptible. See Annuals A 6.

Root and collar rots

Phytophthora root and stem rot (*Phytophthora cinnamomi, P. nicotianae*)
Rhizoctonia collar rot (*Rhizoctonia solani*)
Sclerotium stem rot (*Sclerotium rolfsii*)

See Trees K 7, Vegetables M 7, M 8.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) and ***spiral nematode*** (*Helicotylenchus* sp.) have been recorded on *D. odora*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Foxglove aphid (*Aulacorthum solani*)
Green peach aphid (*Myzus persicae*)
Aphids may attack growing tips. Their main importance is that they are ***vectors of virus diseases***. See Roses J 4, Trees K 10.

Scales (Hemiptera)

Armoured scales (Diaspididae)
Oleander scale (*Aspidiotus nerii*)
Red scale (*Aonidiella aurantii*)
Soft scales (Coccidae)
Black scale (*Saissetia oleae*)
Soft brown scale (*Coccus hesperidum*)

See Citrus F 39, F 41, Trees K 16.

Others: ***Mealybugs*** (Pseudococcidae) may infest daphne in warm humid sites. ***Weevils*** (Curculionidae), eg ***Fuller's rose weevil*** (*Asynonychus cervinus*), ***garden weevil*** (*Phlyctinus callosus*) and ***black vine weevil*** (*Otiorhynchus sulcatus*) may ***chew daphne leaves***.

Non-parasitic

Environment: ***Frost*** may damage new growth. Small green or scabby lumps ***(oedema)*** develop on ***leaf undersurfaces*** near the ground where humidity is high. See Geranium A 35.

Fasciation probably arises from ***genetic changes*** in a single growth area of the plant. Fasciations have been recorded from more than 1/3rd of the known families of flowering plants. In daphne the ***stem*** is wider and flatter than normal, almost resembling a ribbon (Fig. 235), and multiple buds may develop (as it does in cucurbits). In other genera of plants, ***flowers, fruit, underground roots and stems***, can also be affected. Many plants seem to produce fasciations in accordance with definite laws of inheritance, but most fasciations appear irregularly and unpredictably, the reason for their development being unknown. Fasciations are more abundant some seasons than others. Sometimes they can be induced by ***mechanical injury*** or by ***chemicals such as hormone herbicides***. No control is available, affected parts can be pruned off when they appear, but further fasciations may develop. Some research workers consider that some forms of fasciation, eg as in euonymus, may be linked with ***virus diseases*** (Cooper 1993) or with ***bacteria***. Do not propagate from affected plants

Nutrient deficiencies, toxicities: ***Iron deficiency*** may be indicated by yellowing between the veins on new leaves, soil should be slightly acid. ***Nitrogen*** deficiency may cause all over yellowing at the end of winter. See Trees K 20.

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State/Territory Departments of Agriculture/Primary Industry eg
Virus Diseases of Daphne (Vic Agnote)
Associations, Journals etc.
GrowSearch (database Qld DPI)
See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Daphne is a woody shrub and one of the most popular plants grown by home gardeners for its ***scented flowers*** in winter. It is easily grown either in the ground or in containers. When in flower, containers can be taken indoors for a short while. Plant only ***virus-tested plants***, which although not always selected for their flowering, grow more vigorously and are more tolerant of cultural conditions than older, virus-infected strains. Ensure that propagation material is ***scale-free***. ***Propagation*** by cuttings, growth regulators are used for striking cuttings. ***Plant*** daphne in semi-shade in sites protected from hot drying winds in summer and cold winter winds. Plant in soil rich in organic matter, well drained and slightly acid, do not lime. Mulch to keep soil cool and moist but keep mulch away from direct contact with the stem which favours diseases such as *Phytophthora* collar rot and *Sclerotium* stem rot. Apply a complete ***fertiliser suitable for daphne*** in spring. ***Prune lightly*** after flowering. Daphne has a life expectancy of ***10-15 years*** after which plants usually start to decline. ***Harvest*** flower stems by cutting the stem on an angle with a sharp knife or secateurs. Change the vase solution every 2 days. Many woody-stemmed shrubs are very thirsty so place in deep water and top up regularly. Warm water may be beneficial in easing the flow of water up stems (Jones and Moody 1993).

Fig. 234. Virus symptoms on daphne leaves.

Fig. 235. Fasciated daphne stem. Dept of Agric., NSW.

Elm

Ulmus spp.
Family Ulmaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Elm yellows (phloem necrosis mycoplasma) has ***killed thousands of elms*** in North America. Trees decline, leaves droop and curl, turn bright yellow, brown and finally fall. Later, inner layers of peeled bark (phloem) at the stem base become brown and have a ***pleasant fragrant smell*** (used for a quick diagnosis). Most trees die within one season. ***Spread*** by a leafhopper (*Scaphoideus luteolus*). ***Injection*** of tetracyclines into recently infected trees has resulted in remission of symptoms for up to 3 years. Severely diseased or dead trees are removed and burned. Neither the disease or vector is known to occur in Australia. All American elms are susceptible. The threat to European and Asian elms is unknown (Spencer et al. 1991). ***Other virus diseases*** may affect elms overseas. Symptoms include leaf mottling, oak leaf patterns, mosaics, scorching and zonate cankers on stems (Cooper 1993). See Trees K 4.

BACTERIAL DISEASES

Bacterial wet wood (various bacteria) affects the xylem of elms. The bacteria may enter through pruning, injection or other ***wounds***. Symptoms include dark brown discolouration of xylem, weeping of fluid that turns brown in air and wilting of some branches. There is no known control, ***prune carefully*** and repair any damage promptly. See Trees K 4.

FUNGAL DISEASES

Branch, trunk and twig cankers: ***Coral spot*** (*Nectria cinnabarina*) is caused by fungi invading wounds and is rarely severe. The oval lesions, over the years acquire concentric layers of callus. ***Cytospora cankers*** (*Cytospora* sp.) on ***branches*** are slightly sunken, bark may be yellow, brown, reddish or greyish. Avoid pruning wounds, mechanical damage, sunscalding, prune out dead or dying branches in spring and summer. See Trees K 5.

Dutch elm disease *(DED)* (*Ceratocystis ulmi,* Ascomycetes) which affects elm (*Ulmus* spp.) is not known to occur in Australia. The fungus when introduced into the tree proliferates in the tree's sap-bearing vessels. ***Toxins and enzymes*** released by the fungus cause the tree to secrete a ***sticky gum*** that impedes, and then halts, the ***flow of sap***, killing the tree. ***Spread*** by the elm bark beetle (*Scolytus multistriatus*), by vegetative propagation, eg cuttings, and by movement of infected plant material. ***Resistant species***, eg *Ulmus* x hybrida Sapporo Autumn Gold, *Ulmus* x hybrida Urban. ***Not very susceptible***, eg *U. parviflora*, *U. pumila*, *Zelkova serrata*. ***Moderately susceptible***, eg *U. carpinifolia*, *U. hollandica*, *U procera*. ***Highly susceptible***, eg *U. americana, U. glabra*, *U. carpinifolia* x *glabra*. Elm hybrids are bred resistant to ***DED*** in the USA. Tree trunks may be injected with ***fungicide*** which prevents the fungus from developing spores, without harming the tree. Tree injection is preventative and curative, but is labour-intensive and may be costly. Even so, it is a more efficient approach to curing ***DED*** than controlling the elm bark beetle. Success rate with tree injection is > 90%. An ***antifungal vaccine*** is being researched. ***Biocontrol*** either in the form of parasites of the fungus or of the beetle vectors may be a possibility (Stackhouse 1995). Contingency plans to control ***DED*** have been drawn up should it enter Australia (Kwong 1994). See Trees K 7.

Fungal leaf spot (*Phloeospora ulmi*) causes yellow angular flecks about 1 mm across on ***leaf uppersurfaces*** and brown and white patches underneath. Margins and tips of leaves brown, Leaves yellow prematurely. Usually occurs in autumn. Control is not warranted. See Trees K 6.

Root and collar rots: ***Armillaria root rot*** (*Armillaria luteobubalina*), ***cylindrocladium rot*** (*Cylindrocladium scoparium*), ***phytophthora*** (*Phytophthora* sp.). See Trees K 7.

Others: ***Damping off*** (*Fusarium, Pythium, Rhizoctonia*), ***wood rots*** (*Ganoderma applanatum, Phellinus* spp., *Polyporus versicolor*).

INSECTS AND ALLIED PESTS

Borers (Lepidoptera): ***Fruit-tree borer*** (*Maroga melanostigma*), ***small fruit-tree borer*** (*Cryptophasa albacosta),* ***common splendid ghost moth*** (*Aenetus ligniveren*). See Trees K 10, K 12.

Elm bark beetle (*Scolytus multistriatus,* Curculionidae, Coleoptera) is about ***3 mm*** long and a vector for ***DED***. It attacks all elms and *Zelkova*. ***Beetle injury*** itself may cause trees to die back. Pheromone traps ***monitor*** and assist in reducing beetle numbers as a defence against possible entry of ***DED*** (Spencer et al. 1991). Overseas, other bark beetles, eg *Hylurgopines rufipes*, may also spread ***DED***. See Conifers K 47, Pine K 109, Trees K 10.

Elm leaf beetle (*Pyrrhalta luteola,* Chrysomelidae, Coleoptera) is about ***6 mm*** long, orange-yellow to dull green, black spots on thorax and head, black stripe on outer margins of wing covers. They chew ***holes in leaves***. ***Larvae*** are ***12 mm*** long, yellow and spotted with 2 stripes along the back. They ***skeletonise leaves***, which brown and fall. Larvae ***pupate*** in the ground or in bark crevices on the trunk. There are 1-2 generations during summer. ***Overwinters*** as adults. ***Spread*** by adults flying, adults and larvae on nursery stock and other plant material. ***Insecticides*** may be applied to ***nursery stock*** in spring when eggs have hatched. Trees may be ***banded*** with 0.5 m of insecticide, a permanently sticky material or strong adhesive tape facing outwards. These trap larvae as they move down the trunk to pupate and reduce the adult population for the following year. A strain of ***Bacillus thuringiensis*** effective against elm leaf beetle larvae is available. A ***fly*** (*Erynniopsis antennatta*) lays eggs in larvae and a ***wasp*** (*Tetrastichus gallerucae*) parasitises the eggs (Kwong 1994). See Trees K 15.

Elm tree leafhopper (*Ribautiana ulmi,* Cicadellidae, Hemiptera) sucks sap from *Ulmus* spp. and *Alnussubcordata* sp. causing ***leaf speckling***, but no other major damage. Trees look silvery. ***Do not confuse*** with variegated cultivars. ***Overwinters*** as eggs in buds of stems. Nymphs emerge in spring and infest basal leaves. Adults of the spring generation lay eggs in leaf petioles and veins. It is not known how many generations there are per year under Australian conditions. Very little is known about the biology of *R. ulmi* in Australia, but in England it has been found to prefer the more highly illuminated areas of the tree canopy. See Trees K 15, Vegetables M 15.

Spider mites (Tetranychidae, Acarina)
Bryobia mite (*Bryobia* spp.)
European red mite (*Panonychus ulmi*)
Twospotted mite (*Tetranychus urticae*)
Elm leaves also support populations of ***beneficial mites***. See Trees K 16.

Scales (Hemiptera): ***Frosted scale*** (*Eulecanium pruinosum,* Coccidae) may excrete honeydew. See Stone fruits F 132. Many scales infest elms overseas, eg ***European elm scale*** (*Gossyparia spuria*, Coccidae) occurs in enormous numbers, secretes honeydew, the associated sooty mould makes trees unattractive, trees may ***die*** (Pirone 1978). See Citrus F 41.

Others: ***Aphids*** (Aphididae) may cause shoot tips to die. ***Greenhouse thrips*** (*Heliothrips haemorrhoidalis*) may cause leaf silvering. Elm is an alternate host for ***pear root aphid*** (*E. pyricola*).

Non-parasitic

Environment: Young elm trees require large amounts of ***water***, especially during early spring, their most active growth phase.

Chemical injury: ***Hormone and other herbicides***, eg glyphosate, may injure elms if applied to attached suckers. ***Natural gas and air pollution***, eg ozone, heavy metals, cadmium, lead and zinc, damages elms overseas. Damage includes brown spotting, yellowing and fall of leaves, loss of vigour and stunted growth. Young elms and shoots are very sensitive. ***Very sensitive*** species include *U. americana* and *U. parviflora*.

Others: ***Suckers:*** Most species produce suckers which damage pavements and underground services and are undesirable near buildings. See Trees K 21. *U. glabra* is the recommended rootstock. ***Variegation:*** Some varieties have variegated leaves, eg silver elm (*U. procera* Variegata).

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Associations, Journals etc.
Dutch Elm Disease Contingency Plan
Elm Leaf Beetle Liaison Committee, Melbourne
Friends of the Elms (Elm Watch)
GrowSearch (database Qld DPI)
Lord Mayor's Save the Elms
National Trust (Vic) Save The Elms Fund

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Elms are deciduous or semi-deciduous, and are grown for their foliage and bark features. Some species, eg Chinese elm (*U. parviflora*), are used for bonsai. Elms are grown in cool to temperate climates and prefer full sun or half sun. Select species with some ***resistance*** to ***DED***. Plant ***material free from diseases and pests***, eg cankers, scales, elm bark beetles, etc. ***Propagated*** by cuttings, suckers and layers, budding and grafting, and by seed; use *U. glabra* as root stock.

Eriostemon

Waxflower (*Eriostemon myoporoides*)
Family Rutaceae (citrus family)

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Stem and leaf spot (*Xanthomonas campestris* pv. undetermined) may cause ***stem*** blackening and ***dieback*** of *Eriostemon* spp. See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots (*Seimatosporium* sp., *Phoma* sp., *Vizella* sp., other species) may affect *Eriostemon* spp. Some of these may also cause stem lesions. See Annuals A 5.

Grey mould (*Botrytis cinerea*) may grow on ***flowers, leaves and cuttings*** in very humid conditions. See Greenhouses N 22.

Root rots:

Phytophthora collar rot (*Phytophthora* spp., *P. cinnamomi*) may cause ***shrubs*** to ***die*** in poorly drained areas. See Trees K 6.
Others: Pythium root rot (*Pythium* sp.).

Rust: (*Puccinia eriostemonis*) has been recorded on *E. myoporoides*. See Annuals A 7.

INSECTS AND ALLIED PESTS

Black citrus aphid (*Toxoptera citricidus*) may infest ***new shoots***. See Citrus F 35.

Citrus butterflies (Papilionidae, Lepidoptera)
Large citrus butterfly (*Princeps aegeus*)
Small citrus butterfly (*Eleppone anactus*)
Caterpillars chew ***leaves***. See Citrus F 36.

Soft scales (Coccidae, Hemiptera)
Black scale (*Saissetia oleae*)
Chinese wax scale (*Ceroplastes sinensis*)
White wax scale (*C. destructor*)
See Citrus F 41, Trees K 16.

Others: Several other sap sucking insects may also damage *Eriostemon* spp. including ***citrus mealybug*** (*Planococcus citri*), ***greenhouse whitefly*** (*Trialeurodes vaporariorum*) and ***green planthopper*** (*Siphanta acuta*). ***Free-living psyllids*** (Psyllidae) of a pale orange colour may infest shoots of *E. myoporoides*.

Non-parasitic

Nutrient deficiencies, toxicities: ***Iron deficiency*** may cause new leaves of *E. myoporoides* to yellow between the veins. See Trees K 20.

Sooty mould: Eriostemon shrubs may be covered with sooty mould growing on the honeydew secreted by various ***sap sucking insects***, eg aphids, mealybugs, soft scales and whiteflies, feeding on them or on trees under which they are growing. See Trees K 19.

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See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Eriostemons are ***hardy*** evergreen shrubs for temperate and warm climates. They are ***relatively pest-free***. Generally ***propagated*** from cuttings, occasionally by seed which is explosive. Seeds ripen in early summer over 1-2 weeks and exhibit both chemical and physical dormancy. ***Plant*** in sun or semi-shade, in well drained slightly acid sandy soil to avoid *Phytophthora* collar rot. Shelter from wind and provide summer irrigation and a cool root run. ***Prune*** after flowering to maintain a bushy plant. ***Harvest*** flower stems by cutting the stem on an angle with a sharp knife or secateurs. Many woody-stemmed shrubs are very thirsty so place in deep water and top up regularly. Change the vase solution every 2 days. Warm water may be beneficial in easing the flow of water up stems (Jones and Moody 1993).

Eucalypt, gum

Eucalyptus spp., *Corymbia* spp.
Family Myrtaceae (eucalypt family, myrtle family)
Floral emblem for Tasmania
Tasmanian blue gum (*E. globulus*)

PESTS AND DISEASES
Parasitic

Diseases of eucalypts have been described in detail (Keane et al, 2000).

VIRUS AND VIRUS-LIKE DISEASES

Mycoplasma-like organisms have been associated with witches' broom, progressive decline and general yellowing of eucalypts in Syria. In India, a virus resembling ***tobacco mosaic*** has been detected, but its significance is unknown (Cooper 1993). ***Eucalyptus little-leaf*** (ELL) phytoplasma causes little leaves and witches' broom in Italy (Marcone et al. 1996.

BACTERIAL DISEASES

Occasional records in Australia include ***crown gall*** (*Agrobacterium* sp.) in WA and ***Xanthomonas campestris pv. eucalypti*** on lemon scented gum.

FUNGAL DISEASES

Cankers: Three fungi are commonly found associated with eucalypt trunk cankers in ***living eucalypts***. They contribute to shoot death and crown decline of eucalypts (Olds 1988). These fungi are common wound invaders and widely distributed in southern Australia. They ***do not kill trees***, but they produce kino veins in the stem, considerably downgrading the value of trees for timber production and for ornamental plantings. As a focal point for the development of heart rot these have received little attention. In native forests their impact is apparently small, especially in extensively managed forests. Limbs and trees dieback, trees may gradually decline.

Botryosphaeria ribis is an opportunist pathogen and can grow as a saprophyte on dead stems and can be aggressive on ***stressed trees***. In WA it may cause ***severe cankers*** on stems and death of plantings of narrow-leafed peppermint (*E. radiata*) and other eucalypts. It is also found on cankers in NSW on dry sclerophyll woodland trees. See Trees K 5.

Cytospora eucalypticola is ***common*** and ***serious,*** and is often isolated from cankers on many eucalypts. Large kino veins develop. See Australian native plants N 1 (Fig. 370).

Endothia gyrosa (= *Endothiella gyrosa*) is an opportunist pathogen able to grow as a saprophyte on dead stems. It is most aggressive on ***stressed trees***. It occurs on jarrah in WA, also scribbly gum, spotted gum, Sydney blue gum, wandoo and other eucalypts.

Others: ***Ramularia spp.*** causes stem cankers on spotted gum (*E. maculata*), red-flowering gum. ***Sporotrichum destructor*** causes stem cankers on red-flowering gum. Many other fungi, eg ***Paeciliomyces variotii*** and ***Phialophora bubakii,*** are pioneer invaders of injured sapwood. ***Cryphonectria cubensis*** is an important pathogen of plantation eucalypts overseas, causing ***severe cankers*** on ***stems*** leading to stem death and coppice failure, it may also infect foliage (Davison and Coates 1991). It is a pioneer invader of injured sapwood; an non-aggressive facultative parasite. *C. cubensis* is found in Australia, eg associated with root cankers on jarrah (*E. marginata*) in WA. ***Nattrassia mangiferae*** (= *Hendersonia toniloidea*) causes cankers and exude gum on *E. camaldulensis* in Portugal, Iraq, India and N. America (Matheron 1994).

Favoured by wounds (boring insects, pruning, thinning and logging operations), drought, stressed trees, eg changes in land use and management, severe insect defoliation. ***Crown dieback*** may result from the inability of trees to resist infection by secondary invaders, eg *B. ribis, E. gyrosa,* and as yet unidentified fungi. The ***association*** of canker fungi with boring insects, in dieback of wandoo in WA, appears to be ***induced*** by insect attack and invasion by canker fungi. Some eucalypt ***provenances*** (places of origin of seed from a natural forest) have ***superior resistance*** to canker fungi such as *C. cubensis* (Eldridge et al. 1993). See Trees K 5.

Chestnut blight (*Endothia parasitica,* Ascomycetes) is not known to occur in Australia, but has devastated American chestnuts in the USA and has been found growing on eucalypts in Japan. Although biological control is being developed for chestnut blight in the USA, quarantine regulations aim to ***prevent introduction*** of chestnut blight to Australia (Com. of Aust. 1990). See Chestnut F 32.

Damping off occurs in nurseries, greenhouses and in eucalypt forest soils. Many fungi (and bacteria) may cause damping off, eg *Phytophthora*, *Pythium*, *Botrytis cinerea* (stem rot), *Colletotrichum coccodes*, *Corticium*, *Cylindrocladium scoparium*, *Fusarium*, *Gliocladium*, *Rhizoctonia*, *Verticillium*.

Ramularia shoot blight (*Ramularia* spp., *R. patereka* = *R piterka*, Imperfect Fungi) affects eucalypts, eg lemon-scented gum, yellow bloodwood, red-flowering gum, spotted gum, smooth-barked apple. ***Young shoots and leaves***, especially along leaf edges and mid-veins, are covered with tiny white pustules about 1-2 mm across (Fig. 236). Leaves look as if splashed with white paint. Affected ***shoots*** are severely distorted. Sunken brown areas up to 20 mm long may develop on ***petioles and stems***. Ramularia blight may ***seriously damage*** or kill nursery stock ***> 3 months of age***, in greenhouses and nurseries. Up to ***50%*** of plants may be lost. ***Overwinters*** on infected host plants, debris. ***Spread*** by spores and movement of infected nursery stock. ***Favoured*** by humid conditions (shade, moisture, poor air circulation), eg gullies, nurseries. Most common in spring and autumn but may be present in nurseries all the year. Improve ventilation. ***Fungicides*** may be applied to ***nursery stock*** during spring and autumn.

See Nurseries N 51, Seedlings N 66.

Fungal leaf spots (many species) are ***common*** on eucalypts (Fig. 237). Although unsightly, they usually do not seriously affect the vigour of mature trees. Some may cause ***serious defoliation*** in some areas and in some seasons and on some species. Some can be serious on ***seedlings*** and on ***nursery stock***, especially in crowded nurseries where the local environment is favourable.

Cylindrocladium quinqueseptatum causes a blight of ***leaves*** and ***shoots*** of eucalypts in the wet tropics, and has caused rapid and severe defoliation of eucalypt in field trials in north Qld.
Mycosphaerella spp. may infect ***juvenile leaves*** of some eucalypts, eg eurabbie, shining gum, Tasmanian blue gum, during humid summer months. Trees become ***unsightly*** but recover to put on new foliage the following season. ***Adult leaves*** are more leathery and not so susceptible. Control is not necessary.
Phaeoseptoria eucalypti may be important in ***seedling survival*** in the field under competition and in years where conditions favour disease.
Others: *Ascochyta* spp., *Aulographina eucalypti* (see Australian native plants N 1, Fig. 371), *Cercospora* spp., *Chaetosphaeria talbotii, Coniothyrium kallangurense, Coma circularis, Cylindrosporium* spp., *Hendersonia eucalypti,* ***tar spots*** (*Phyllochora* spp.), *Piggotia substellata, Plectosphaeria eucalypti, Seimatosporium* spp. (Fig. 237), *Septoria* (Pascoe 1987).

Control measures are only necessary for nursery stock and perhaps for regeneration areas in forests. Trees may only be susceptible at certain ages. It may be possible to replant with different species See Annuals A 5.

Powdery mildew (*Oidium* sp.). attacks some *Eucalyptus* spp., especially ***seedlings*** in greenhouses; seedlings can be successively defoliated and eventually ***killed***. ***Favoured*** by warm, humid conditions. ***Fungicides*** may be applied in nurseries at the first sign of disease, regular applications may be necessary. See Annuals A 6.

Root rots

Armillaria root rot (*Armillaria* spp.): *A. luteobubalina* may kill scattered patches of karri in ***WA***, mountain ash in ***Vic*** and shining gum in ***Tas***. Early symptoms include dieback of primary branches, crown thinning and often epicormic shoot development. In ***young eucalypt trees*** death often occurs suddenly. ***Older trees*** decline slowly. White fungal sheets grow rapidly through the cambial zone (between the bark and wood) of infected ***roots*** eventually reaching the root collar. Continued fungal growth ultimately girdles the tree. *Armillaria* produces a white rot of the sapwood and in eucalypts with thick bark, eg messmate stringybark, it may grow through the bark for up to ***7 m*** above ground level. Eucalypts may respond to infection by weeping kino or gum and the bark at the base of the tree often splits. See Trees K 4.
Phytophthora root rot, dieback (*Phytophthora cinnamomi, P. citrophthora, P. cryptogea*) ***(Pc)*** occurs eucalypt forests, eg in the jarrah forest of ***WA***. There is generally a yellowing or dying back of ***foliage*** and a general unthriftiness, which leads to ***death*** of the plant. Large trees may take ***years to die***. Often if the bark is removed at ground level, stem tissues appear brown due to the fungus attacking the lower portion of the stem or trunk in addition to the roots. On removing the plant from the soil, roots are dead and decayed, the root system is also reduced in size. ***Replacement crops*** have been investigated for the jarrah forest of WA, and it is now known which groups of eucalypts are most susceptible. ***Very susceptible species*** include those belonging to the Subgenus Renantherae, eg jarrah. ***More resistant species*** include those belonging to the subgenus Macrantherae, eg blue gum (*E. globulus*). See Trees K 6.
Others: *Rhizoctonia*., *Ganoderma*, *Polyporus*.

See Trees K 7, Vegetables M 7.

Rust (Uredinales, Basidiomycetes): There was no known rust disease of eucalypt until eucalypts were introduced to Brazil. ***Guava rust*** (*Puccinia psidii*) is not known to occur in Australia but may attack many *Eucalyptus* spp. overseas. *Eucalyptus* spp. vary in susceptibility and the disease may be important in ***nursery stock*** or in ***young plantations*** (Com. of Aust. 1985). See Guava F 67.

Wood rots

Wood rotting fungi are more important in ***older plantings***, plantations with shorter rotations are likely to suffer less damage. Some are more common on some species of eucalypts than others.

Heart rots
Common honeycomb (*Osmosporus gunii*)
Eucalypt punk (*Piptoporus portentosus*)
Ring-barking fuscoporia (*Fuscoporia laevigata*)
Tinder punks (*Phellinus* spp.)
Heart rots (*Tyromyces* spp.)
Woody toadstool (*Amauroderma rude*)
Others, eg *Fomes rimosus, Iononotus, Polystictus*
Stump removers, eg *Fomes* spp., *Polyporus* spp., *Poria medullaris, Trametes* spp. Butt and stem rots many be ***secondary*** and associated with ***insect infestation***, eg borers or termites.

See Trees K 8.

Others: ***Karri brown rot*** is a discolouration associated with infection by a number of fungi, *Stereum hirsutum* and *Hymenochaete* being the most common (Crombie and Bunny 1994). It does not affect timber strength, but is unsightly and a precursor to rots, but is unlikely to develop if timber is dried to < 20% moisture content. ***Pink disease*** (*Corticium salmonicolor*) which is present in Australia, has caused cankers in woody shoots of *E grandis* in India severely affecting plantations (Eldridge et al. 1993). ***'Mal de Rio Doce'*** (a fungal disease) is the most damaging disease of eucalypts in Brazil.

PARASITIC PLANTS

Devil's twine (*Cuscuta* spp.), ***mistletoe*** (Loranthaceae), ***native cherry*** (*Exocarpos* spp.) may infest eucalypts (Fig. 238, 239). See Trees K 9.

NEMATODE DISEASES

More than 100 species of nematodes have been recorded in association with > 100 species of eucalypts. Nematode diseases do not appear to be important in Australia, but are likely to become more so with the ***more intensive cultivation*** of ***eucalypts*** and in ***nurseries***. Species include ***burrowing nematodes*** (*Radopholus*), ***dagger nematodes*** (*Xiphinema*), ***lesion nematodes*** (*Pratylenchus*), ***ring nematodes*** (*Criconema*), ***sheath nematodes*** (*Hemicycliophora*), ***spiral nematodes*** (*Helicotylenchus*, *Rotylenchus)*, also *Fergusobia, Scutellonema, Carphodorus bilineatus, Cryphodera.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Most eucalypts recover quickly after insect attack by rapidly producing new buds and leaves. This regrowth is tender, high in nitrogen and very attractive to insects. This leads to ***cycles of defoliation and regrowth****, with trees being depleted of starch reserves and eventually dying. This cycle can only be broken if insect numbers are reduced by environmental factors, eg drought, increase in numbers of natural enemies. In the natural environment the rounded crowns of woodland eucalypts are due to the repeated 'tipping out' of the terminal shoots by insects. Trees seldom if ever die following a single attack of insect damage.* ***Repeated defoliation*** *over a number of seasons or years is more likely to kill trees.*

Borers

Larvae of many borers invade eucalypts.

Ambrosia beetles (Coleoptera) degrade wood of many eucalypts, eg ***eucalypt keyhole borer*** (*Xyleborus truncatus*, Curculionidae) and ***eucalypt pinworm*** (*Atractocerus kreuslerae,* Lymexylidae). See Trees K 10.

Ghost moths (Hepialidae): The best known is the large ***bentwing ghost moth*** (*Zelotypia stacyi*) with a wingspan of 250 mm. The life cycle lasts several years, during which ***caterpillars*** tunnel extensively through eucalypt trunks. Eucalypts rarely die as damage is mainly confined to the sapwood and heartwood region of the trunk and does not affect the inner bark. Caterpillars of ***Abiantiades latipennis*** are up to ***90 mm*** long. They live in ***vertical tunnels*** in the soil and feed externally on the ***roots*** of eucalypts. Caterpillars remove localised areas of bark from roots and feed on the callus produced around the edges of the wound. They may feed for 2 or more years causing pronounced ***root deformities***. Most caterpillars feed within 500 mm of the soil surface. Lesions caused by the caterpillars may be entry sites for *Armillaria*. Caterpillars ***pupate*** in the ***vertical tunnels*** at the soil surface. Moths emerge in large numbers after a fall of rain. ***Bardee, bardee grub, bardi grub*** (*Abiantiades marcidus*) was a source of food for aborigines (see also below). See Trees K 12.

Oecophorid borers (Oecophoridae): Caterpillars of ***Uzucha humeralis*** feed on the bark of smooth-barked eucalypts and angophoras. They have ***no tunnel*** but construct a conspicuous gallery of silk and bark particles to protect themselves. Larvae of some species chew little bark, but feed on ***leaves*** which they drag to tunnel entrances. As caterpillars do not tunnel far into the wood, they are ***easily controlled***. See Fruit F 10, Trees K 12.

Longicorn beetles (Cerambycidae, Coleoptera) commonly attack ***recently felled eucalypt trees (dead/dying)*** of all ages (Wang 1995). A few species attack ***living trees*** and some may kill trees in WA. Longicorns are common but not serious pests of planted eucalypts in Tas. ***Hesthgesis cingulata*** attacks trees which are stressed, eg in waterlogged areas, and bores into the lower stem often causing stem breakage in trees at soil level. ***Common eucalypt longicorn*** (*Phoracantha semipunctata*) attacks freshly felled logs and dying trees of most eucalypt species in spring and summer. It may also attack eucalypts under stress and by ***ringbarking*** them cause their death above ground; many regrow from surviving rootstock. ***Tuart longicorn*** (*P. impavida*) attacks young tuart trees < 5 years old. Larvae bore ***under bark*** and eventually ***ringbark*** non-vigorous trees. They also attack the branches of older trees, causing death or the common stag-headed appearance of many older tuarts. ***Yellow longicorn*** (*P. recurva*) attacks spotted gum, Sydney blue gum, river red gum and smooth-barked apple. ***Beetles*** are 30-35 mm long. ***Larvae*** are 50-60 mm long and are active 12 months of year. Larvae work in the ***phloem-cambium*** and enter the sapwood to pupate. Exit holes are oval 7-9 mm. Also ***Coptocercus rubriceps*** (Fig. 240), ***bullseye borer*** (*Tryphocaria acanthocera*), ***eucalypt ringbarking longicorn*** (*T. mastersi*). Also ***Bardee, bardee grub, bardi grub*** (*Bardistus cibarius*) was a source of food for aborigines (see also above). See Trees K 11.

Weevils (Curculionidae, Coleoptera): ***Elephant weevil*** (*Orthorhinus cylindrirostris*) chews ***buds and green bark***, larvae tunnel in ***trunks***. See Eucalypt K 64. Trees K 12.

Wood moths (Cossidae, Lepidoptera), eg ***Australian goat moth*** (*Culama calignosa*) caterpillars attack eucalypt especially sugar gum and smooth-barked apple. ***Moths*** are 50 mm across outspread wings. ***Caterpillars*** are creamy with a dark head and up to ***35 mm*** long, They feed, often in groups of 4-10, beneath the bark in the ***phloem-cambium*** for up to 12 months and enter the sapwood to pupate. See Trees K 12, Wattle K 133.

Others: ***Ironbark beetle***, ironbark borer (*Zopherosis georgei,* Zopheridae, Coleoptera), ***jewel beetles*** (Buprestidae, Coleoptera).

See Trees K 10.

Bugs (Hemiptera):

Squash bugs (Coreidae) feed on new shoots and inject ***toxic saliva*** during feeding during spring and summer. New shoots wilt and die. When attack is severe, apical dominance loss can occur (Elliott and deLittle 1984). They emit a strong odour when disturbed. ***Eucalyptus tip bug*** (*Amorbus alternatus*) is variable in size, drab brown and about ***22 mm*** long (Fig. 241). Nymphs are 10-20 mm long and brightly coloured. Also *A. obscuricornis,* ***crusader bug*** (*Mictis profana*) and ***gelonus bugs*** (*Gelonus* spp.). ***Control*** is seldom required as birds prey on them. On individual young trees collecting by hand and destroying them is effective. See Trees K 12, Vegetables M 12.

Caterpillars (Lepidoptera)

Caterpillars of > 180 species of moths, but few butterflies, feed on eucalypts. Caterpillars of most moths feed on ***foliage*** but some are ***borers***, eg wood moths and others are ***leafminers***, eg jarrah leafminer.

Autumn gum moth (*Mnesampela privata,* Geometridae) caterpillars are ***serious pests*** of many eucalypts, especially young trees ***< 3 m*** high with blue-grey foliage, eg juvenile leaves of Tasmanian blue gum. ***Moths*** are dark brown, about 20 mm long with a wingspan of about 40 mm and are rarely seen. ***Caterpillars*** are greenish-brown, up to ***35 mm*** long with 2 conspicuous yellow spots about 1/3rd of the way along their back (Fig. 242). During the day they hide in rolled webbed leaves. Young caterpillars skeletonise leaves, older ones may chew whole leaves. Severely damaged trees look scorched, growth is severely affected for about 1 year. If extensive defoliation occurs over consecutive years trees may die. Caterpillars pupate (6-9 months) in the ground with 1-2 generations per year depending on locality. ***Favoured*** by humid weather. Caterpillars usually feed during February-April, but may be found at any time of the year depending on locality. Rain and wind wash off larvae and disperse them up to 12 m to other trees. ***Monitor young trees*** regularly in autumn. ***Wasps and flies*** parasitise eggs and caterpillars.

Bag-shelter moths (Eupterotidae): ***Lewin's bag-shelter moth*** (*Panacela lewinae*) caterpillars infest eucalypts and brush box in eastern Australia. Moths are 40-45 mm across their outspread wings. Caterpillars are 40 mm long. Hairs cause a ***rash***.

Butterflies: Caterpillars of only a few species of blues, copper and hairstreak butterflies (Lycaenidae) feed on eucalypts, eg ***damel's blue butterfly*** (*Jalmenus daemeli*) on silver-leaved ironbark, ***dull oakblue*** (*Arhopala* centaurus) on pink bloodwood, ***fiery jewel*** (*Hypochrysops ignitus ignitus*) and *Theclinesthes miskini* on long-fruited bloodwood.

Case moths (Psychidae): ***Ribbed case moth*** (*Hylarctica nigrescens*) is a ***serious defoliator*** of eucalypt, especially sugar gum, blue gum and blackbutt, also pine. ***Others*** include ***faggot case moth*** (*Clania ignobilis*), ***leaf case moth*** (*Hyalarcta huebneri*), ***Saunders's case moth*** (*Oiketicus elongatus*). Damage is seldom severe enough to warrant control measures. See Trees K 13.

Cup moths, Chinese junks (*Doratifera* spp., Limacodidae) damage eucalypt, also angophora, brush box, stone fruit, apple, guava. ***Moths*** are brown, stout with a wingspan of 25-45 mm. ***Caterpillars*** are bright, up to ***25-30 mm*** long, slug-like, with 4 raised fleshy tubercles (Fig. 243). If disturbed, spines emerge from the tubercles and cause skin irritations if touched. Small groups of young caterpillars skeletonise ***leaf uppersurfaces***. Older caterpillars feed singly, eat whole parts of leaves causing defoliation, and may migrate to other trees for food. Ground beneath heavily infested trees is often covered with their droppings. There may be 2 generations per year. Female moths lay eggs on host plants. ***Overwinter*** as non-feeding caterpillars in cocoons (up to 2 years) on twigs, under bark, or on debris nearby. Moths emerge from hard, cup-like cocoons (6-15 mm long), empty cocoons remain on the tree. A few caterpillars on a small tree may be ***removed by hand*** and destroyed (wear gloves). ***Natural controls*** include virus diseases, overcrowding, food shortages, wet weather. Wasps and flies ***parasitise*** caterpillars. Birds and other ***predators*** may be repelled by the stinging spines. Control on eucalypts is not usually necessary. See Macadamia F 77.

Emperor gum moth (*Opodiphthera eucalypti,* Saturniidae) caterpillars feed on foliage of eucalypt especially *E. leucoxylon rosea*, spearwood mallee, *Tristania conferta* and a few other species during summer. ***Moths*** have a wingspan of 120-140 mm. ***Caterpillars*** are green with fleshy protuberances bearing coloured spines (blues and reds) and are up to ***100 mm*** long. Rarely seen in numbers large enough to defoliate trees. Large birds are effective predators. Control is seldom needed.

Gumleaf skeletoniser (*Uraba lugens,* Nolidae) caterpillars cause ***economic loss*** of many eucalypts, eg river red gum, Sydney blue gum, river peppermint, jarrah, wandoo, lemon-scented gum, red-flowering gum, blue gums, messmate stringybark, *Angophora,* brush box. They can defoliate individual ornamental trees and large areas of mature and actively growing eucalypts especially during winter and spring in WA. There may be mountain and coastal ***strains***. ***Moths*** are grey and black with a wingspan of 25-30 mm and about 10 mm long. They are weak fliers and lay eggs during summer in clusters on leaves. ***Caterpillars*** are cream with yellow, brown or pink dorsal markings, up to about ***25 mm*** long and covered with hairs and spines. Empty head capsules, after skin shedding during growth, remain piled above their heads. Caterpillars and cocoons may ***irritate skin***. Young caterpillars are gregarious and skeletonise ***leaf uppersurfaces***, but later disperse and feed more or less singly, eating whole leaves. Usually 1 generation each year. Female moths lays their eggs in rows on leaves. They pupate on or under the bark, on twigs or in leaf litter. Flies and wasps ***parasitise*** cocoons.

Whitestemmed gum moth (*Chelepteryx collesi*, Anthelidae) caterpillars feed on scribbly gum, brush box, native plants. ***Moths*** are large, with a wing span of 125-150 mm and night-flying. ***Caterpillars*** are up to ***125 mm*** long and covered with hairs which may cause ***serious skin irritation*** (do not handle). ***Cocoons*** have hairs from the caterpillar bodies and also cause ***skin irritation***. Caterpillars feed on ***foliage*** at night, damage is seldom serious. One generation each year. Female moths lay eggs on eucalypt bark during winter, caterpillars feed on foliage in spring and pupate in cocoons usually on the stems of infested plants.

Others: ***Anthelid caterpillar*** (*Anthela varia*), ***mistletoe browntail moth*** (*Euproctis edwardsii*), ***scribbly gum moth*** (*Ogmograptis scribula*), ***hawk moth*** (*Metamimas australasiae*), ***web moths*** (Pyralidae).

See Annuals A 8, Trees K 13.

Froghoppers and spittle bugs,
leafhoppers, planthoppers, treehoppers

Froghoppers and spittle bugs: ***Common froghopper*** (*Chaetophyes compacta,* Machaerotidae), ***spine-tailed froghopper*** (*Machaerota finitima,* Machaerotidae). A ***spittle bug*** (*Anyllis leiala,* Aphrophoridae) is common on eucalypts in eastern Australia. See Trees K 14.

Leafhoppers, planthoppers, treehoppers: Leafhoppers (Cicadellidae), ***green planthopper*** (*Siphanta acuta,* Flatidae), ***green treehopper*** (*Sextius virescens,* Membracidae) and ***spiny treehopper*** (*Sertorius australis,* Membracidae) may infest eucalypts. ***Gumtree hoppers*** (*Eurymela* spp., Eurymelidae) infest eucalypt, casuarina and wattle. ***Adults*** are about ***10 mm*** long, brightly coloured or predominantly dark blue or black with whitish yellow or orange markings (Fig. 244). Wings at rest are held roof-like over the abdomen. ***Nymphs*** are small, wingless versions of the adults. Both adults and nymphs are ***gregarious*** and suck sap from ***young twigs***, causing ***malformation*** and producing large quantities of ***honeydew***, so ants and sooty mould are associated with them. Adults jump when disturbed and the nymphs tend to rotate around the stem and are difficult to catch. Adults occur all year on trees and there are a number of generations each year. Eggs are laid in ***slits in the bark of twigs*** and may ***ringbark*** them. Gumtree hoppers can weaken and kill recently planted ***seedlings*** (1-3 year old). ***Favoured*** by stress. Populations are normally ***controlled*** by birds and other predatory insects. See Australian native plants N 6, Trees K 15.

Control is often not necessary. If ***insecticides*** are required in ***nurseries*** and young plantings, the addition of a wetting agent may assist control.

Gall insects:
Some insects may cause galls on roots, stems, branches, leaves and flower buds. Shapes are ***characteristic*** of the attacking insect, and are thought to be produced following a growth reaction of the host to the attack.

Coccid galls (Eriococcidae, Hemiptera): ***Apiomorpha spp.*** cause spectacular galls on eucalypts (Fig. 245). ***Sphaerococcopsis spp.*** causes blister-like galls. See Eucalypt K 63.

Flies (Diptera): ***Maggots*** of *Fergusonia*, in association with nematodes (*Fergusobia*), cause galls on eucalypt ***blossoms*** resulting in loss of seed production. *Fergusonia* and other flies, eg gall midges (Cecidomyiidae), cause galls on ***leaves***.

Mites (Acarina): ***Blister mites*** (Eriophyidae) live in and feed from small blister galls on the surface of ***leaves*** of some eucalypts (Fig. 251) and *Angophora*.

Psyllid galls (Psyllidae): *Schedotrioza* spp. cause round, ***woody or fleshy galls***, while some species, eg *Glycaspis*, cause ***bladder-like*** galls on eucalypt leaves about 8 mm across.

Wasps (Hymenoptera): ***Bluegum eulophid*** (*Ophelimus eucalypti,* Eulophidae) is often reared from eucalypt galls and ***seed chalcids*** (*Megastigmus,* Torymidae) from stem, leaf and flower galls of eucalypts and other plants. ***Pimple galls*** develop on red flowering gum.

Weevils (Curculionidae): ***Gregarious gall weevils*** (*Strongylorhinus ochraceus, S. clarki*) cause galls on young eucalypt ***stems*** (Fig. 246). Larvae, after hatching from the eggs laid in the stem tissue, live in small chambers in a cluster or swelling about 100 mm long. This increases in size as larvae develop and after pupation adult beetles emerge through 5 mm diameter holes on its surface. This may weaken the tree enough for it to break in strong wind, but mostly trees produce fresh wood over damaged areas.

See Australian native plants N 6, Trees K 14.

Leafeating beetles (Coleoptera)

Leaf beetles (Chrysomelidae): ***Eucalyptus leaf beetles***, eucalyptus tortoise beetles (*Chrysophtharta* spp., *Paropsis* spp.) affect eucalypt. ***Beetles*** are ***5-15 mm*** long, variously coloured, generally bright and shiny about the size of ladybird beetles and tend to feed individually and chew leaf edges (Fig. 247). ***Larvae*** are cream or yellow, slug-like, about ***10-20 mm*** long, cluster on and skeletonise leaves. Both beetles and larvae cause ***partial defoliation*** of fast growing eucalypts. Female beetles lay eggs in ***distinctive patterns*** on stems and foliage. Larvae hatch from the eggs, feed on leaves and drop to the ground to pupate. A number of generations each year. Adults are present on trees during frost-free periods of the year, reaching population peaks in late spring and early autumn. ***Tasmanian eucalyptus leaf beetle*** (*C. bimaculata*) is a ***major pest*** of eucalypts, eg mountain ash, messmate stringybark, alpine ash and shining gum, especially in Tasmania. ***Beetles*** are ***9 mm*** long, dome-shaped, variable in colour, green (summer) to dark red brown (winter) with 2 black markings. ***Larvae*** are dark green to black and feed in groups. Beetles and larvae feed on new growth. Young trees are ***very susceptible***, repeated attacks over seasons affects form, reduces tree growth and may even kill them. Trees with ***new red leaves***, eg *E. regnans*, suffer more defoliation than species with ***new greener leaves***. ***Overwinters*** as adults under bark or in cracks in dead wood. In spring adults emerge and on warm sunny days, cluster on young foliage and feed. When cool and windy they seek shelter. Eggs are laid on foliage in late spring and late summer. Larvae fall to ground to pupate in leaf litter, adults emerge. By April all larvae activity has ceased and adults have found overwintering sites. Select eucalypts with some ***resistance***. Also ***swarming leaf beetles*** (*Rhyparida* spp.). See Trees K 15.

Scarab beetles (Scarabaeidae, Coleoptera) attack foliage of young eucalypts and other plants on grassy sites. They are ***major defoliators of eucalypts*** during late spring and early summer. ***Beetles*** vary in colour, are ***5-35 mm*** long, stout-bodied, forelegs modified for digging. Depending on the species, they have a 1-2 year life cycle of which only 1-10 weeks is spent in the adult stage. ***Larvae*** are ***10-70 mm*** long, cream, plump, soft-bodied, C-shaped with hard, true legs only, brown heads and strong jaws. They live in the soil and feeds on the ***roots*** of ***grasses*** and other plants. ***Favoured*** by planting in old pasture land. There is an increase in nitrogen, phosphorus and potassium in leaves of eucalypts due to the ***excreta*** of grazing stock under trees. Insects feeding on them grew faster and develop larger pupae (Beckman and Davidson 1990). Beetles have ***few natural enemies*** apart from birds and arboreal animals which are almost non-existent in improved pasture because of over-clearing and loss of suitable habitat. ***Christmas beetles*** (*Anoplognathus* spp.) are golden, ***10-30 mm*** long and ***serious pests*** of eucalypts (Fig. 248). Adults of certain species of beetle prefer particular species of eucalypts. They produce at first a ***saw-tooth pattern*** of damage, later the whole leaf may be eaten. Individual trees by roadsides, or on large areas of grass, are damaged more than trees growing together in big groups. On small trees, beetles may be hand picked, only very occasionally in severe infestations is it considered necessary to spray small trees. ***Green scarab beetle*** (*Diphucephala colaspidoides*) is large and chews foliage of wattle and eucalypts. ***Spring beetles*** (*Liparetus* spp.) may cause ***serious*** defoliation of young eucalypts in the wheat belt of WA. Also ***small brownish cockchafers*** (*Sericesthis* spp.), ***brown eucalypt beetle*** (*Lepidiota rothei*). See Trees K 16, Turfgrasses L 11.

Leafminers

Beetle (Coleoptera): Larvae of a ***small beetle*** (*Syrbis alycone*) mine in leaves of messmate stringybark and silvertop ash (*E. sieberi*).

Leafblister sawflies (*Phylacteophaga eucalypti* and *P. froggatti,* Pergidae, Hymenoptera) infest eucalypt, brush box. Often damage is just cosmetic. ***Adults*** are 5 mm long. ***Larvae*** are ***5-6 mm*** long and mine inside ***leaves*** causing brown and papery blistering (Fig. 249), leaves fall, trees look scorched. Trees ***< 5 m*** in height may be defoliated. Infestations which persist year after year may cause dieback. ***Complete metamorphosis*** (egg, larva, pupa, adult) with several generations each year. The female sawfly lays eggs in the leaf surface using her sawfly ovipositor. The larvae pupate in raised blister areas. ***Favoured*** by exposed trees, street trees, leaves on trees ***< 4 m*** high. ***Control*** light infestations by pruning out infested portions from small trees and destroying them. Not much is known about their natural enemies. ***Susceptible species*** include white ironbark, snow gum, *E. nicholii* and *E. tereticornis.* Many trees tolerate light infestation and as the trees outgrow this problem, avoid spraying, unless infestation is severe. If hard oval lumps ***(pupae)*** can be seen in most blisters then it is too late to spray that season. A systemic insecticide may be applied to trees ***< 3 m*** high when mines are first noticed in spring. Wetting agents are usually necessary for effective control when spraying eucalypts.

Moths (Lepidoptera): ***Blackbutt leafminer*** (*Acrocercops laciniella,* Gracillariidae) caterpillars mine in blackbutt. Moths have a wingspan of about 15 mm. Caterpillars are about 10 mm long. ***Jarrah leafminer*** (*Perthida glyphopa,* Incurvariidae) is a ***serious pest*** of jarrah in WA; several other eucalypts may suffer minor damage. ***Moths*** are tiny, about 6 mm long. Creamy ***caterpillars*** up to 4 mm long, mine in ***new leaves*** during winter, forming large reddish-grey blotch mines. Trees look scorched. In spring caterpillars cut and make a case 5 mm long from leaf upper and undersurfaces, with silk. This drops to the ground and the caterpillar buries it ***20-30 mm*** deep for pupation. Moths emerge in autumn and lays eggs on new growth. ***Favoured*** by flushes of new leaf growth. ***Wasps*** parasitise caterpillars but do not provide economic control. Insecticides are difficult to apply and relatively ineffective. ***Resistant species*** are being researched.

Spread by adults flying and by movement of infested plants. Only apply ***insecticides*** to nursery stock or young trees. See Azalea K 28, Trees K 15.

Lerp insects, psyllids

Scientific name: Psyllidae, Hemiptera:
Bluegum psyllid (*Ctenarytaina eucalypti*)
Brown basket lerp, brown lace lerp (*Cardiaspina fiscella*)
Eucalypt shoot psyllid (*Blastopsylla occidentalis*)
Fingered lerp (*Cardiaspina maniformis*)
Horn lerps (*Creiis* spp.)
Ironbark lace lerp (*Cardiaspina vittaformis*)
Pinkgum lerp (*Cardiaspina densitexta*)
Redgum basket lerp (*Cardiaspina retator)*
Redgum sugar lerp (WA, NT, Qld) (*Glycaspis blakei*)
Spottedgum psyllid (*Eucalyptolyma maideni*)
White lace lerp (*Cardiaspina albitextura*)
Yellowbox lerp (*Lasiopsylla rotundipennis*)

Host range: Native trees, especially ***eucalypts***. One species can usually only attack a ***few species*** of eucalypts. ***Bluegum psyllid*** (*Ctenarytaina eucalypti*) infests blue gum (*E. globulus*), shining gum and a number of other species with blue-grey foliage.

Description and damage: ***Adult lerps and psyllids*** are small sap sucking insects with 2 pairs of wings held roof-like over the head, they are not strong fliers. ***Nymphs*** of ***lerp insects*** form a cover, or a lerp with shapes and colour ***characteristic*** of that species, about 1-5 mm across, beneath which they shelter and feed (Fig. 250). Unlike scales they remain fully mobile through all stages. ***Adults*** are winged. Because nymphs are so small, the first sign of attack is the presence of lerp coverings on ***leaves***. If the attack is severe and the lerp species produces whitish lerps, the masses of lerps give trees a ***silvery appearance***. Discarded lerp coverings fall from the tree. Lerps of some species were used by aborigines for food. ***Purplish patches*** develop on ***leaves*** due to the sucking of the nymphs and adults and the toxic saliva of some lerp insects. Leaves then brown and trees look as if scorched by fire. If there has been heavy attack, infested leaves may ***fall*** prematurely. Trees usually recover from one infestation, but if infestations are sustained during consecutive seasons, trees may die. Lerp insects produce ***honeydew*** which attracts ants and on which ***sooty mould*** grows, making trees and evergreen plants underneath them look black. ***Psyllids*** are free-living, they do not form a lerp covering for their nymphs. They move freely over the surface of foliage, producing malformation and discolouration of leaves and terminal shoots where they feed. Adults are up to ***10 mm*** long.

Pest cycle: Gradual metamorphosis (egg, nymph, adult) with several generations each year. Eggs are laid on leaf surfaces.

Overwintering: The main ***lerp stage*** appears to be from autumn through to spring. Development is slow in winter. Adults appear in summer. Heavy infestation does not usually occur until autumn, when the summer leaf growth has replaced the foliage defoliated by the previous infestation.

Spread: Adults fly to adjacent plantings (but they are not strong fliers). In SA, the bluegum psyllid is common on ***seedlings*** in commercial nurseries.

Conditions favouring: Plague numbers do not occur every year.

Control is ***difficult***. Small trees continually attacked may be replaced with other species.

Biological control: ***Birds*** and some ***insects*** prey on lerps so treatment may not be necessary. Holes in lerp coverings indicate ***parasitism***.

Resistant varieties*:** Different species of lerp insects favour different species of eucalypt. ***Susceptible eucalypt, eg swamp mahogany, yellow box, red gum. ***Slightly susceptible***, eg red box, white ironbark, white brittle gum.

Pesticides: Systemic foliage ***insecticides*** may be applied to ***small trees*** at the first sign of infestation (the protective lerp covering makes contact sprays ineffective). ***Wetting agents*** improve effectiveness. One application per season should give adequate control as adult insects do not fly far.

Mites (Acarina)

Bunch mites (Eriophyidae) may feed on ***new shoots*** causing ***witches' broom***. New leaves are distorted, stunted and severely deformed.

Blister mites (Eriophyidae) shelter in small blisters on ***leaves*** of eucalypt and angophora, they crawl in and out of the blisters through tiny holes to feed on leaves (Fig. 251). Blistered areas may discolour and die.

Others: Felty gall mite (Eriophyidae) cause deep pink felty patches on ***leaves***. ***Redlegged earth mite*** (*Halotydeus destructor*) may whiten ***leaves*** of eucalypt seedlings by their sap sucking.

See Grapevine F 62.

Scales (Hemiptera)

Eriococcid scales (Eriococcidae): ***Gumtree scale*** (*Eriococcus coriaceus*) is a ***common*** and ***serious pest*** of eucalypts. ***Females*** are 2-3 mm long, grey, yellowish or red and egg-shaped (Fig. 252). Males are 1-1.5 mm long and usually found above females on ***stems***. ***Ants and flies*** are attracted to secreted honeydew and black sooty mould grows on it. Gradual metamorphosis (egg, nymph and adult) with several generations each year. Young scale emerge as crawlers from the top of the old scale and move along the ***branches*** in spring and early summer. ***Cultivated eucalypts*** seem to be ***most susceptible***, mainly in spring and autumn. ***Control*** is difficult. Young trees severely attacked over many years may be removed. ***Natural controls*** include ***predators***, eg moth caterpillars (*Stathmopoda melanchora*, *Creobota coccophthora*, *Catoblemma dubia*, *C. mesotaenia*, *Eublemma* spp.); caterpillars of a moth (*Batrachedra arenosella*) feed on scale insects of eucalypts and macadamia and *Populus deltoides* grown in plantations; predatory ladybird beetles and their larvae (*Rhyzobius* spp., *R. ventralis, Harmonia conformis, Coccinella repanda*); and ***parasites***, eg wasps. Eucalypts which may be ***severely affected,*** include spinning top gum, silverleafed gum, scribbly gum, wandoo, white peppermint; those ***variably affected*** include white spotted gum, Argyle apple, ribbon gum, blue gum, red gum; those ***relatively free from attack*** include boxes and ironbarks. ***E. serratibolus*** and ***eucalypt leafgall scale*** (*Opisthoscelis subrotunda*) also infest eucalypts. ***Coccid galls*** (*Apiomorpha* spp.) form distinctive galls; female galls occur on ***stems or leaves***, male galls are usually smaller and occur on ***stems, leaves and fruits*** or as outgrowths of the maternal gall (Fig. 245). See Citrus F 41.

Armoured scales (Diaspididae): Adult males are slipper-shaped, smaller than females and usually clustered together, either on ***leaves*** near the females or on the same ***branchlets***. Males are delicate 2-winged insects. Scales usually cluster on ***twigs, leaf petioles*** or about ***leaf veins***. See Citrus F 39.

See Citrus F 39, F 41.

Seed insects may attack eucalypt seed ***before*** it is shed from the capsule (gum nut) or ***after*** it falls to the forest floor. Two species of tiny ***beetles*** (*Dryophilodes* spp.), and a small ***wasp*** (*Megastigmus* sp.) lay their eggs in eucalypt ***flowers***. After hatching, the tiny larvae tunnel down into developing seeds and eat the contents. Adults usually emerge through the sides or top of the capsule before it opens to shed seed. Eucalypt seed on the ground may be damaged by the ***strawberry bug*** (*Euander lacertosus*) or harvested by several species of ***ants***. See Seeds N 74.

Steelblue sawflies, spitfires

These are the ***largest*** and ***most common*** of the eucalyptus-feeding sawfly larvae. They are found from Tasmania to north Qld.

Scientific name: Pergidae, Hymenoptera:
Eucalypt-defoliating sawfly (*Pergagrapta bella*)
Ironbark sawfly (*Lophyrotoma analis*)
Large green sawfly (*P. affinis insularis*)
Spitfire grubs (*Perga* spp.)
Steelblue sawfly (*P. affinis affinis, P. dorsalis*)

Host range: Steelblue sawflies may be ***serious pests*** of various species of eucalypt including Blakely's red gum, river red gum, South Australian blue gum (*E. leucoxylon*), and yellow box and red ironbark, manna gum, snow gum.

Description and damage: ***Female sawflies*** have a saw-like egg-laying structure to cut plant tissues and insert their eggs. They are about 20 mm long, steel blue with yellow marks on head and thorax, yellow antennae and legs. Wings are yellow with well marked veins. ***Males*** are rare, smaller and not needed for reproduction. Adults do not feed. ***Larvae*** (spitfires) are up to ***60-75 mm*** long, black and covered with short white hairs (Fig. 253). They have ***no prolegs*** on the abdomen. If disturbed, they raise their heads, bend back their bodies, and eject a thick yellow ***concentrated eucalyptus material*** (which can irritate the eyes), at the same time raising the tips of their abdomens and ***tapping*** up and down. When young they are yellowish with black heads and cluster around branches during the day in a tight mass. At night they wander singly over ***foliage*** to feed and can seriously defoliate ***young trees***. Effects on older trees are not usually long lasting. Clusters migrate to the ground to look for a new food source, larvae maintain physical contact with each other by ***drumming*** their tails (abdomens) on a hard surface. Larvae of ***cattlepoisoning sawfly*** (*Lophyrotoma interrupta*) which feed on eucalypts and *Angophora*, if eaten, may poison cattle.

Pest cycle: Complete metamorphosis (egg, larva (spitfire), pupa, adult) with 1 generation each year in temperate climates. Adult females die after laying eggs into ***slits cut in leaf uppersurfaces*** close to the ground. As larvae develop they move upwards and outwards feeding on terminal shoots. When fully fed, they descend from the tree in a slow moving mass and wander (up to 250 in one formation) about on the ground for several days, before ***selecting soft ground*** around the trunk base to pupate. They burrow 50-100 mm into the soil and spin brown cylindrical cocoons (about 25 mm long and 12 mm across) in rows against each other, usually with their heads all facing one way. See Soil N 84 (Fig. 451)

Overwintering: Really ***oversummering***. As larvae in cocoons in soil to avoid hot dry summers. Some individuals remain in cocoon for years.

Spread: As adults flying and as larvae crawling.

Conditions favouring: Late summer to early autumn. ***Newly planted eucalypts***.

Control:

Sanitation: If only a few trees are affected and clumps of spitfires are within reach, prune off, remove with a stick, or a jet of water, and destroy.

Biological control: Natural controls include ***heat***, and ***bird damage*** to egg pods. Large cockatoos eat larvae. ***Parasitic wasps and flies*** attack the eggs and larvae. Eggs are either laid directly in the sawfly larvae or on leaves, being eaten by the larvae during feeding. ***Fungal diseases*** destroy larvae in cocoons in unseasonably wet conditions.

Resistant varieties*:** Eucalypts vary in ***susceptibility.

Pesticides*:** In the home garden, if larvae are within reach, they may be sprayed lightly with a household insecticide. Large areas of young trees ***< 3 m infested with many clumps of young spitfires may be sprayed with an insecticide; the addition of a wetting agent such as white oil, improves effectiveness. Apply when larvae are ***< 25 mm*** long, well before they aggregate on stems and become readily visible. ***Monitor*** populations.

Stick insects

Stick insects, leaf insects (Phasmatodea) are difficult to see and resemble a dead twig (Fig. 254). They grow up to ***200 mm***, move slowly. They are voracious ***leaf feeders***. Rarely a pest in gardens, but may be ***very destructive in forests*** when they occur in plague proportions, causing severe and widespread defoliation of alpine ash forest in NSW. ***Repeated infestations*** may cause heavy mortality of trees over appreciable areas and marked reduction in growth. Severe plagues only occur ***sporadically***, eg after a cold wet summer; susceptible species of eucalypts are stripped and often thousands of hectares look as if they have been badly burnt by fire. Trees may be thickly draped with stick insects that glide or fall clumsily to a fresh source of leaves.

Ringbarker phasmatid (*Podacanthus wilkinsoni*) ravages large areas of eucalypt, brush box, etc.

Spiny leaf insect (*Extatosoma tiaratum*) is a solitary, slow moving insect, which chews lumps out of ***leaves*** of eucalypt, wattle and other plants. Adults are large, bright-green or brown and up to ***120 mm*** long. The edges of the abdomen and legs have flattened, leaf-like plates and the whole surface is covered with short, sharp spines. The head is prominent and conical, and it often curls its abdomen when at rest. There is ***an incomplete metamorphosis*** (egg, nymph, adult). Thick shelled eggs fall to the ground and lie loosely on top of soil and litter. On hatching, nymphs climb any upright object and feed on leaves. ***Lizards*** and ***insects*** eat eggs, some ants store them in their colonies. ***Wasps*** parasitise eggs. ***Birds*** prey on adults and nymphs. Control is rarely necessary.

Spurlegged phasmatid (*Didymuria violescens*) damage eucalypts, brushbox, etc in forests.

Tessellated phasmatid (*Ctenomorphodes tessulatus*) has been associated with ***eucalypt dieback***. It also feeds on *Allocasuarina littoralis, Lophostemon* spp. *Syncarpia glomifera.*

Termites

Termites (Isoptera): *Coptotermes aciniformis, C. frenchii* and *Porotermes adamsoni* are the major ***wood-destroying*** species. See Trees K 17.

Thrips (Thysanoptera)

Australothrips bicolor (Thripidae) lives on eucalypt ***leaves***. See Greenhouses N 24.

Eucalyptus thrips (*Thrips australis = Isoneurothrips australis,* Thripidae) is the dominant thrips in eucalypt ***flowers***. Other species found in eucalypt flowers include ***plague thrips*** (*Thrips imaginis*), and ***Andrewarthaia sp.*** (Aeolothripidae) which is white to dark brown and feeds on ***plant tissue*** and ***insects*** (CSIRO 1990). See Roses J 6.

Weevils (Curculionidae, Coleoptera)

Elephant weevil (*Orthorhinus cylindrirostris*) feeds on ***buds and bark***, larvae tunnel in ***trunks and roots***. See Trees K 12.

Eucalyptus weevil (*Gonipterus scutellatus*) is hard, dull brown and ***7-10 mm*** long. Weevils firmly grasp twigs, so are difficult to remove by hand, and feed on the soft bark of ***new shoots*** which look pitted, and scallops leaf margins. ***Larvae*** are ***10-15 mm*** long, legless, pale yellow-green with a black stripe along each side and black spots on the back. They are slug-like and often trail a thread of faeces. They feed on ***leaves*** leaving only the midrib. There are 1-2 generations each year depending on the locality. ***Overwinters*** as adults under loose bark. ***Favoured*** when trees are planted out of their natural location, or suffer stress. Usually no long term damage. ***Parasitic flies*** (Tachinidae) regulate populations.

Fruit-tree root weevil (*Leptopius squalidus*) is dull-grey, slow moving and grazes on the ***leaf surface***. A rarely noticed native insect. Larvae bore tunnels in the ***roots***, especially very deep roots. See Fruit F 11.

Redlegged weevil (*Catasarcus impressipennis*) is grey-green, ***10-15 mm*** long and chews ***leaf edges*** giving a scalloped appearance (Fig. 255). It and other species can cause ***serious damage*** in summer to tuart in WA and bluegums near Albany (Howe 1990).

Gregarious gall weevil (*Strongylorhinus* spp.) larvae cause galls on ***young eucalypt stems*** (Fig. 246). Trees may break in the wind.

Others

Others: ***Australian plague locust*** (*Chortoicetes terminifera*), ***katydids*** (*Caedicia* spp.) and other Orthoptera, feed on eucalypts. ***Green gum tree katydid*** (*Torbia perficta*) lays eggs about 5 mm long, usually in double rows, on twigs. See Trees K 14, Vegetables M 13.

VERTEBRATE PESTS

Birds may damage eucalypts by feeding on ***larvae of borers*** in ***trunks*** and ***branches***. They may ***tip prune*** eucalypts when feeding on ***seeds***. Birds also eat ***vast quantities of insects***, up to 70% of the production of insects in eucalypt woodland in New England. Birds have the potential to influence insect populations and management of eucalypt dieback caused by foliage-feeding insects (Keast et al. 1985). ***Opossums*** may damage river red gums.

Non-parasitic

Allelopathy: Eucalypts release ***chemicals*** into the environment which interfere with surrounding plants. ***Leachates*** from bark on trees, shed bark and leaf litter, are a major source. Fibrous barked trees are ***more inhibitory*** than smooth barked ones. Effects are likely to be more significant in low rainfall areas.

Environment: There are ***species of eucalypt*** to suit ***every climate***. Select species to suit the local environment. ***Frost lift*** may occur when ice decapitates seedlings or lifts seedlings entirely out of the ground. ***Drought, floods and wind*** may take their toll. The population of eucalypts on rural lands is ***ageing*** due to poor regeneration. Eucalypts are major emitters of ***hydrocarbons*** (isoprenes and terpenes) which contribute to smog. See Trees K 21.

Fire adaptation: Some trees, eg eucalypts, some proteas, waratahs, produce ***lignotubers*** which act like epicormic shoots. They are a swelling at the base of the trunk from which new shoots arise if the trunk is damaged or destroyed, eg by fire.

Fungi and insects

Cryptococcosis: Fungal spores of a ***yeast-like fungus*** (*Cryptococcus neoformans* var. *gattii*) are released into the air when the ***river red gum*** (*E. camaldulensis*) ***flowers*** and may be inhaled by humans. Two types of disease may occur. The ***1st*** occurs in otherwise healthy individuals who may contract a primary lung infection, with flu-like symptoms, that usually does not need treatment. The ***2nd*** occurs when the fungus causes systemic disease, attacking the central nervous system. It is often associated with immuno-suppressed patients suffering from diseases such as AIDS and cancer. A similar association has been established between *C. neoformans* var. *gattii* and forest red gum (*E. tereticornis*). *Cryptococcus* is isolated from ***decaying wood debris*** found accumulated around the base of trees, especially from small hollows or other sheltered habitats (Ellis and Pfeiffer 1990, 1994)

Lichens (symbiotic algae and fungi) may grow on branches and trunks. See Trees K 18.

Mycorrhizae: Inoculation of eucalypt seedlings, eg bluegum (*E. globulus*), with ectomycorrhizal fungi (Mycobeads®) can increase growth rates by up to ***30%*** on recently cleared bush. When nutrients are plentiful trees rely less on mycorrhizae. Mycorrhizae may play an increasingly important role in ***fast rotation plantations*** in the future (rotations may be as short as 5-10 years) and as nutrients in soil diminishes following several harvests.See Trees K 18.

Sooty mould (various species) grows on the honeydew secreted by leafhoppers lerp, scale and other sap sucking insects. See Trees K 18.

Many beneficial insects are associated with eucalypts, eg ***parasites*** and ***predators*** of pests which damage eucalypts. Other insects may shelter on, or under bark, or feed on exudates, eg ***moths***, may feed on sap exuding through bark.

Genetic variation: Susceptibility to ***Christmas beetles*** varies not only ***between*** *Eucalyptus* species and populations, but also ***on individual trees***, where a single branch can be resistant to attack. These differences are due to the composition of terpenoid oils. Christmas and leaf beetles are general feeders, but still may prefer ***certain species*** over others. Seedlings from the same seed source can vary in their ***vase life***. ***Genetic diversity*** is needed to produce healthy vigorous progeny, with vigour and ability to cope with diseases, pests and climatic changes. There is ***no formal certification scheme*** in Australia for eucalypt seed, however, the quality of seed and of detailed information provided by CSIRO's Australian Tree Seed Centre, gives assurance of place of origin and botanical identity, corresponding to ***OECD*** (Organisation for Economic Co-operation and Development) 'source identified' (Eldridge et al. 1994). See Trees K 19.

Humans: Eucalypt forests have been depleted by ***clearing*** for agriculture, mining, forestry and urbanisation. ***Irrigation systems*** have resulted in salinity problems which have killed eucalypts.

Kino (gum veins) is an ***external indicator*** of damage to the bark/wood bond. It may be an indication that a wound has exposed the cambial region of the stem. ***Fungal colonisation*** of wounds can be extremely rapid (within 4 weeks). Most commonly, black to grey mycelium with fruiting bodies is visible. ***Ceratocystis sp***. may develop on sapwood of several wounded trees, and is a pioneer saprophyte associated with ***superficial sap-stain***.

Nutrient deficiencies, toxicities: Symptoms of deficiencies are not common in natural bushland. ***Nutrient levels*** are usually only important in nurseries and young plantations where optimum growth is desired (Attiwill and Adams 1996). ***Soil analyses*** should be carried out for potting media and prior to field planting. ***Symptoms*** include yellowing, browning, reddening and deformation of leaves, and dieback of shoot tips. ***Plant analysis*** can be used to confirm visual symptoms. ***Salt toxicity*** is a problem in agricultural areas. See Citrus F 43.

Poisonous properties: ***Cattle, goats and sheep*** may die suddenly, after feeding on sucker or mature leaves of sugar gum (*E. cladocalyx*) and red box (*E. polyanthmos*), especially if wilted. They produce cyanogenetic compounds (McBarron 1983). ***Eucalyptus oils*** are used for medicinal purposes, industry and perfumery. Small quantities are toxic and bottles have a POISON label schedule (S6).

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State/Territory Departments of Agriculture/Primary Industry eg

Case Moth Caterpillars (NSW Agfact)
Chinese Junk Caterpillars (NSW Agfact)
Cup Moths (NSW Agfact)
Dieback (NSW Forestry Commission)
Eucalypt Oils (NSW Agfact)
Eucalypt Oil from Blue Mallee (NSW Agfact)
Mistletoe Brown Tail Moth : A Skin Irritation Caterpillar (NSW Agfact)
Insect Pests of Eucalypts & Other Native Plants (WA Farmnote)
Insect Pests of Farm Trees (Farm Trees No.8, NSW Agric & Fish.)

NSW Forest Protection Series

Autumn Gum Moth
Borers and Termites in Trees (Leaflet No.4)
Christmas Beetles
Collecting Insects for Identification
Eucalypt Sawflies
Gumleaf Skeletonizer
Insect Damage in Young Eucalypt Plantations
Leaf Beetles
Leafblister Sawflies
Leaf eating insects (Leaflet No. 3)
Psyllids in Eucalypt Plantations
Sap sucking Insects (Leaflet No. 2)
The Control of Insects on Eucalypts

NT Dept of Primary Production

Insects in the Home Garden and Recommendations for their Control.

Associations, Journals etc

ACIAR. Eucalypts : Curse or Cure?
Environmental Management : The Role of Eucalypts and Other Fast Growing Species (Proc. Workshop 1996. CSIRO/DIST, Canberra)
Australian Forest Grower
Australian Forestry
CSIRO Div. of Forest Research, Canberra
Euclid : Interactive Key to the Identification of Eucalypts (CD -ROM) in prep. (Aust. Nat. Herbarium)
Greening Australia (catalogue of published material)

See Autralian native plants N 9, Nurseries N 56, Trees, shrubs and climbers K 22, Urban bushland N 87

Remember, always check for recent references

MANAGEMENT

Eucalypts are used for timber production, pulp and paper, florists' foliage, oils, ornamental plantings, windbreaks and reclamation. Diseases and pests of local species should be ***identified and monitored***. Problems affecting eucalypts ***change with the age of the tree***. Young plants are susceptible to autumn gum moth, leafblister sawfly, etc. In the ***2nd year*** attacks by Christmas beetles and sawflies occur, and so on. Insects appear to consume more sap and leaves in young regenerated eucalypt stands than in mature forests. ***Stem decay fungi*** could become more significant due to altered branch shedding in some fast-growing eucalypts, or if trees are pruned. In subtropical areas damage from ***heart rot*** and ***termites*** is considered likely to be of major importance in plantations that produce large volumes of non-durable wood. Do not confuse ***dieback*** caused by ***Pc*** on jarrah in WA, with ***dieback*** caused by ***Armillaria root rot*** in Victoria and Tasmania, with ***dieback*** caused by ***foliage-feeding insects*** such as Christmas beetles and sawflies in the north of the ACT, or with ***various***

environmental problems such as drought, waterlogging, or a combination of these. ***Select provenances*** with the required ***horticultural assets*** and ***some resistance*** to special local problems, eg ***Pc***, lerp, scale, leaf beetles. Species resistant in one area may be susceptible to different problems in other areas. Many individuals within a species lack vigour or show extremely variable performance (Beardsell et al. 1994). ***Planting material*** should be free from known diseases and pests. ***Propagation*** is by seed, cuttings from young suckers taken close to the rootstock, tissue culture, micropropagation. Diseases are not usually seedborne. There is a national scheme of Elite Seed, so that the desired species and provenances can be selected to suit current and possibly future climates, sites, pests and diseases. ***Cultural methods:*** Damage from diseases such as ***Pc*** and *Armillaria* root rot should be avoided by careful ***site and species selection***. Damping off during winter may occur when moisture intensity and air movement are reduced. Fertilising, irrigation and careful pruning are necessary for young trees to grow satisfactorily. ***Sanitation:*** On small trees prune off shoots infested with scale or other pests; severely infested young trees may be removed and replaced with species with some resistance to local problems. ***Plant quarantine:*** Some diseases occur on eucalypts overseas, but are not known to occur in Australia, eg rust (*Puccinia*). Effective quarantine measures, detection, identification and containment of pests and diseases, depend largely on a detailed knowledge of the biology of the diseases and pests and their hosts. Recent changes in quarantine policy, which seek to balance trade and economic considerations with biological risks need to be carefully assessed in relation to pests and diseases. ***Pesticides*** are registered for use on young eucalypts. ***Growth regulators*** are used for compactness, ***herbicides*** for weed control in forests and around new ornamental plantings, and ***insecticides and fungicides*** in nurseries. ***Pest management:*** Regular ***monitoring*** of diseases and insects (Stone 1991) should be carried out and incorporated into management plans for all eucalypt plantings, eg urban plantings, plantations, regeneration and nature parks. ***Harvest for florists' foliage:*** Eucalypts, especially *E. gunnii*, are grown for their juvenile foliage. Choose ***foliage*** with firm undamaged leaves; avoid foliage with wilted tips. ***Storage:*** In water containing a commercial preservative at 1°C for up to 2 weeks. ***Vase life:*** Recut stems, use a commercial preservative, keep well watered and revive wilted eucalypt by searing (Jones and Moody 1993, Jones et al. 1994).

Fig. 236. Ramularia shoot blight (*Ramularia* sp.). Leaves look as if splashed with white paint.

Fig. 237. Angular leaf spot (*Seimatosporum* sp.) on *E. regnans*. B. A. Fuhrer.

Fig. 238. Mistletoe (Loranthaceae) parasitic on eucalypt stems.

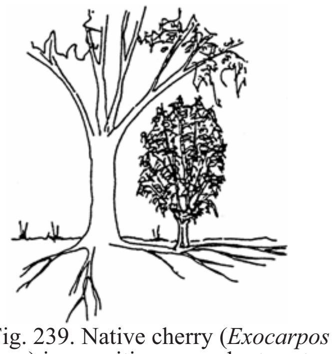

Fig. 239. Native cherry (*Exocarpos* spp.) is parasitic on eucalypt roots.

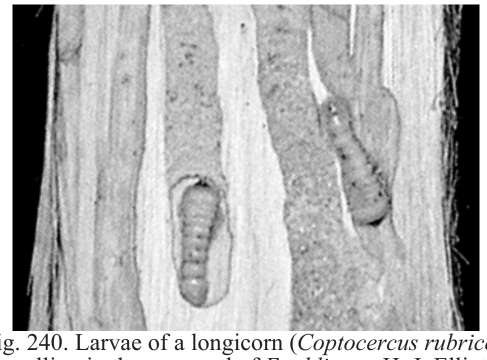

Fig. 240. Larvae of a longicorn (*Coptocercus rubriceps*) tunnelling in the sapwood of *E. obliqua*. H. J. Elliott.

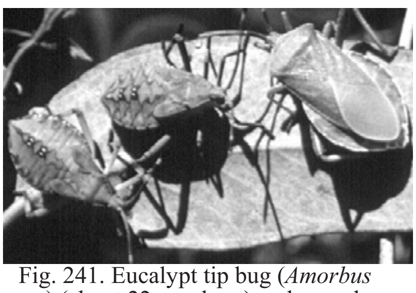

Fig. 241. Eucalypt tip bug (*Amorbus* sp.) (about 22 mm long) and nymph.

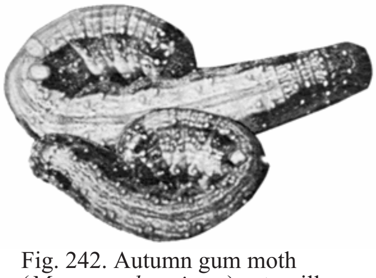

Fig. 242. Autumn gum moth (*Mnesampela privata*) caterpillar (35 mm long) For. Com., NSW.

Fig. 243. Cup moth (*Doratifera* spp.) caterpillar (25-30 mm long).

Fig. 244. Leafhopper (*Eurymeloides lineata*) (10 mm long). H. J. Elliott.

Fig. 245. Apiomorpha galls (*Apiomorpha* spp.). Female on left, males on right.

Fig. 246. Damage by the gregarious gall weevil (*Strongylorhinus ochraceous*). H. J. Elliott.

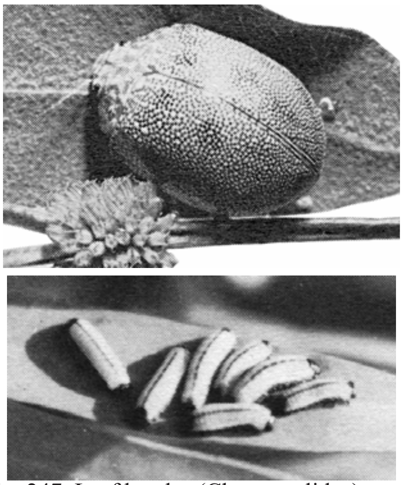

Fig. 247. Leaf beetles (Chrysomelidae). ***Top :*** Adult (10 mm long) and eggs. ***Lower :*** Larvae (10-12 mm long). For. Com., NSW.

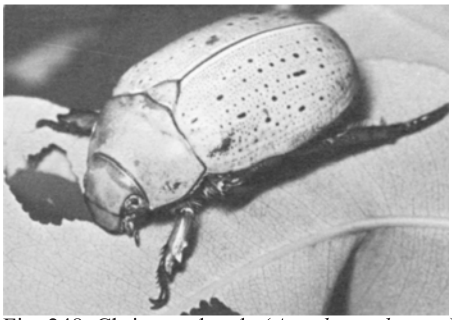

Fig. 248. Christmas beetle (*Anoplognathus* sp.) is 25 mm long. For. Com., NSW.

Fig. 249. Brown blister caused by leafblister sawfly (*Phylacteophaga* sp.) For. Com., NSW.

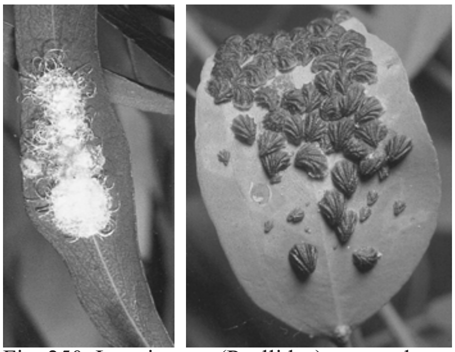

Fig. 250. Lerp insects (Psyllidae) on eucalypt leaves.

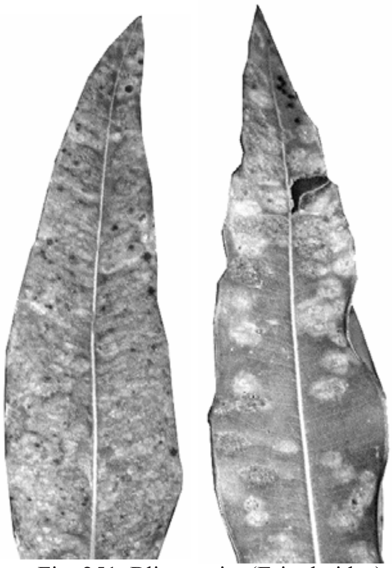

Fig. 251. Blister mite (Eriophyidae) galls on *Angophora*.

Fig. 252. Gumtree scale **(*Eriococcus coriaceus*).** For. Com., NSW.

Fig. 253. Steelblue sawfly (*Perga* sp.) larvae (spitfires) during the day.

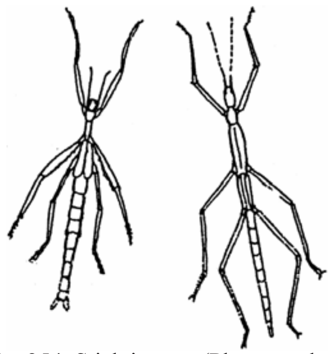

Fig. 254. Stick insects (Phasmatodae) (up to 200 mm long).

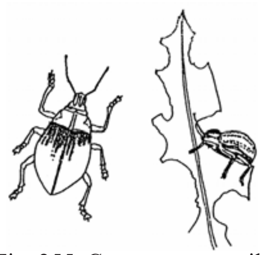

Fig. 255. Catasarcus weevil (*Catasarcus* spp.) up to 15 mm long and chewing damage.

Euonymus

Spindle tree

Euonymus spp.
Family Celastraceae

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Fungal diseases
Fungal leaf spots
Powdery mildew
Root rots
Insects and allied pests
Leaf beetles
Scales
Weevils
Non-parasitic
Environment
Flies
Genetic

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas, veinclearing, yellow rings and oak leaf patterns in young leaves, also leaf mottling and yellow blotches and rings, have been ***associated with*** strawberry latent ringspot, tomato ringspot virus and cherry leaf roll virus in euonymus but not conclusively proven. Virus-like particles have been found in fasciated euonymus but not that they cause fasciation (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots (various species) mainly affect ***older leaves***. See Annuals A 5.

Powdery mildew (*Oidium* sp.) is the ***most serious and unsightly disease*** of euonymus. ***New growth*** is severely affected. Avoid using euonymus as a feature plant; place in well ventilated sites and ***avoid pruning*** shrubs unnecessarily, as the disease is more severe on regularly trimmed hedges. Planting ***resistant varieties*** is the most effective means of control. ***Susceptible species*** include *Euonymus japonicus* Aureo-variegata. Varieties with ***slight resistance*** include *E. japonicus* Aureo-marginata and *E. japonicus* Albo-marginata, but if conditions are very favourable, even they may be seriously affected. The use of ***fungicides*** to control powdery mildew is not recommended except for nursery stock. See Annuals A 6.

Root rots
Armillaria root rot (*Armillaria luteobubalina*)
Phytophthora root rot (*Phytophthora* sp.)
See Trees K 7.

INSECTS AND ALLIED PESTS

Leaf beetles (*Pedrillia* spp., Chrysomelidae, Coleoptera) have been associated with *Euonymus* and *Santalum*. ***Beetles*** feed ***externally***, and ***larvae*** either ***externally or internally*** on living tissue in roots, foliage, stems, growing tips, leaves, flowers, pollen fruits and seeds. See Trees K 15.

Scales (Hemiptera)

Armoured scales (Diaspididae)
Red scale (*Aonidiella aurantii*)
Many other species overseas
Soft scales (Coccidae)
Black scale (*Saissetia oleae*)
White wax scale (*Gasgardia destructor*)

Scales cluster on ***stems*** and/or ***leaves*** depending on the species. Although soft scales disfigure plants with associated honeydew and ants, armoured scales may be more damaging. Oil sprays provide control. See Citrus F 39, F 41, Trees K 16.

Weevils (Curculionidae, Coleoptera) scallop holes from the ***centres and margins of leaves***.
Fuller's rose weevil (*Asynonychus cervinus*)
Garden weevil (*Phlyctinus callosus*)
See Trees K 17, Vegetables M 17.

Non-parasitic

Environment: During ***cool weather*** leaves of some species develop a pink pigmentation.

Flies (Diptera) are attracted to the flowers and may annoy people in outdoor areas.

Genetic: ***Fasciation*** causes a flattening of stems. See Daphne K 53. ***Green shoots or sports*** are frequently produced on variegated species or cultivars. See Trees K 19. Fasciated shoots and green sports may be pruned off but may recur.

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Pirone, P. P. 1978. *Diseases & Pests of Ornamental Plants*. 5th edn. John Wiley & Sons, NY.
See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Euonymus suits all climates and may be grown in the ground or in containers. Species ***susceptible*** to powdery mildew should ***not be selected*** for hedge or specimen plants, but planted in shrubberies of mixed species, where the problem is not so obvious. Euonymus will ***tolerate*** dry conditions. Plant ***nursery stock free from scales*** and other problems. ***Propagate*** by cuttings. Euonymus prefers full sun in a cool temperate climate, but will tolerate hot dry conditions. ***Pruning*** susceptible species produces new growth which is very susceptible to powdery mildew.

Fuchsia

Fuchsia spp., *Fuchsia x hybrida*
Family Onagraceae (evening primrose family)

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Fungal diseases
Fungal leaf spots
Grey mould (*Botrytis*)
Root and collar rots, wilts
Rusts
Nematode diseases
Insects and allied pests
Aphids
Apple leafhopper
Caterpillars
European earwig
Greenhouse thrips
Greenhouse whitefly
Longtailed mealybug
Mites
Snails and slugs
Non-parasitic
Environment
Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt virus is spread by various species of thrips, and has been found to infect fuchsia overseas (Pirone 1978). See Trees K 4.

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) may cause galls on stem bases. See Stone fruits F 125.

FUNGAL DISEASES

Fungal leaf spots (*Cercospora*, *Septoria*, other species) may cause ***defoliation and loss of flowers***. Avoid watering late in the afternoon. See Annuals A 5.

Grey mould, petal blight (*Botrytis cinerea*) decays ***stems, leaves and flowers*** after establishing on wounded tissue, or where flower parts have fallen. See Greenhouses N 22.

Root and collar rots, wilts
Armillaria root rot (*Armillaria luteobubalina*)
Damping off (*Pythium*, *Phytophthora nicotianae, Rhizoctonia solani, Thielaviopsis basicola*)
Phytophthora root rot (*Phytophthora* spp.), may also cause a foliage blight
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Thielaviopsis black root rot (*Thielaviopsis basicola*)
Verticillium wilt (*Verticillium dahliae*)
See Trees K 7, Vegetables M 7, M 9.

Rusts (*Pucciniastrum epilobii*, *Uredo fuchsiae*). ***P. epilobii*** is ***common and serious*** and initially causes purple-red blotches on ***leaf uppersurfaces***, these later brown and have purple edges. On the lower surface, yellow-orange rust spores develop under each blotch. Leaves fall and there is poor flower production. ***Favoured*** by hot and moist conditions. Some cultivars, eg Orange Drops and Novella, are ***very susceptible***. See Annuals A 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) and ***root knot nematodes*** (*Meloidogyne* spp.) may infest *Fuchsia x hybrida*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera), eg ***green peach aphid*** (*Myzus persicae*), may cause distortion of flowers and buds, dieback of stems. See Roses J 4.

Apple leafhopper (*Edwardsiana australis*) is green and up to ***6 mm*** long. Their sap sucking causes ***leaf speckling***. Severe attacks may cause reduction in plant vigour. See Pome fruits F 112.

Caterpillars (Lepidoptera)
Grapevine hawk moth (*Hippotion celerio*), also scrofa hawk moth (*H. scrofa*)
Grapevine moth (*Phalaenoides glycinae*)
Lightbrown apple moth (*Epiphyas postvittana*)
Looper caterpillars (*Chrysodeixis* spp.)
Vine hawk moth (*Theretra oldenlandiae*), also *T. latreillei*
Caterpillars of some of these moths feed on a wide range of plants, others only on a few species. They can ***seriously damage new growth and flower buds***. ***Grapevine moth*** caterpillars may defoliate stems. ***Lightbrown apple moth*** caterpillars web leaves together. See Annuals A 8, Grapevine F 61, Trees K 13.

European earwig (*Forficula auricularia*) chew ***leaves and flowers*** ragged. Their exreta spoils the appearance of plants. See Vegetables M 14.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause ***leaf silvering***. See Greenhouses N 24.

Greenhouse whitefly (*Trialeurodes vaporariorum*) and nymphs feed on ***leaf undersurfaces*** causing leaf mottling. See Greenhouses N 24.

Longtailed mealybug (*Pseudococcus longispinus*) sucks sap from ***leaf undersurfaces***. Soft tip growth may wilt and die. Overseas also ***citrus mealybug*** (*Planococcus citri*). See Greenhouses N 25.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) causes ***leaves*** to curl ***downwards***. See Greenhouses N 26.
Cyclamen mite (*Steneotarsonemus pallidus*) ***distorts new shoots***. See Cyclamen C 16.
Twospotted mite (*Tetranychus urticae*) feeds mainly from ***leaf undersurfaces***. Leaves become sandy mottled, yellow and may fall. Webbing may occur on leaf undersurfaces. See Beans (French) M 29.

See Trees K 16.

Others: ***Capsid bugs*** (Miridae, Hemiptera) are 6-12 mm long, green to brown and resemble large aphids. Nymphs and adults suck sap from leaves, reducing plant vigour. ***Passionvine hopper*** (*Scolypopa australis*) may damage young shoots.

SNAILS AND SLUGS

Common garden snail (*Helix aspersa*) ***destroys leaves, flower buds*** and ***tip growth***. See Seedlings N 70.

Non-parasitic

Environment: ***Leaf fall*** may be caused by draughts, poor drainage, lack of soil or atmospheric moisture, excessive watering, sudden large changes in temperature, excessive use of fertiliser, infestation by sucking insects, eg twospotted mite and mealybugs, or by rust. ***Bud drop*** and ***bull-heading*** (coloured buds failing to open) may be caused by the same environmental conditions that cause ***leaf fall***. Plants grown in containers are prone to bud drop and may need repotting each year in late winter with roots and branches pruned off. ***Container fuchsias have a limited life***, when vigorous growth stops they should be replaced. See Camellia K 40. ***Wind***, if accompanied by hot and dry weather, may cause wilting of leaves and flowers, both of which may later fall prematurely. Branches of fuchsia are ***brittle*** and may be damaged by strong winds. Site plants to protect them from wind. ***Dry weather***, during either hot or cold temperatures, may cause wilting of flowers and leaves, defoliation and ***death***. Water regularly. If plants are completely dry dip pots into a bucket of water until soil mix is thoroughly soaked. ***Frost*** may kill new shoots, leaves and flowers. ***Sunscorch*** may occur during hot, sunny weather, ***flowers fade and leaves are burnt***.

Nutrient deficiencies, toxicities: ***Nitrogen deficiency*** results in even yellowing of leaves, starting with the older leaves and spreading to growing tips. ***Defoliation and death*** may follow. Regularly apply a balanced fertiliser in spring, summer and autumn. See Trees K 20. ***Salt toxicity:*** Fuchsias are susceptible to excess salt in soil due to ***too concentrated*** or ***too frequent*** fertiliser applications. A buildup of chemicals in the soil prevents water from being taken up by the plant roots, so that plants do not get the balanced food and water they require, leaves may yellow or blotch with green veins. Discontinue feeding and leach out salts by heavy watering. Ensure that the water supply is low in salt. Do not fertilise in winter. See Trees K 20.

Others: ***Some fungicides*** damage fuchsia. Always test on a few cultivars first. ***Wettable sulphur*** burns fuchsia leaves and flowers.

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Pirone, P. P. 1978. *Diseases & Pests of Ornamental Plants*. 5th edn. John Wiley & Sons, NY.

State/Territory Departments of Agriculture/Primary Industry eg

Fuchsias in the Garden (NSW Agfact)
Fuchsias (Vic Agnote)

Association and Journals eg

Australia Fuchsia Society
GrowSearch (database Qld DPI)
State/Territory/Regional Fuchsia Societies
National American Fuchsia Society (Fuchsia Fan)
Most Societies produce a newsletter or books

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Fuchsia may be grown in the garden, as espaliers, in containers or as popular hanging baskets. Some cultivars, eg the yellow fuchsia Lockebie, show a number of valuable characteristics, including ***good tolerance*** to rust, extreme heat and as much as 6^{o}C frost. ***Propagate*** by tip cuttings, also from seed (usually used for hybridising or raising new varieties). Plants require bright ***filtered sunlight*** throughout the day (partial shade), with 3-4 hours of morning sunlight. Flower drop may be caused by insufficient light. ***Most cultivars*** need shelter from strong winds, summer temperatures of 20^{o}C, abundant water in hot weather; leaves may be misted, or plants hosed down with water during hot weather. ***In winter*** they require a cool dormant season, ie a temperature of 6-10^{o}C, and limited watering. Fuchsias may be ***pruned or trained*** to produce bush, trailing or standard types. Prune stems once new spring growth commences otherwise stems may bleed. Remove any dead wood or damaged or badly positioned shoots, and finally shorten remaining shoots to within 50-80 mm of their bases. Vigorous plants may be cut back even further. Constantly ***pinch out tips*** of branches once new growth is underway, to encourage more lateral branches and a bushier plant and ultimately more flowers. ***Harvest*** at the beginning of flowering. Flowers are ***ethylene sensitive*** (abscission of buds, flowers, petals), commercial growers may treat potted plants with anti-ethylene compounds prior to sale (Nowak and Rudnicki 1990). ***Judging standards*** may be general, or specific to particular fuchsia societies.

Gardenia

Gardenia spp.
Family Rubiaceae

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots (various species) may develop if plants are too close together and leaves become ***wet*** during watering. See Annuals A 5.

Grey mould (*Botrytis cinerea*) may cause ***bud rot*** especially in greenhouses. Pick off and destroy affected buds. See Greenhouses N 22.

Root rots (*Cylindrocladium scoparium*, *Phytophthora* sp.). See Trees K 7, Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)
Bee hawk moth (*Cephonodes kingii*, Sphingidae), also *C. hylas*
Budworms (*Helicoverpa* spp.) feed in flower buds.
Painted apple moth (*Teia anartoides*)
Twig looper (*Ectropis excursaria*)
See Annuals 8, Trees K 13.

Mealybugs (Pseudococcidae, Hemiptera) may feed on ***stems and leaves***. See Greenhouses N 25.

Plague thrips (*Thrips imaginis*, Thripidae, Thysanoptera) may infest ***flowers***. See Roses J 6.

Soft scales (Coccidae, Hemiptera)
Soft brown scale (*Coccus hesperidum*)
White wax scale (*Gascardia destructor*)
See Citrus F 41, Trees K 16.

Weevils (Curculionidae) chew leaves.
Fuller's rose weevil (*Asynonychus cervinus*)
See Trees K 17.

Whiteflies (Aleyrodidae) may infest ***leaf under surfaces***. See Greenhouses N 24.

Non-parasitic

Environment: Full sun will quickly ***burn flowers***. Gardenia may need protection in ***very cold climates.*** Flower buds may ***drop*** just before they open, due to inadequate soil moisture, too low humidities, insufficient light or too high temperatures. ***Overwatering*** may suffocate roots causing branches to die.

Nutrient deficiencies, toxicities:

Iron deficiency: Gardenia prefers slightly acid soil. Iron is unavailable in alkaline soils. Initially ***new leaves*** have green veins on a yellow background. See Trees K 20.
Magnesium deficiency may occur on ***older leaves*** which have characteristic V-shaped green and yellow patterns. See Citrus F 43, Trees K 20.

Senescence: Occasionally yellow leaves, which are senescing, appear.

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State/Territory Departments of Agriculture/Primary Industry eg
Gardenias : Indoor and Out (Vic Agnote)
See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Gardenias are warm temperate to subtropical plants. ***Propagate*** by cuttings. Choose a ***semi-shaded*** position with a ***slightly acid soil***. Fertilise and water regularly in summer. ***Growth regulators*** are used to promote flowering and control height. ***Harvest*** when flowers are almost fully open, and handle by stems as any contact with the petals, causes browning. ***For corsages*** harvest without foliage attached, individual flowers are wired, attached to a paper collar with leaves attached to the collar. Flowers are placed in trays and sprinkled with water and sealed to keep humidity high. ***Vase life*** is short (Jones and Moody 1993).

Geraldton wax

Chamelaucium uncinatum
Family Myrtaceae (eucalypt family, myrtle family)

PESTS AND DISEASES
Parasitic
- **Bacterial diseases**
  - Crown gall
- **Fungal diseases**
  - Cankers
  - Flower blights, leaf spots
  - Powdery mildew
  - Root rots
- **Nematode diseases**
- **Insects and allied pests**
  - Caterpillars
  - Geraldton wax gall wasps
  - Ringbarking weevil

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Crown gall (*Agrobacterium* sp.) may cause ***galls*** at ***stem bases*** of Geraldton wax (*Chamelaucium uncinatum*). See Stone fruits F 125.

FUNGAL DISEASES

Cankers (various species) on ***stems*** may cause ***dieback***. See Trees K 5.

Flower blights, leaf spots: *Alternaria blight* (*Alternaria* spp.) and ***grey mould*** (*Botrytis cinerea*) may both cause ***flower blights***. ***Both fungi*** are attracted to ageing tissue and cause flower fall ***postharvest***, but not in the field. The fungi are ***latent***, waiting for something to facilitate their growth. The appearance of flowers is affected. These fungi may also cause ***leaf*** and ***stem*** spotting, ***buds*** may drop. The infected and wounded tissues produce more ethylene causing ***flowers to fall*** (abscission). Grey mould may infect ***flowers*** under humid conditions, ie ***condensation*** on the surface of flowers. Grey mould may also cause ***damping off*** (see below). In Qld, *C. uncinatum* Lady Stephanie has proven a good, ***Botrytis-resistant*** variety and popular for export markets. Appropriate ***packaging*** and ***storage conditions*** prevent growth of the fungi. Flowers may be treated with an ***ethylene inhibitor***. Infection may be prevented by the application of ***fungicides*** (Gollnow 1992). See Annuals A 5, Azalea K 27, Greenhouses N 22.

Powdery mildew (*Oidiopsis taurica*): ***Foliage*** becomes yellow and has distinct bands of green. Leaves may fall prematurely (Bodman et al. 1996). See Annuals A 6.

Root rots are ***serious and common***.

Cylindrocladium* collar and stem rot, leaf spot, shoot blight** (*Cylindrocladium* spp.) attacks nearly ***all parts of **Myrtaceae** plants. ***Young plants*** are most susceptible.

Damping off (*Botrytis cinerea*, *Cylindrocladium*, *Phytophthora*, *Pythium, Rhizoctonia*) can cause ***debilitating root problems*** as the fungi can spread quickly from infected plants when planted in the field. *Rhizoctonia* can cause collar rot of ***lower stems***, grey mould (*Botrytis cinerea*) a soft rot of ***cuttings***. See Seedlings N 66.

Phytophthora root rot (*Phytophthora cinnamomi, P. cryptogea, P. nicotianae, Phytophthora* sp.) is the ***most common problem*** affecting Geraldton wax. *Phytophthora* has also been recorded on other *Chamelaucium* spp., eg Esperance waxflower (*C. axillare*). See Trees K 6.

Others: Armillaria root rot (*Armillaria luteobubalina*).

Only purchase stock from reputable suppliers, particularly those prepared to offer a ***guarantee*** of ***plant health*** and ***freedom from Phytophthora***. Inspect plants on arrival and do not plant out unhealthy plants, until they have been tested for root disease. See Trees K 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.) has been recorded in WA on Geraldton wax. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera): ***Teatree web moth*** (*Catamola thyrisalis*, Pyralidae) caterpillars infest Geraldton wax, but do not cause serious damage and are ***easily controlled*** with insecticides. See Tea-tree K 124.

Geraldton wax gall wasps (eulophid wasps Eulophidae, Hymenoptera) have little impact in WA, but are ***serious pests*** of ***susceptible varieties*** in Qld and SA. See Australian native plants N 12 (Fig. 381). Even when galls are not a major problem in production, ***their presence reduces the value*** of plants and may affect the ***quarantine status*** of plants. If detected, galls on leaves result in rejection of cut flowers for export to Japan and the USA. Once galls are formed they cannot be removed. Wasps in ***WA*** are possibly kept in check by ***parasites or predators***, or perhaps the climate in WA is not suitable for the population to increase. ***Spread*** by vegetative propagation from infested plants, introduction of infested plants and by adults flying. The most promising control seems to be the use of ***resistant varieties***. The search for better gall-resistant varieties, especially white varieties is essential. ***Disease-free planting material:*** Growers should make sure that cuttings are free of gall wasps. ***Pesticides:*** Spraying has proved difficult, because the wasps are enclosed in galls and the infestation rate is very high. Some postharvest disinfestation treatments have caused unacceptable damage to flowers. See Citrus F 37, Trees K 14.

Ringbarking weevil (Curculionidae, Coleoptera) is native to WA and can ringbark Geraldton wax and other ***Myrtaceae***. *C. ciliatum*, *C. axillare,* and *Verticordia* may also be ***severely damaged***. ***Weevils*** lay eggs near the base of the plant. ***Larvae*** are ***5-10 mm*** long. They feed on the ***stem*** just below ground level, ***ringbarking*** it. Half the plants may be ***killed***. Pot-bound plants are ***more susceptible*** to injury. Damage is not obvious until plants start dying, usually during times of ***water stress***. If considered necessary plantations may be drenched with insecticide once per year. See Trees K 18.

Others: ***Aphids*** (Aphididae), ***mealybugs*** (Pseudococcidae), and ***soft brown scale*** (*Coccus hesperidum*) may attack plants in greenhouses.

Non-parasitic

Environment: Geraldton wax, usually considered hardy, may suffer from ***drought stress***. In the short term, Geraldton wax will tolerate levels of water deficit stress that would kill exotic species. It can survive a water deficit stress about 3 times the general permanent wilting point. However, ***reduced water supply*** causes a ***decrease in total flower production***, ***retards plant growth*** and causes ***leaf shedding***. Stress also causes thickening of the stems and stunts stem length, both undesirable for the cut flower industry. *C. uncinatum* Purple Pride is ***more sensitive*** to water deficit stress than *C. uncinatum* Alba.

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State/Territory Departments of Agriculture/Primary Industry eg

Insect Pests of Wildflowers and Proteas (WA Farmnote)

Wildflower Production : Geraldton Wax and Related Species (WA Farmnote)

Pests of Young Plants (WA Farmnote)

Associations, Journals etc.

Australian National Flower Show Workshops

GrowSearch (database Qld DPI)

Wax Flower Growers Group (Qld)

See Australian native plants N 9,
Trees, shrubs and climbers K 22

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: Geraldton wax is a major ***cut flower export***. Select clones which bloom at different times and have a good vase life. It may also be grown in pots. It tolerates a wide range of conditions but grows best in poor soils in dry warm conditions, neutral to alkaline pH, with undisturbed roots. Frosts in late winter to spring will affect flower quality and may render crops unmarketable. Perfect drainage is required and sandy soils preferred. Full sun or no more than light shade is required for good flowering (Wrigley 1988). ***Resistant varieties:*** Select cultivars with some resistance to grey mould and gall wasp. ***Disease-free planting material:*** Planting material must be free from gall wasps and from *Phytophthora cinnamomi*. An overview of the industry has been outlined by Coombs (1995).

Establishment and Maintenance

Propagation by cuttings. Avoid damaging roots when transferring rooted cuttings as this can cause premature death some years later. ***Cultural methods:*** Plants such as Geraldton wax and thryptomene, which are both excellent cut flowers, are usually ***pruned*** enough by cutting flowers for indoors. ***Prune*** Geraldton wax cultivars at or after flowering, to keep bushes to a manageable size and ensure vigorous stem growth for next season. Young bushes can be shaped after their first flowering season even though flowers are not being harvested. Stems of 300 mm length can be cut from established plants, this keeps the plant bushy. Do not allow mulch or other plants to keep the main trunk damp at ground level, keep soil fairly dry. The most likely problem is *Phytophthora* root rot. ***Growth regulators*** are used on potted specimens to retard growth.

Postharvest

Harvest when 30-50% flowers have opened, full unopened buds, flowers well coloured, green but not yellowish foliage. To prevent ageing and flower fall, cool fresh flowers as soon as possible after harvest (2^{o}C and 95% relative humidity is acceptable). Low temperatures slow ageing, high humidities prevent flowers drying out. Geraldton wax is very sensitive to ***ethylene*** so growers may treat flowers with an ethylene-inhibiting product. Remove any dropped flowers. ***Store*** at 0-2^{o}C and rehydrate after storage. ***Vase life:*** Place in commercial preservative, or make your own preservative (only use 1/2 strength sugar to prevent flowers producing more nectar and becoming sticky). Do not mist flowers as they are susceptible to grey mould. Recut stems under water, use a preservative and top up regularly with water; flowers are very thirsty (Jones and Moody 1993). Geraldton wax promptly ***drops flowers and leaves*** when out of water. Bud and flower drop is often a problem in export shipments. ***Retail potted plants*** when the majority of flowers are open, as flower opening is poor under low light conditions. Flowers have an impressive shelf life under simulated home or office conditions. Quality Assurance Programs are available for Geraldton wax.

Grevillea

Grevillea spp.
Family Proteaceae (waratah family)

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots

Leaf spot (*Verrucisporota* spp., *V. proteacearum*) causes ***red-brown spots*** on ***leaves*** of grevilleas and hakeas in warm, humid climates. Small black fruiting bodies develop in the centres of the spots.

Sooty spot (*Placoasterella* spp., *P. baileyi*) commonly infects grevillea, especially *Grevillea* Robyn Gordon, *G. laurifolia*, and hakea, in humid weather. Sooty spot appears as more or less ***circular black spots*** on ***leaves***, which disfigure plants in the bush and in cultivation. This superficial fungal spot does not seem to affect the underlying tissue but cannot be easily be wiped off. Affected foliage may be pruned off.

Others: *Cercospora agharkarii, Seimatosporium grevilleae* (Walker 1994).

See Annuals A 5.

Root, collar and stem rots

Damping off: **Grey mould** (*Botrytis cinerea*), **phytophthora rots** (*Phytophthora* spp.), **pythium rot** (*Pythium irregulare*). See Seedlings N 66.

Phytophthora root rots (*Phytophthora* spp., *P. cinnamomi*, *P. cryptogea, P. hibernalis*, *P. nicotianae* var. *parasitica, P. palmivora*) are considered to be the ***most serious diseases*** of grevilleas. See Trees K 6.

***Others:* Armillaria root rot** (*Armillaria luteobubalina*), **butt and root rot** (*Phellinus noxius*), **rhizoctonia collar rot** (*Rhizoctonia solani*), **root rots** (*Pythium spinosum*), **sclerotium stem rot** (*Sclerotium rolfsii*)

See Trees K 7, Vegetables M 7.

Others: ***Cankers*** (various species) and ***wood rots*** (Basidiomycetes), eg ***tinder punk*** *(Phellinus* spp.) and other species. See Trees K 5, K 8.

PARASITIC PLANTS

Devil's twine (*Cassytha* spp.) and ***mistletoes*** (Loranthaceae) may infest grevillea. See Trees K 9.

NEMATODE DISEASES

Burrowing nematode (*Radopholus*), ***dagger nematode*** (*Xiphinema*), ***sheath nematode*** (*Hemicycliophora* sp.) and *Hemicriconemoides*, *Paralongidorus* and *Scutellonema* have been associated with *Grevillea* spp. in Qld and WA. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers are considered by some to be a ***major cause of damage and death*** of *Grevillea* spp.
Auger beetle (*Xylodeleis obsipa*, Bostrichidae)
Longicorn beetles (Cerambycidae, Coleoptera)
Oecophorid borers (Oecophoridae, Lepidoptera)

Inspect stems and trunks regularly, every 2-4 weeks in warm weather for ringbarking near the soil line, sawdust and exit holes. See Trees K 10.

Bugs (Hemiptera): ***Crusader bug*** (*Mictis profana*) and several species of ***lace bugs*** (Tingidae) are associated with grevilleas. See Trees K 12.

Caterpillars (Lepidoptera): Many species feed on *Grevillea* spp.

Grevillea case moth (*Lepidoscia arctiella*, Psychidae) caterpillars feed on grevillea, *Brachyloma* and other plants. Caterpillars construct a slender elongate ***case*** ornamented with short spirally arranged pieces of ***twig*** cut from the plants on which they feed. See Trees K 13

Grevillea loopers (*Oenochroma vinaria, O. pallida,* Geometridae) feed on grevillea, banksia, hakea and other plants. ***Moths*** have a wingspan of 50 mm and are usually rosy-purple on top with a purplish spot on the underside of the forewing. ***Caterpillars*** are up to ***80 mm*** long, smooth, slender, taper slightly towards the head and are green with many small spots and 2 small fleshy projections towards the head. They move with a ***looping action***. Leaves are eaten and in some areas shrubs can be defoliated. Two similar species feed on geebungs (*Persoonia* spp.).

Macadamia twig-girdler (*Xylorycta luteotactella,* Oecophoridae) caterpillars live either in a ***webbing shelter*** among ***twigs*** and ***leaves*** or in a ***short tunnel*** in a ***twig*** or the ***woody fruits***. ***X. heliomacula*** caterpillars feed on *G. striata* and mistletoes (*Amyema*). See Macadamia F 77.

Pyralid moths (Pyralidae): ***Macadamia flower caterpillar*** (*Cryptoblabes hemigypsa*) and ***web moths*** (*Catamola* spp.). See Tea-tree K 124

Tussock moths (Lymantriidae): ***Painted apple moth*** (*Teia anartoides*), ***painted pine moth*** (*Orgyia australis*). See Pine K 108, Pome fruits F 133.

Variegated caterpillar (*Anthela varia*, Anthelidae) is a ***sporadic pest*** of grevillea and other plants. ***Caterpillars*** are ***hairy, brown-grey***, up to ***60 mm*** long. Solitary or in small groups, caterpillars eat chunks out of mature leaves. See Trees K 13.

Others: **Banksia moth** (*Danima banksiae*), **cryprotus blue butterfly** (*Candalides cyprotus*) on *G. bracteosa*, **doubleheaded hawk moth** (*Coequosa triangularis),* **dryandra moth** (*Carthaea saturnoides*), **lightbrown apple moth** (*Epiphyas postvittana*), **processionary caterpillar**, bag-shelter moth (*Ochrogaster* sp.). ***Nanaguna breviuscula*** (Noctuidae) feeds on grevillea in northern Australia.

See Annuals A 8, Trees K 13.

Psyllids (Psyllidae, Hemiptera) may infest grevillea and other plants, eg ***leaves and shoots*** of *G. coochin* Hills and *G. juncifolia*, *G. sericea*, *Acacia fimbriata*, ***flowers and new growth*** of *G. rosmarinifolia*. In subtropical areas flowers of some species, and hybrids of grevilleas with flowers arranged on short nearly equal flower stalks, may be attacked. ***Adults*** are tiny, speckled, winged pale insects about ***1.5 mm*** long, often found sheltering amongst foliage and on undersurface of leaves. ***Nymphs*** may secrete a white waxy secretion which is a sign of their presence. They are minute and yellow or orange depending on the species. Nymphs and adults suck sap from ***young shoots***, and it is thought that they inject a toxic saliva into the plant during feeding, which causes leaves and young shoots to become distorted and tightly bunched together ***(bunch psyllids)*** providing shelter for nymphs. Plants are stunted and woody. Shoots do not elongate normally, leaves are small and sparse. ***Flower spikes*** may be small, buds fail to open. ***Buds*** may shrivel and fall, the main flower stalk is curled and brown. Other sucking insects, eg mites, may cause similar damage. ***Insecticides*** may be applied when new growth is expected. See Eucalypt K 62, Trees K 15.

Scales and mealybugs (Hemiptera)

Armoured scales (Diaspididae)
Latania scale (*Hemiberlesia lataniae*) mainly on *G. obtusiflora* Little thicket
Ground pearls (Margarodidae)
Cottonycushion scale (*Icerya purchasi*)
Mealybugs (Pseudococcidae)
Grevillea mealybug (*Australicoccus grevilleae*)
See Greenhouses N 25.

See Citrus F 39, F 41, Trees K 16.

Silkyoak leafminer, grevillea leafminer (*Peraglyphis atimana,* Tortricidae*,* Lepidoptera) is a ***sporadic pest*** of broadleaved grevillea in coastal, inland, tropical and subtropical areas. ***Moths*** are about 15 mm long. ***Caterpillars*** are about ***10 mm*** long and mine in ***leaves*** causing brown blisters. Severely mined leaves fall prematurely, repeated attacks weaken plants. ***Parasitic wasps*** lay eggs through the tunnel wall into the body of the caterpillars; small birds, eg pardalotes, may prey on them. ***Susceptible varieties:*** Silky oak (*G. robusta*), red and white Bank's grevilleas (*G. banksii*), *Grevillea* Robyn Gordon, other broadleaved species. ***Insecticides*** may be applied to ***nursery stock*** to protect new foliage. See Azalea K 28.

Others: ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***mites*** (Eriophyidae), ***passionvine hopper*** (*Scolypopa australis*).

Non-parasitic

Allergic reactions: The flowers, foliage, and other parts, and even sawdust of certain grevilleas, eg *G. banksiae, G. hookeriana, G. robusta* and hybrids Robyn Gordon and Mason's Hybrid, may cause ***dermatitis*** in susceptible individuals. Associated symptoms include dizziness and fatigue (Lothian 1989).

Nutrient deficiencies, toxicities: Grevilleas may suffer from ***iron deficiency***, ***phosphorus toxicity*** or ***salt toxicity***. See Trees K 20.

Others: ***Fasciation*** is quite frequent on *Grevillea* Sandra Gordon. Some species have ***spiky*** growth or ***variegated leaves.***

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See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

There are about 250 species of *Grevillea* in Australia, with few exceptions they have horticultural potential with flowers of many different forms and colours (Wrigley 1989). They are often called 'spider flowers' because of the shape of the flowers. Grevillea are grown for garden and park trees, shrubs and ground cover and as bird attractants. Some species are very ***susceptible*** to fungal leaf spots, *Phytophthora* root rot, silkyoak leafminer and scale. Only propagate from ***disease and pest-free*** stock plants. ***Propagation*** is usually by cuttings and by grafting on to silky oak (*G. robusta*) rootstock because of its resistance to *Phytophthora* and its ability to cope with a wide range of soil and climatic conditions. In general, ***grevillea prefer*** well drained, sunny sites, slightly acid soil types, and balanced fertilisers. ***Excess of phosphorus*** may prove fatal. ***Plant growth regulators*** are used to produce compact plants. ***Harvest*** foliage with firm undamaged leaves, avoid foliage with wilted tips, may be stored in water at 1^{o}C for up to 2 weeks, place in a solution containing a germicide, ***vase life*** is approximately 15-16 days (Jones and Moody 1993).

Hakea

Hakea spp.
Family Proteaceae (waratah family)

PESTS AND DISEASES
Parasitic
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf spots
  - Grey mould (*Botrytis*)
  - Root rots
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Gall wasps
  - Leafminers
  - Mites
  - Psyllids
  - Scales
  - Whiteflies

Non-parasitic
- Environment
- Fungi
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial leaf blight (*Pseudomonas viridiflava*) may cause leaf spotting. See Grapevine F 58.

FUNGAL DISEASES

Fungal leaf spots

Leaf spot (*Verrucisporota* spp., *V. proteacearum*) attacks both grevilleas and hakeas in very warm, humid climates or sites. Reddish-brown spots develop on ***leaves***, small ***black fungal fruiting bodies*** develop in the centres of the spots. Especially *Grevillea robusta, G. banksii, G. hilliana, G. venusta.*

Sooty spot (*Placoasterella baileyi*) is ***very common*** on grevillea and hakea, eg *G. laurifolia, Hakea salicifolia* and *H. suaveolens*, both in the ***bush*** and in ***cultivation*** during humid weather. The more or less circular ***black spots*** are superficial and do not seem to affect the underlying tissue and can with difficulty be wiped off. It disfigures plants but probably does not cause permanent damage. ***Prune off*** affected foliage. ***Fungicides*** may be applied if necessary.

Others: *Seimatosporium hakeae* and *S. kennedyae* on *Hakea saligna,* also *Vizella banksiae* (Pascoe 1987, Walker 1994). Some hakeas seem to be ***commonly affected*** by fungal leaf spots, eg *H. elliptica* and *H. petiolaris* (Fig. 256).

See Annuals A 5, Trees K 6.

Grey mould (*Botrytis cinerea*) on fineleaved grevillea, eg *G. pilulifera,* in shady or protected situations, also on ***seedlings and cuttings*** in propagation structures. See Greenhouses N 22.

Root rots

Damping off (*Phytophthora* spp., *Pythium* sp.), grey mould (*Botrytis cinerea*). See Seedlings N 66.

Phytophthora root rot (*Phytophthora* sp., *P. cinnamomi, P. cryptogea, P. nicotianae*). Many species are ***very susceptible*** and are grafted on to ***rootstock*** with recognised ***tolerance or resistance***, eg *H. salicifolia* (McKenzie 1994). See Trees K 6.

Others: Armillaria root rot (*Armillaria luteobubalina*), ***dieback*** (*Fusarium oxysporum*) (unconfirmed).

See Trees K 7.

Others: ***Cankers*** (various species) on stems may cause dieback. See Trees K 5. ***Wood rots,*** eg ***tinder punk*** (*Phellinus* spp.) and other species, may affect trunks. See Trees K 8.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) has been recorded on *H. bucculenta* and *H. laurina.* ***Other nematodes*** recorded on *Hakea* spp. include *Helicotylenchus, Hemicriconemoides, Morulaimus, Scutelloma*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers: ***Moth borers*** (Lepidoptera) may infest hakeas See Trees K 12.

Caterpillars (Lepidoptera):

Doubleheaded hawk moth (*Danima banksiae*) caterpillars are green and ***120 mm*** long (Fig. 257) and feed on ***leaves***. See Banksia K 31.

Loopers (Geometridae): ***Grevillea looper*** (*Oenochroma vinaria*) attacks ***leaves*** of mainly ***Proteaceae***, eg hakea and grevillea. They pupate usually in flimsy cocoon in debris or soil. ***Twig looper*** (*Ectropis excursia*). See Avocado F 19.

Macadamia twig-girdler (*Xylorycta luteotactella*) caterpillars attack ***leaves***. They live either in a webbing shelter among ***twigs and leaves*** or in a short tunnel in a ***twig or the woody fruits***. Also ***X. leucophanes***. See Macadamia F 77.

Seed borer (*Carpospina autologa,* Carpospinidae) caterpillars feed in the ***woody seed capsules*** of hakea. They pupate in crevices or on soil.

Others: *Amelora milvaria*, *Hypographa* sp., *Lissomma drakei*, *L. serpentaria, Phallaria ophiusaria.*

See Annuals A 8, Trees K 13.

Gall wasps (Torymidae, Hymenoptera): ***Megastigmus spp.*** is cosmopolitan and commonly yellow-brown with metallic patches. Several ***gall-forming species*** have been reared from ***stem, leaf and flower galls*** of banksia, citrus, eucalypt, hakea, *Helichrysum*, kurrajong, wattles, often in association with other insects. ***Xenostigma spp.*** causes ***galls*** on ***hakea buds***. See Trees K 14.

Leafminers (Lepidoptera) are common (Fig. 258).

Hakea leafminer (*Peraglyphis aderces*, Tortricidae) caterpillars mine mainly in the ***tips of leaves***. Damage is often mistaken for drought or wind injury. It is related to ***silkyoak leafminer*** (*P. atimana*). See Grevillea K 76.

Hakea leafminer (*Stegommata leptomitella*, Lyonetiidae) caterpillars commonly mine in ***young leaves*** of *H. saligna*. Initially the mines are linear, later expanding into an irregular ***blotch***, especially along the margins. When mature the caterpillar pupates in a flimsy elliptical cocoon, suspended hammock-wise from silk threads stretched across a hollow, often near the edge of a leaf. ***Mined leaf tips*** often become ***tattered***.

Macadamia leafminer (*Acrocercops chionosema*) slows tree growth due to ***dieback of new leaves***. ***Favoured*** by high-altitude rainforest areas and plantings protected from wind. See Macadamia F 78.

Leafminers are only controlled on ***nursery stock***. See Azalea K 28, Trees K 15.

Mites (Acarina): ***Eriophyid mites*** (Eriophyidae) may cause ***bunchy growth*** (witches' broom) on *Hakea dactyloides*. See Trees K 16.

Psyllids (Hemiptera): Free living ***Acizzia spp.*** (Psyllidae) infests new growth of hakea. Free living ***Aacanthocnema sp.*** (Triozidae) also occur on hakea. See Eucalypt K 62, Trees K 16.

Scales (Hemiptera)

Armoured scales (Diaspididae)
Latania scale (*Hemiberlesia lataniae*)
Oleander scale (*Aspidiotus nerii*)
Adult females scale are about 1-2 mm in diameter and roughly circular. They are white to brownish in colour and attack ***bark and leaves***.

Ground pearls (Margarodidae)
Cottonycushion scale (*Icerya purchasi*)
Auloicerya, which is closely related to *Icerya,* feeds on *Acacia* and *Hakea*.

See Citrus F 39, F 41, Trees K 16.

Whiteflies (Aleyrodidae, Hemiptera): ***Hakea whitefly*** (*Synaleurodicus hakeae*) may infest hakea (Jones and Elliot 1986). See Greenhouses N 24.

Non-parasitic

Environment: Hakeas require well drained sites and ***will not tolerate waterlogging***.

Fungi: An ***epiphyllous parasite*** (*Thallochaete baileyi*) may grow on ***leaves*** in humid situations. ***Sooty mould*** (*Capnodium anonae*) may grow on honeydew excretions from sap sucking insects, eg psyllids, scales. See Trees K 19.

Nutrient deficiencies, toxicities: ***Phosphorus toxicity:*** Hakea is arguably not as sensitive to excess phosphorus as many other Proteaceae. *H. francisiana* is ***very sensitive*** to phosphorus toxicity and *H. laurina* is ***moderately susceptible***. Hakea has specialised ***proteoid roots*** for abstracting nutrients from poor soils, if fertilising them, then choose one for Australian native plants. See Trees K 18, K 20.

Others: Overseas ***fly larvae or maggots*** (Cecidomyiidae, Diptera) assist in controlling introduced *Hakea* spp. which are ***potential weeds***.

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Associations. Journals etc.
GrowSearch (database Qld DPI)
See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Hakeas are endemic to Australia and of the 130 or so species, approximately half are found in the south west of WA (Wrigley 1988). Hakeas are evergreen woody plants that vary in size from < 1 m to > 10 m in height. Most are grown for their attractive, conspicuous flowers, their attractive nutlike woody fruits, their stiff broad leaves with toothed margins. They are fast growing and used for ***screening*** or ***windbreaks***. Many with sharp pointed leaves are called ***needle bushes*** and may be planted under windows to prevent burglaries. ***Propagated*** easily by ***seed***; in all but a few species the fruit remains intact until the bush dies or is damaged by fire; by ***grafting*** to make them more reliable in a wider range of conditions and to increase their ***tolerance*** to *Phytophthora*, and by ***cuttings***. Hakeas will grow in all climates except the coldest districts. They require a sunny, well drained sandy or gravelly soil for good flowering.

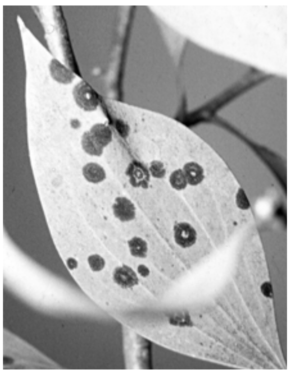

Fig. 256. Fungal leaf spot on *Hakea petiolaris.*

Fig. 257. Caterpillar (120 mm long) of the doubleheaded hawk moth (*Danima banksiae*).

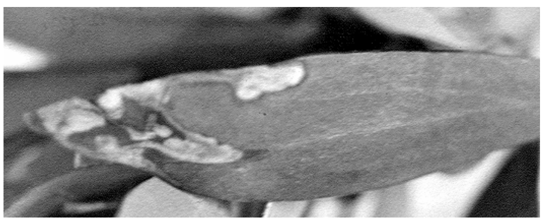

Fig. 258. Moth leaminer (Lepidoptera) damage to leaf tips.

Hardenbergia

False sarsaparilla (*H. violacea*)
Family Papilionaceae

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Fungal leaf spots
  - Powdery mildew
  - Rust
- **Nematode diseases**
  - Root knot nematode
- **Insects and allied pests**
  - Caterpillars

Non-parasitic
- Environment
- Weed potential

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots (*Elsinoe hardenbergiae,* other genera) may ***disfigure leaves*** of hardenbergia. Nursery stock of *Hardenbergia violacea* Happy Wanderer in Victoria may be severely affected by *Elsinoe hardenbergiae* during autumn, winter and spring when weather is cool. ***Susceptibility*** of other cultivars of *Hardenbergia violacea* is not known. Initially small brown spots, sometimes surrounded by yellow haloes, develop on ***leaves***, spots may enlarge to become angular, brown and scabby, coalescing to form large patches up to 5 mm in diameter. Reddish-brown spots 1-5 mm long develop on ***stems and petioles***. Severe infections can distort young growth and defoliate plants. Plants are non-saleable at flowering time. The fungus ***overwinters*** on stem lesions on nursery parent stock plants. Spores may be ***spread*** by wind and water splash. ***Prune out*** affected stems before taking cuttings for propagation. ***Discard*** rooted cuttings that are affected by disease. The nursery site should be cleared of any debris remaining from previously infected plants. Apply preventative ***fungicides*** to nursery stock thoroughly and frequently, during late autumn-early spring (Smith 1986). ***Other leaf spotting fungi*** may also attack hardenbergia including *Mycosphaerella*. See Annuals A 5.

Powdery mildew (*Oidium* spp.): A white powdery growth develops on upper and lower leaf surfaces, mainly on ***white cultivars*** of *H. violacea*. Avoid very shady, humid sites. See Annuals A 6.

Rusts (*Phakopsora pachyrhizi*, *Uromyces hardenbergiae*) have been recorded on *H. violacea*. See Annuals A 7.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne javanica*) has been recorded on *H. violacea*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera) of several moths feed on foliage and seeds.

Ivy leafroller (*Cryptoptila immersana*) caterpillars feed between joined ***leaves***. See Ivy K 88.
Painted apple moth (*Teia anartoides*) caterpillars may be ***very destructive***. See Pome fruits F 113.
Native seedeating moth (*Cydia zapyrana*) caterpillars feed on ***seed pods*** of *Hardenbergia* and *Glycine cladestina* from southern Qld to Victoria. *C. zapyrana* is related to ***codling moth*** (*C. pomonella*). See Pome fruits F 113.
Twig looper (*Ectropis excursaria*) feeds on ***foliage***. See Trees K 13.
Web moth (Pyralidae) caterpillars web chewed ***leaves*** and frass together. See Tea-tree K 124.

See Annuals A 8, Trees K 13.

Others
Crusader bug (*Mictis profana*) sucks shoot tips.
Green planthopper (*Siphanta acuta*)
Passionvine hopper (*Scolypopa australis*)
Pear and cherry slug (*Caliroa cerasi*)
Plague thrips (*Thrips imaginis*) may infest flowers.

Non-parasitic

Environment: Some species and cultivars may be sensitive to ***frost***. Tableland collections of *H. violacea* may be frost hardy but eastern states coastal collections may not be.

Weed potential: Hardenbergia may spread into ***surrounding areas*** or up on to ***trees***.

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See Australian native plants N 9, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Hardenbergias are hardy in well drained sites, preferring full sun or semi-shade and are suitable for trellis or ground cover. *H. violacea* in the eastern states may have white, pink or mauve flowers. *H. comptoniana* in WA is purple flowering but not as dark as its eastern counterparts. ***Propagate*** from ***leaf spot-free plants*** by cuttings to preserve ***clonal properties***, eg frost ratings and flower colour, or by scarified seed.

Hebe

Speedwell

Hebe spp., *Veronica* spp., *Parahebe* spp.
Family Scrophulariaceae

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Downy mildew (*Peronospora grisea*) has been recorded on *Hebe hulkeana* and speedwell (*Veronica arvensis*). See Annuals A 5.

Fungal leaf spots (*Septoria* spp.) are ***common and serious***. They occur on *Hebe speciosa, Veronica spicata* and *V. derwentiana*. ***Other leaf spotting species*** may also affect this group of plants. *Fusicladium veronicae* (= *Ramalia veronicae*) has been recorded on *Parahebe* sp. (Pascoe 1987). See Annuals A 5.

Powdery mildew (*Oidium* sp.) is ***common and serious***, and occurs on *H. speciosa* and *Veronica* spp. See Annuals A 6.

Root rots
Armillaria root rot (*Armillaria luteobubalina*)
Phytophthora root rot (*Phytophthora cryptogea, P. nicotianae* var. *parasitica*) on *H. speciosa.*
See Trees K 7.

Rust (*Aecium disciforme*) occurs on *V. calycina* and *V. gracilis* and the ***rust*** (*Aecidium veronicae*) on speedwell (*Veronica* spp.). See Annuals A 7.

NEMATODE DISEASES

Root lesion nematode (*Pratylenchus thornei*) has been recorded on *Veronica hederifolia* in SA (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Leafminer (*Platyptilia omissalis*, Pterophoridae) occurs widely in southern Australia. The caterpillars mine in and later feed on ***leaves*** of *Parahebe perfoliata* (Common 1990). An unidentified leafminer has been observed on *Hebe* sp. See Azalea K 28.
Rayed blue butterfly (*Candalides heathi*, Lycaenidae) caterpillars feed on *Parahebe derwentiana* (Common and Waterhouse 1981). See Annuals A 8, Trees K 13.

Scales (Hemiptera)

Soft scales (Coccidae)
Chinese wax scale (*Ceroplastes sinensis*)
White wax scale (*Gascardia destructor*)

See Citrus F 41, Trees K 16.

Others: ***Spittle bugs*** (Cercopoidea) may disfigure ***shoots*** occasionally.

Non-parasitic

Environment: ***Frost*** may damage some species. ***Hot, very dry areas*** are also unfavourable.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

These plants can be grown successfully ***in a wide range of climates***, but hot, very dry areas would be least suitable. Most species tolerate cold conditions but some may be damaged by severe frosts. Some tolerate exposed sites near the sea. ***Prune*** lightly after flowering to keep the bush compact. ***Propagated*** by cuttings or division. ***Harvest*** veronica when flowers are beginning to open (*V. bonariensis*) and 1/2 open (*V. longifolia*). Immediately place in water after harvest to prevent fast wilting. Use a floral preservative (Nowak and Rudnicki 1990).

Hibiscus

Hibiscus *spp.*
Family Malvaceae (mallow family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Hibiscus chlorotic ringspot
- **Bacterial diseases**
  - Bacterial leaf spot
- **Fungal diseases**
  - Branch and trunk cankers
  - Fungal leaf spots
  - Grey mould
  - Root and collar rots, wilts
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Cottonwood psyllid
  - Greenhouse whitefly
  - Hibiscus flower beetle
  - Leafmining moth
  - Mealybugs
  - Metallic flea beetles
  - Mites
  - Soft scales
  - Thrips
- **Snails and slugs**

Non-parasitic
  - Environment
  - Insects in flowers

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-DISEASES

Hibiscus chlorotic ringspot virus affects *Hibiscus* sp., Chinese hibiscus (*H. rosa-sinensis*). ***Leaves*** develop a mottle or many tiny yellow flecks, rings or veinbanding. Environmental factors, age of the plants or leaves, genetic diversity within the species or gene pool of individual plants, may reflect some of the reasons for the great genetic ***variability of symptoms*** in *H. rosa-sinensis* in nature. ***Spread*** by vegetative propagation (cuttings, budding, grafting), by mechanical inoculation (on sap on hands, tools or clothes). There is no vector. Remove infected plants. ***Do not vegetatively propagate*** from diseased plants. See Trees K 4.

Others: Overseas, several other virus-like diseases have been recorded in Malvaceae, eg ***tomato big bud*** (mycoplasma-like organism). ***Rugose leaf curl*** (rickettsia-like organism) has been recorded on *Hibiscus* spp.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas syringae* pv. *syringae*) causes large purplish spots on ***leaves***, especially on *H. rosa-sinensis* Apple Blossom. See Vegetables M 5.

FUNGAL DISEASES

Branch and trunk cankers
Stem canker (*Sphaeropsis hibisci*)
Grey mould (*Botrytis cinerea*) (see below)
See Trees K 5.

Fungal leaf spots (*Ascochyta*, *Phyllosticta,* many other species). Several species may cause brown or black circular or irregular shaped spots on leaves. ***Flyspeck*** (*Microthyriella hibisci*, Ascomycetes) affects Chinese hibiscus (*H. rosa-sinensis*). ***Leaves*** yellow and may fall. The black specks on the leaves are the fruiting bodies of the fungus, they are not always clearly visible. Serious damage is uncommon and ***control*** is not usually necessary. Overhanging larger plants may be pruned to provide more sun. See Annuals A 5.

Grey mould, flower blight (*Botrytis cinerea*) may affect ***flowers*** (blossom blight). Flower infections may grow into ***stems and branches*** of hibiscus causing elongated and sunken cankers. These may eventually encircle stems causing them to ***die***. See Greenhouses N 22.

Root and collar rots, wilts

Phytophthora collar rot (*Phytophthora* spp., *P. nicotianae*): Chinese hibiscus (*H. rose-sinensis*) is ***very susceptible*** and is often grafted on to tolerant rootstock. See Trees K 6.
Others:
Armillaria root rot (*Armillaria* sp.)
Stem rot of cuttings (*Rhizoctonia solani*)
Root and crown rot (*Phellinus noxius*)
Sclerotinia rot (*Sclerotinia sclerotiorum*)
Sclerotium base rot (*Sclerotium rolfsii*)
Verticillium wilt (*Verticillium dahliae*)

See Trees K 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) has been recorded on *H. cannabinus, H. rosa-sinensis, H. schizopetalus, H. sabdariffa* and *H. trionum.* ***Root lesion nematodes*** (*Pratylenchus* spp.) on *H. rosa-sinensis* and *H. subdariffa,* and ***ring nematode*** (*Criconema* sp.) and *Graciliacus steineri* on *H. rosa-sinensis*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) infest ***new shoots*** and ***open flowers*** making them unsightly.

Cotton aphid, melon aphid (*Aphis gossypii*) is blackish-green but varies from yellow to nearly black and occasionally causes ***leaf curling***.
Cowpea aphid (*Aphis craccivora*) is black with white legs and clusters on ***new shoots and flowers***. Aphids secrete copious amounts of honeydew on which sooty mould may grow. See Pea M 74.

See Roses J 4.

Bugs (Hemiptera)

Seed bugs, chinch bugs (Lygaeidae): ***Coon bug*** (*Oxycarenus arctatus*) is ***black and white***, winged and about ***3 mm*** long. They may swarm on hibiscus sucking sap from ***new shoots***. ***Cottonseed bug*** (*O. luctuosus*) feeds on ***Malvaceae***, eg Norfolk Island hibiscus, *H. rosa-sinensis* and cotton. Adults are small ***grey-black*** insects, about ***3 mm*** long. Adults and nymphs cluster on ***new shoots***, in and around buds, flowers and fruit, sucking sap causing distortion and wilting. Insecticides are registered for use.

Cotton harlequin bug (*Tectocoris diophthalmus,* Scutelleridae) feeds on ***young shoots*** of ***Malvaceae***, eg abutilon, cotton, native and exotic hibiscus, buds may drop. ***Adults*** are ***jewel bugs***, ***15-20 mm*** long and strongly convex. Females are yellow-orange with 6-8 small patches of metallic green or blue scattered over the body. Males are metallic green and blue with red patches and are smaller than females. ***Nymphs*** vary in colour with each moult

Others: Crusader bug (*Mictis profana*). ***Harlequin bug*** (*Dindymus versicolor*) and ***Rutherglen bug*** (*Nysius vinitor*) may cause ***bud drop***.

See Vegetables M 12.

Caterpillars (Lepidoptera): More than 20 moth species and 1 butterfly may infest hibiscus.

Budworms (Noctuidae), eg ***budworms*** (*Helicoverpa* spp.), are a ***major cause*** of ***bud drop***. Other budworms include ***bollworms*** (*Earias* spp.), ***cotton looper*** (*Anomis flava*). Also ***hairy leafeating caterpillars*** (*Xanthodes* spp.), ***looper caterpillars*** (*Chrysodeixis* spp.). See Sweetcorn M 89.

Common oakblue (*Arhopola micale amphis,* Lycaenidae) caterpillars feed on *H. tiliaceus.*

Cotton tipworm (*Crocidosema plebejana,* Tortricidae) caterpillars of this very small borer attack ***growing tips*** in spring, tip pruning plants. The loss of the growing tip prevents the green wood maturing into flowering wood. Regular sprays may be required.

Pink spotted bollworm (*Pectinophora scutigera*, Gelechiidae) is a minor pest of cotton in Qld, hibiscus is the native host plant. Caterpillars feed in ***seed capsules*** of ***Malvaceae***.

Others: Sandal-box hawk moth (*Coenotes eremophilae*, Sphingidae).

See Annuals A 8, Trees K 13.

Cottonwood psyllid

Cottonwood psyllid (*Mesohomotoma hibisci*, Carsidaridae, Psylloidea) is a ***sporadic pest*** of ***Malvaceae*** especially cottonwood (*H. tiliaceus*). ***Adults*** are fleshy brown insects about ***6 mm*** long, nymphs exude masses of ***white waxy filaments***. Colonies contain mixed stages and feed on young ***shoots and leaves***. Affected areas become covered with white waxy filaments exuded by the insects. Affected leaves may wilt and die (Jones and Elliot 1986). See Trees K 15.

Greenhouse whitefly

Greenhouse whitefly (*Trialeurodes vaporariorum*) are small, white, moth-like, about ***1-2 mm*** long. Nymphs are translucent, greenish and scale-like with fine waxy marginal filaments. Nymphs and adults suck sap from ***new shoots*** and ***leaf undersurfaces***. Sooty mould grows on the honeydew they excrete. See Greenhouses N 24.

Hibiscus flower beetle

Hibiscus flower beetle (*Aethina (Olliffura) concolor,* Nitidulidae, Coleoptera) is a ***serious pest*** of hibiscus, especially *H. rosa-sinensis* and magnolia in the tropics and subtropics. ***Beetles*** are black, oval, about ***3 mm*** long and are often found in large numbers in hibiscus ***flowers***. It is predominantly a ***pollen feeder,*** but may occasionally ***chew holes in petals***. If necessary spray but not when bees are present.

Leafmining moth

Leafmining moth (*Phyllonorycter stephanota,* Gracillariidae, Lepidoptera) mines in ***leaves*** of ***Malvaceae***, eg abutilon, hibiscus, *Sida subspictata* and *Malvastrum spicatum*. See Oak K 101.

Mealybugs (Pseudococcidae, Hemiptera)

Hibiscus mealybug (*Maconellicoccus hirsutus*)
Longtailed mealybug (*Pseudococcus longispinus*)
See Greenhouses N 25.

Metallic flea beetles

Metallic flea beetles (*Altica* spp., Chrysomelidae, Coleoptera) damage ***ornamentals***, eg dahlia, fuchsia, hollyhock, hibiscus, Norfolk Island hibiscus, zinnia, ***fruit***, eg avocado, rhubarb, ***vegetables***, eg cucurbits, lettuce, potato, sweet potato, ***weeds***, eg mallow. ***Beetles*** are small, shiny, metallic, purple-black up to ***6 mm*** long with thickened hind legs adapted for jumping. Beetles chew tiny holes of irregular shapes in ***young leaves and buds***. Leaves look as if they have been peppered with fine shot. See Australian native plants N 12 (Fig. 382). As leaves grow, the holes enlarge. ***Larvae*** are whitish, slender, delicate, cylindrical, ***3-8 mm*** when fully grown, with tiny legs and brownish heads. Larvae of most species feed in ***stems*** but seem to do little damage. ***Complete metamorphosis*** (egg, larva, pupa, adult) with possibly 1-2 generations each year. Little is known about the life cycle. ***Overwinters*** possibly as adult beetles in herbage. ***Spread*** by beetles flying and jumping, by introduction of infested plants carrying eggs, larvae, pupae and adults. ***Sanitation***: Control weeds in and around hibiscus, adults often feed and breed on weeds. ***Physical and mechanical methods:*** Young plants may be protected by fine gauze. Boxes or shields lined with a sticky material, eg tangle foot, may be placed over infested plants to catch beetles as they jump off infested plants. ***Insecticides*** may be applied at the first sign of damage but not when bees are present. See Trees K 15.

Mites (Acarina)

Hibiscus erinose mite (*Eriophyes hibisci,* Eriophyidae) causes disfiguring ***galls*** on ***leaves, buds, petioles and calyces*** on Chinese hibiscus (*H. rosa-sinensis*) (Carson 1992). Overseas it also affects okra. Pruning infested branches does not provide control. Badly affected shrubs should be removed and burnt or buried. ***Do not move*** infested cuttings or plants from infested areas to mite-free areas. ***Miticides*** have been approved for use. See Grapevine F 62.

Twospotted mite (*Tetranychus urticae*) may infest ***leaves*** and ***kill plants***. See Beans (French) M 29.

Soft scales (Coccidae, Hemiptera)

Black scale (*Saissetia oleae*)
Nigra scale (*Parasaissetia nigra*)
White wax scale (*Gascardia destructor*)
See Citrus F 41, Trees K 16.

Thrips (Thripidae, Thysanoptera)

Plague thrips (*Thrips imaginis*) feeds in ***flowers*** and buds causing premature browning. Buds may yellow and fall for other reasons, eg too much or too little water, too much chemical fertiliser. See Roses J 6.
Greenhouse thrips (*Heliothrips haemorrhoidalis*) causes ***leaf silvering***. See Greenhouses N 24.

Others: ***Ants*** (Formicidae) are attracted to honeydew produced by aphids, mealybugs and soft scales. ***Borers*** (unconfirmed species) may damage trunks. ***Leafhoppers*** (Cicadellidae) may suck sap from leaves, resulting in a stippling effect. ***Locusts*** (Orthoptera) of various species and katydids damage *H. tiliaceus* foliage. ***Millipedes and slaters*** which thrive in damp soils may damage cuttings and sprouting seeds.

SNAILS AND SLUGS

Snails and slugs may injure plants in damp, shady areas. See Seedlings N 70.

Non-parasitic

Environment: ***Bud drop*** commonly affects hybrid hibiscus, buds yellow and fall. Bud drop may be caused by ***insufficient water and fertiliser, excessive nitrogen*** associated with foliar fertilisers, or ***heavy infestations of insects***, eg budworms, thrips or hibiscus beetles. Regularly fertilise and water. Double-flowered forms seem ***more susceptible*** than singles. Bud drop is more severe in some seasons than in others and some varieties are more severely affected than others. If the variety is severely and continually affected remove and replace with another. See Camellia K 40. ***Oedema*** may occur on the native *H. arnhemensis* in greenhouses, white waxy lumps develop on stems which later turn black. See Geranium A 35. ***Frost:*** *H. rosa-sinensis*, *H. mutabilis* and *H. schizopetalus* prefer warm climates, *H. syriacus* thrives in cooler areas and ***tolerates frosts***. The native *H. tiliaceus* is widely grown in coastal Qld. *H. moscheutos* Southern Belle has a flower the size of a dinner plate, but dies back to the ground each year. ***Watering:*** Hibiscus need regular watering, well drained soil in the full sun.

Insects in flowers: ***Bees*** (*Lithurge* sp, Megachilidae, Hymenoptera) forage only on large flowered ***Malvaceae***, eg native hibiscus. Bees are dependent on ***nectar*** from flowers as their chief source of carbohydrates and on ***pollen*** as their chief source of protein. ***Flies*** (Chyromyidae, Diptera) are very small, stout, black and yellowish. Adults of *Aphaniosoma* and *Gymnochiromyia* occur on ***flowers***, eg of *Hibiscus, Santalum*. Maggots of *Gymnochiromyia* have been found in bat guana in Australian caves and in nests in British birds. ***Hibiscus flower beetle*** (*Aethina* (*Olliffura*) *concolor*) is predominantly a ***pollen feeder***. See Hibiscus K 82.

Others: ***Malathion and other insecticides*** may injure hibiscus. ***Senescence:*** Evergreen hibiscus naturally discard their old leaves several times a year. Larger older leaves at the base turn bright yellow a few days before dropping.

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State/Territory Departments of Agriculture/Primary Industry eg
Diseases of Cotton (NSW Agfact)
Insect Pests of Cotton (NSW Agfact)
Associations, Journals etc.
GrowSearch (database (Qld DPI)
Hibiscus Society of Qld

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

There are many different types of hibiscus so it is not possible to generalise. Some ***rootstocks***, eg Wilcox, have a degree of ***tolerance*** to *Phytophthora* and wet and dry conditions. Only plant ***disease and pest-free planting material***. ***Propagated*** by tip and hardwood cuttings, by tissue culture and grafting. Hibiscus require a ***regular watering and a fertilising*** program to look their best. Spent flowers should be ***removed*** every day to reduce pests. ***Bug Zappers*** are sometimes used at night (from dusk to dawn) to reduce budworm moths (*Helicoverpa* spp.), one of the main causes of bud drop. Different ***pruning*** practices are necessary for different types. *H. syriacus* should be cut back severely in the first few years to encourage a bushy framework. Some *H. rosa-sinensis* cultivars require harder pruning than others but none until the danger of frost has passed. ***Growth retardants*** may be used to dwarf, bunch, and attractively market, potted hibiscus (*H. rosa-sinensis*) for indoors in cold climates. *H. rosa-sinensis* may remain retarded for ***5 years***. ***Potted hibiscus*** (*H. rosa-sinensis)* are retailed at the beginning of flowering. During storage and transport prior to sale, potted plants will not tolerate more than 3 days of darkness and are highly sensitive to ethylene which may cause buds and flowers to drop (Nowak and Rudnicki 1990).

Holly

Ilex spp.
Family Aquifoliaceae

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Damping off
  - Fungal leaf spots
- **Insects and allied pests**
  - Scales
  - Twospotted mite
- **Vertebrate pests**

Non-parasitic
- Environment
- Sooty mould
- Spine damage

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Damping off (various species, overseas *Cylindrocladium scoparium*, *Phytophthora* spp.) may occur on ***cuttings***. See Seedlings N 66.

Fungal leaf spots (various species) may occur occasionally. See Annuals A 5.

INSECTS AND ALLIED PESTS

Scales (Hemiptera) may be ***serious pests*** of holly. Vast amounts of honeydew are produced by soft scales, the associated sooty mould and ants ***disfigure*** plants.

Armoured scales (Diaspididae)
- Circular black scale (*Chrysomphalus aonidium*)
- Greedy scale (*Hemiberlesia rapax*)
- Oleander scale (*Aspidiotus nerii*)
- Purple scale (*Lepidosaphes beckii*)

Soft scales (Coccidae)
- Black scale (*Saissetia oleae*)
- Pink wax scale (*Ceroplastes rubens*)
- Soft brown scale (*Coccus hesperidum*)

See Citrus F 39, F 41, Trees K 16.

Twospotted mite (*Tetranychus urticae*) may infest holly grown in ***greenhouses***. See Beans (French) M 29.

Others: There are many more insect pests of holly overseas. In America, these include ***holly leafminer*** (*Phytomyza ilicis*, Diptera) and ***southern red mite*** (*Oligonychus ilicis,* Tetranychidae, Acarina).

VERTEBRATE PESTS

Birds may eat ***berries***. See Fruit F 13.

Non-parasitic

Environment: ***Lack of water*** during hot dry weather, or ***sunburn***, may cause ***leaves*** to brown. Dead areas are colonised by ***secondary fungi***.

Sooty mould (various fungi) indicates the presence of honeydew-secreting ***soft scale insects***, eg black scale, pink wax scale or soft brown scale. See Trees K 19.

Spine damage may occur when ***leaves*** are ***punctured*** by the spines of adjacent leaves.

Others: Holly berries contain ***toxic substances*** (Frohne and Pfander 1983).

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Holly prefers cool climates and full sun, and plenty organic matter in the soil. Trees require irrigation in hot dry weather. Only propagate from ***scale-free*** trees. ***Propagate*** by seeds, cuttings, grafting, budding, air-layering. ***Harvest*** English holly (*Ilex aquifolium*, *I. aquifolium* Albo-marginata) when leaves are fully mature, and it may have a ***vase life*** of up to 2 months. Cut stems on an angle with a sharp knife, change vase solution every 2 days and place in deep water and top up regularly as woody stems are thirsty. Warm water may help to ease the flow of water up stems. Defoliate if necessary to allow berries to be seen. Spraying with hair spray or clear fixative is sometimes recommended to prevent berries from shrivelling too quickly (Jones and Moody 1993). After harvest holly can be ***stored*** for 1-3 weeks in moisture-retentive boxes at $0^{o}C$ (Nowak and Rudnicki 1990).

Honeysuckle

Lonicera spp.
Family Caprifoliaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Fungal leaf spots
  - Powdery mildew
- **Insects and allied pests**
  - Caterpillars
  - Greenhouse whitefly
  - Honeysuckle aphid
  - Scales
  - Wingless grasshopper

Non-parasitic
  - Potential weed

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tobacco leaf curl virus affects honeysuckle in Australia, overseas also tobacco, tomato, green capsicum, common thornapple, *Ageratum conyzoides, Zinnia elegans*. The main symptom is ***vein yellowing*** which is considered to give variegated honeysuckle (*Lonicera japonica* Aureo-reticulata) its ***horticultural value***. ***Overwinters*** in infected honeysuckle, possibly other hosts. ***Spread*** by cotton whitefly (*Bemesia tabaci*, Aleyrodidae), by cuttings, by grafting, not by contact between plants, not by seed (Buchen-Osmond et al. 1988).

Others: Overseas, cucumber mosaic virus may cause distorted leaves and ringspots; lonicera latent virus may cause mottled leaves in *L. periclymenum* and is transmitted by aphids, eg ***honeysuckle aphid*** (*Hyadaphis foeniculi*) (Cooper 1993).

See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots: ***Several species*** including *Cercospora*, *Septoria,* may cause minor leaf spotting. See Annuals A 5.
Honeysuckle leaf blight (*Insolibasidium deformans*) Vic

Powdery mildew (*Oidium* spp.) is a ***serious disease*** of ***young cuttings*** of ***variegated honeysuckle*** (*L. japonica* Aureo-reticulata) in humid conditions. Cuttings may ***die***. Powdery mildew causes a white fungal growth mainly in spring and early summer on new foliage. Plant cuttings in ***well ventilated sites***. It may be necessary to apply ***fungicides*** to cuttings as new leaves emerge. See Annuals A 6.

INSECTS AND ALLIED PESTS

Caterpillars (Tortricidae, Lepidoptera)
Ivy leafroller (*Cryptoptila immersana*)
Lucerne leafroller (*Merophyas divulsana*)
See Annuals A 8, Ivy K 88.

Greenhouse whitefly (*Trialeurodes vaporariorum*) may result in ***leaf blackening*** overseas. See Greenhouses N 24.

Honeysuckle aphid (*Hyadaphis foeniculi,* Aphididae, Hemiptera) is greenish and occasionally attacks ***young shoots*** of honeysuckle and flower heads of hemlock. Overseas this aphid may spread virus diseases. See Roses J 4.

Scales (Hemiptera)

Armoured scales (Diaspididae)
White palm scale (*Phenacaspis eugeniae*)
Probably other species including:
Greedy scale (*Hemiberlesia rapax*)
Oystershell scale (*Quadraspidiotus ostreaeformis*)
San Jose scale (*Q. perniciosus*)

See Citrus F 39, Trees K 16.

Wingless grasshopper (*Phaulacridium vittatum*) may sporadically damage honeysuckle and is not usually noticed until ***after insects have gone***. Plants damaged severely one year may suffer no damage during subsequent years. See Vegetables M 14.

Non-parasitic

Potential weed: Honeysuckle may be an ***invasive weed*** and may need containment.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Honeysuckle may be semi-deciduous or evergreen, with fragrant spring flowers which are creamy, yellow, pink or red, depending on the species. It is ***very adaptable*** to climate and soil, plants may be pruned after flowering to keep them contained. Giant Burmese honeysuckle (*L. hildebrandiana*) requires a warm situation protected from frosts.

Hydrangea

Hydrangea macrophylla
Family Saxifragaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Hydrangea ringspot virus is considered to infect 91-98% of *H. macrophylla* worldwide (Larson 1992). ***Foliage*** symptoms include stunting, chlorotic spots and rings on older leaves, leaf crinkling and asymmetry, some necrotic stem-pitting and fewer and smaller florets on short stalks in the cymes. Symptoms vary with ***environment and season***. ***Spread*** by pruning knives, by leaf contact, but not by insects and not by seed. ***Virus-free hydrangea*** have been developed overseas but are not widely available at present. Only take cuttings from ***virus-free plants*** and ***sterilise*** pruning knives.

Virescence: Mycoplasma-like bodies, possibly tomato big bud mycoplasma (greening), may cause ***abnormal inflorescences*** with phyllody (sepals instead of being pink, white or blue have reverted to green leaves) and distorted growth especially at production temperatures > 19^{o}C. In some instances ***leaves*** have vein yellowing and may be unusually small (Cooper 1993). See Tomato M 97.

Others: Overseas, also arabis mosaic virus, cucumber mosaic virus, tobacco rattle virus, tobacco ringspot virus, tomato ringspot virus. Some of these viruses are considered to be more damaging than hydrangea ringspot virus, and may be present in combination. Some are ***spread*** by aphids as well as by other means. Irrespective of the virus, symptoms expressed ***differ with the cultivar*** and are dependent on ***environmental conditions*** (Cooper 1993).

Take cuttings only from ***virus-free plants. Sterilise*** pruning knives. Only ***commercial nurseries*** may attempt to control any viruses spread by insects using insecticides. See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots (unconfirmed species of *Alternaria*, *Phyllosticta hydrangea*). Many more species may affect hydrangea overseas. See Annuals A 5.

Grey mould (*Botrytis cinerea*) is the ***most damaging disease*** of hydrangea in humid conditions. ***Buds, flower heads and stems*** may rot particularly during propagation. Cultivars vary in ***susceptibility***, Kuhnert and Strafford are most resistant while Merveille and Rose Supreme are least resistant (Bailey 1989). See Greenhouses N 22.

Powdery mildew (*Microsphaera polonica*) is a ***common and serious disease*** of hydrangea in humid conditions both outdoors and in greenhouses. White powdery spots on ***leaves*** may later turn ***blackish***. This can make the disease ***difficult to diagnose***. See Annuals A 6.

Root and stem rots
Armillaria root and stem rot (*Armillaria mellea*)
Sclerotium stem rot (*Sclerotium rolfsii*)
Overseas also *Phytophthora* and *Rhizoctonia*
See Trees K 7, Vegetables M 7.

Others: ***Silver leaf*** (*Stereum purpureum*).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) on *Hydrangea* sp. Overseas also ***root lesion nematode*** (*Pratylenchus* sp.), ***foliar nematode*** (*Aphelenchoides* sp.) and ***stem and bulb nematode*** (*Ditylenchus* sp.). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest ***new leaves***. See Roses J 4.

Greenhouse whitefly (*Trialeurodes vaporariorum*) may infest hydrangea in ***greenhouses***. See Greenhouses N 24.

Hydrangea scale (*Pulvinaria hydrangeae,* Coccidae, Hemiptera) infests ***leaves and stems*** of hydrangea, camellia, other plants. ***Adult scales*** are oval and about 3 mm long. Towards the end of spring, females produce soft, white, waxy ***ovisacs*** which hold the eggs and are up to ***15 mm*** long. The dead female scale can be seen at one end of the ovisac. When eggs hatch, young scales or crawlers settle under leaves and on stems, sucking sap. When winter arrives they enter a resting stage and only become active again in the spring when they commence feeding and become adults. Although infestations are often only noticed when the ovisacs are produced, ***control is difficult*** at this stage because of the quantities of wax present. If considered necessary, apply ***insecticide*** when most of the eggs have hatched in early summer and cover leaf undersurfaces and stems. About 4 weeks after spraying, ***dead scales*** will be dry or produce a thick liquid if squashed. ***Living scales*** produce a watery liquid, if many of these occur, spraying should be undertaken again. Overseas, ***apple mussel scale*** (*Lepidosaphes ulmi*, Diaspididae) may also infest stems of hydrangea. See Citrus F 41, Trees K 16.

Spider mites (Tetranychidae, Acarina)

Hydrangea spider mite (*Tetranychus hydrangea*) may ***severely damage*** hydrangea during spring. ***Foliage*** becomes severely mottled; cup-like blisters develop on younger leaves. ***Flower heads*** are deformed, reduced in size and show irregular part-coloured mottled affect.

Twospotted mite (*T. urticae*) may cause leaf mottling of leaves especially in ***greenhouses***. See Beans (French) M 29.

SNAILS AND SLUGS

Snails may ***severely damage*** young plants, especially of oakleaf hydrangea (*H. quercifolia*). See Seedlings N 70.

Non-parasitic

Environment: Leaves especially of ***variegated varieties*** may be scorched by ***sun***.

Flower colour: The colour of flowers, in all except the white or greenish cultivars, is influenced by the ***pH*** of the soil. If the ***soil*** is ***strongly acid flowers*** will be ***deep-blue***; aluminium sulphate and iron sulphate may be used to reduce the pH, ie to make the soil more acid; commercial bluing tonics are available. If the ***soil*** is ***slightly alkaline flowers*** will be ***clear pink or rosy-red***; lime and magnesium sulphate may be used to increase the pH, ie to make the soil more alkaline. There is a range of pale-blues, mauves and pale-pinks in between. Flowers of white and coloured varieties may ***green during senescence***. Altering the ***pH*** also influences the ***availability of iron*** and other nutrients.

Lack of flowers may be due to ***severe pruning***, 2 or 3 pairs of buds must be left at the base.

Nutrient deficiencies, toxicities: ***Iron deficiency*** (chlorosis) may cause yellowing between the veins of new leaves if soil is ***alkaline***. See Azalea K 29, Citrus F 43. ***Magnesium and potassium deficiencies*** may also occur in artificial media.

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State/Territory Departments of Agriculture/Primary Industry eg

Hydrangea Culture (SA Adel. Bot. Gar. Leaflet)

Associations, Journals etc.

GrowSearch (database Qld DPI)

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Hydrangea are grown in gardens, in containers outdoors and indoors and are used as dried flowers. Only plant ***virus and scale-free plants***. ***Propagated*** by cuttings. Hydrangeas are best suited to cool moist climates, if grown in cold areas, they must be protected from frost. Strong dry winds or hot sun will burn foliage. Water well in hot weather. ***Prune*** by removing old woody stems down to the lowest double bud. Unflowered shoots with single terminal buds should be left unpruned. ***Pasteurise media*** for propagation and containers, control weeds and dispose of dead plant material to reduce *Botrytis* inoculum. ***Examine plants regularly*** for diseases and pests. ***Harvest for cut flowers*** when cool; cut stems, give a long drink, use a floral preservative and vase life should be excellent. ***For drying flowers*** cut late in season, then put in 30 mm water; do not add any extra water and keep out of sunlight to prevent fading (Jones and Moody 1993). ***Retail potted plants*** at the beginning of flowering. Plants grow best in bright, indirect light, but they also tolerate shade. They need a temperature of 14-18^{o}C, abundant water and high air humidity and periodic fertilisation. The large leaves and plentiful flowers accelerate transpiration, so watering should be carefully monitored (Nowak and Rudnicki 1990). ***Lack of watering*** by retailers or consumers is probably the ***most frequent cause*** of ***short post-greenhouse life***. When flowering is finished consumers can re-bloom hydrangeas by cutting the plants back and following basic propagation procedures (Larson 1992).

Ivy

English ivy *(Hedera helix)*
Family Araliaceae

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Bacterial leaf spot
Fungal diseases
Fungal leaf spots
Root rots
Insects and allied pests
Aphids
Caterpillars
Mites
Scales
Snails and slugs
Non-parasitic
Environment
Fungi (lichens, slime moulds, sooty mould)
Smothering effect
Weed potential

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas, yellow veinbanding, blotches and broad ring patterns on ivy ***leaves***, have been attributed to various viruses, eg arabis mosaic virus, strawberry latent ringspot virus. See Trees K 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Xanthomonas campestris* pv. *hederae*) causes small, round pale green spots on ivy ***leaves***. These gradually enlarge becoming more angular, centres become dark brown to black and margins reddish brown, sometimes cracking. Leaves may yellow and fall. Spots may also be formed on ***petioles and stems***. Use a pesticide only as last resort. See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots may produce rather ***spectacular spots*** with fruiting bodies arranged in concentric circles. Others, in addition to causing leaf spots, cause ***twig blights***. Leaves may yellow and fall, plants look ragged. Leaf spots are not often important on ivy plants in gardens.

Anthracnose, fungal leaf spot (*Colletotrichum trichellum*) affects ivy during cool spring weather and plants growing in cool damp situations. ***Leaves*** develop brown, circular spots, then yellow and fall. See Fruit F 5.
Leaf blight (*Alternaria panax*) can infect Araliaceae, eg ivy, also umbrella tree (*Schefflera actiniphylla*), dwarf umbrella tree (*S. arboricola*), fatshedera (*Fatshedera*), *Aralia*, *Panax*, *Polycias*, *Dizygotheca*.

Circulation may be improved by ***trimming back*** the ivy and perhaps ***pruning*** surrounding trees. On individual plants infected leaves may be removed and destroyed. ***Fungicides*** may be applied to ***nursery stock***. See Annuals A 5.

Root rots

Phytophthora rots (*Phytophthora* spp.) may cause ***leaf spots, foliage blights*** as well as root rots (Bodman et al. 1996).
Others: Thielaviopsis black root rot (*Thielaviopsis basicola*); ***Pythium sp.*** may cause root rots overseas

See Trees K 7, Vegetables M 7

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Ivy aphid (*Aphis hederae*)
Aphids may cause ***leaves*** to ***roll under***. See Roses J 4, Trees K 10.

Caterpillars (Lepidoptera)

Ivy leafroller (*Cryptoptila immersana,* Tortricidae) infests ***ornamentals***, eg hardenbergia, ivy, kennedia, *Clematis glycinoides*, *Eustrephus latifolius*, a cycad (*Bowenia serrulata*), fern (*Acrotrichum aureum*), honeysuckle, privet, poplar, lantana, rose, ***fruit***, eg avocado, citrus, strawberry, blackberry, apricot. ***Caterpillars*** are yellowish-green with 4 prominent black wedge-shaped marks on the white head capsule. They feed between ***webbed leaves*** causing ***serious damage***. Several natural enemies attack ivy leafroller, including the ***predatory*** larvae of a hover fly, and several ***parasitic*** wasps and flies. The extent to which they exert control depends on the disruption caused by pesticides applied to control other pests (Brough et al. 1994). See Avocado F 19.
Twig looper (*Ectropis excursaria*, Geometridae) caterpillars ***commonly*** damage ivy and many other exotic and native plants. See Trees K 13.
Others: Caterpillars of a ***blue butterfly*** (*Candalides consimilis*) ***commonly*** feed on ivy.

See Annuals A 8, Trees K 13, Vegetables M 13.

Mites (Acarina)

Ivy mite (*Bryobia kissophila*) is a spider mite (Tetranychidae) which occurs overseas. It is only distinguishable from ***bryobia mite*** (*B. rubrioculus*) in its biology. No eggs are laid in cold weather, 6-8 generations occur throughout the year overseas. ***Overwinters*** in all stages. Mites congregate on twigs during the day and spread out at night to feed on ***leaves*** causing a faint white leaf mottle. See Fruit F 12.
Twospotted mite (*Tetranychus urticae*) may infest ivy grown ***indoors*** in warm dry positions. ***Leaves*** develop a faint sandy mottle, become whitish and may fall. See Beans (French) M 29.

Scales (Hemiptera)

Armoured scales (Diaspididae):
Oleander scale, ivy scale (*Aspidiotus nerii*)
Red scale (*Aonidiella aurantii*)
Soft scales (Coccidae):
Pink wax scale (*Ceroplastes rubens*)
Soft brown scale (*Coccus hesperidum*)

See Citrus F 39, F 41, Trees K 16.

Others: ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***passionvine hopper*** (*Scolypopa australis*).

SNAILS AND SLUGS

Snails and slugs may be a problem on ***neglected ivy*** grown as ground cover. See Seedlings N 70.

Non-parasitic

Environment: Leaves may be ***sun scorched*** if ivy is grown in sunny exposed sites, eg leaves face west, or plants are in containers. ***Oedema*** may occur on ivy especially on container plants. On ***leaf undersurfaces*** raised pinhead-sized blisters or corky pimples develop. Sometimes the whole of the leaf undersurface may be affected. Growth is otherwise normal and only market quality may be affected. Oedema usually occurs ***when water uptake exceeds water loss***, so that water-filled areas occur in and around the stomata especially on leaf undersurfaces. This condition develops when relative humidity and soil temperatures are high. The larger and more vigorous the root system, the greater the water uptake and the more severe the problem. Sometimes oedema can be caused by ***sprays or deposits on leaves*** which seal the stomata and other pores. Oil-based sprays or those which contain spraying oil are known to have this effect. Sometimes damaged leaf tissue becomes colonised by ***secondary pathogens***, eg *Alternaria*, *Botrytis* or soft rotting bacteria. Oedema may be ***prevented*** by avoiding high relative humidities and high soil temperatures especially when plants are growing vigorously. Avoid frequent applications of oil-based sprays. Space affected plants to allow air circulation, and water sparingly. ***Inspect plants regularly*** for the development of secondary rots (Fletcher 1984). See Camellia K 40, Geranium A 35.

Fungi: ***Lichens*** and ***slime moulds*** may grow on leaves close to the ground. ***Sooty mould*** (various species of fungi) will grow on honeydew from aphids and soft scales infesting ivy or overhead trees. See Trees K 19.

Smothering effect: Ivy foliage may ***smother*** trees. Ivy with ***suckers*** (small adhesive aerial roots on its stems) may leave marks on bricks and will lift bricks if there are cracks for shoots to get into.

Weed potential: ***Seed*** is spread by ***birds*** to other gardens and urban bushland. When ivy is established it is ***difficult to eradicate***.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Ivy is a ***low maintenance*** plant used for nature strips and as an indoor plant. English ivy (*Hedera helix*) is used for hanging baskets, and runners may be trained on supports and trellises on walls. Long shoots or trails of cultivars of the common ivy (*H. helix*) and the leaves of *H. canariensis* and the creamy blotched cultivar *H. canariensis* Variegata, may be used by ***florists***. Since ivy is susceptible to caterpillar and slug and snail damage, as well as fungal leaf spots, ivy for ***cutting*** is best grown on wire supports. ***Propagated*** by seeds, cuttings, grafting, budding, air layering. Proper control of environmental factors is necessary if ivy is being grown as a foliage plant. It will tolerate deep shade and freezing without injury (Larson 1992, Nowak and Rudnicki 1990). Ivy should be ***pruned*** frequently to stimulate bushy growth. In summer ivy prefers abundant water, in winter it needs only moderate watering (depends on the temperature). ***Harvest*** foliage on fully mature stems. Ivy has a ***vase life*** of 1-2 weeks and may be ***stored*** at 2-4^{o}C for 2-3 weeks in a preservative solution (Larson 1992). ***Retail potted ivy*** when plants are well established in pots.

Kennedia

Kennedia spp.
Family Fabaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Kennedya Y virus may infect dusky coral pea (*Kennedia rubicunda*) causing a mild marble mosaic on leaves. ***Not spread*** by vectors or by seed.

Kennedya yellow mosaic virus may infect *K. rubicunda*, *Desmodium triflorum*, *D. scorpiurus*, *Indigofera australis, Clitoria ternata.* Symptoms include mild yellow local lesions and a systemic ***bright blotchy yellow mosaic*** on ***leaves***. See Australian native plants N 3 (Fig. 369). ***Not spread*** by vectors, by contact between plants, by seed, or by pollen.

Potato Y virus in WA on coral vine (*K. coccinea*). ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), cotton aphid (*Aphis gossypii*), by grafting. See Potato M 77.

See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots (various unconfirmed species of fungi). See Annuals A 5.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*). See Trees K 4.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) have been recorded in SA and Qld on running postman (*K. prostrata*). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Caterpillars (Lepidoptera)

Ivy leafroller (*Cryptoptila immersana*) caterpillars feed between ***webbed leaves***. See Ivy K 88.

Pea blue butterfly (*Lampides boeticus*) caterpillars when young, tunnel into ***flowers*** and later into ***pods***, feeding on developing seeds. See Pea M 74.

See Annuals A 8, Trees K 13.

Leafminers (Lepidoptera)

Moth (*Phyllonorycter aglaozona,* Gracillariidae) caterpillars form characteristic ***tentiform mines*** in ***leaves*** of *K. rubicunda*, *Glycine*, *Desmodium*, French bean. ***Moths*** are black and white. ***Caterpillars*** form a small mine in which the silk lining causes the epidermis to contract to form a characteristic cell. See Oak K 101.

Moth (*'Stigmella'* spp., Nepticulidae) ***caterpillars*** form ***spiral*** then ***tortuous mines*** in ***leaves*** of *K. rubicunda* in coastal NSW. Faecal material is deposited in a thin central line throughout the length of the mine, except for the last few millimetres before the larva leaves it. Caterpillars spin their cocoons in August-early September. ***Moths*** have an ochreous brown head, white eye-caps and dark forewings with shining whitish transverse bands. See Correa K 51.

See Azalea K 28.

Non-parasitic

Environment: Most species of *Kennedia* are ***frost sensitive***. Frost tolerant species include *K. retrorsa.*

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Kennedia are grown for ground cover, climbers or in containers. Most species prefer sunny, well drained positions and grow vigorously when planted out. Weeds are not a major problem, but there are exceptions. ***Propagated*** by scarified seed, or semi-ripe cuttings in summer. ***Water*** moderately when in growth and keep dry but not arid in winter. ***Prune*** after flowering to remove overcrowded growth.

Kurrajong

Kurrajong (*Brachychiton populneus*)
Family Sterculiaceae

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spot (*Phyllosticta sterculiae*) and ***tar spot*** (*Phyllochora* spp.) occur on bottlebrush, fig and native plants. See Annuals A 5, Bottlebrush K 36.

Root rots:* *Armillaria root rot (*Armillaria luteobubalina*) and ***phytophthora root rot*** (*Phytophthora palmivora*). See Trees K 7.

Wood rots (Basidiomycetes): *Fomes*, *Polyporus*. See Trees K 8.

PARASITIC PLANTS

Mistletoe (Loranthaceae) may infest kurrajongs especially ***during drought***. Removing affected branches just below the point of attachment is recommended during winter so that cut surfaces are not exposed to ***insect attack***. See Trees K 9.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.), ***spiral nematode*** (*Helicotylenchus*, *Rotylenchus*) and *Paralongidorus*, *Pateracephalanema*, *Scutellonema, Tylenchorhynchus,* are associated with kurrajong in Qld and the NT. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Kurrajong weevil, mimic bark weevil (*Axionicus insignis,* Curculionidae, Coleoptera) is an ***important pest*** of kurrajong. ***Weevils*** are about ***12 mm*** long, appear grey and are ***difficult to detect*** on the bark of the tree. Having a protective coloration, they remain half hidden in the cracks and crevices in the bark of trees during the day (mimic bark weevil). White scales form patches on the thorax and towards the tip of the wing covers. Adults may be found throughout the year on the trunks of trees. ***Larvae*** are up to ***12 mm*** long, stout, legless, with white bodies and small reddish heads. Eggs are laid in the branches and trunks of kurrajong trees and larvae honeycomb the ***wood*** with ***round tunnels*** packed with frass. When fully-fed they pupate in the end of one of these burrows. Later adults emerge and the tree is riddled with ***exit holes***. ***Favoured*** by stressed trees or those injured by stock or careless pruning. Damaged or dying branches are susceptible to attack. ***Control*** by removing or repairing damaged limbs promptly. Bark or pruning scars may be sealed using a recommended grafting paint, fertilise trees. Insecticides are of little value.

Large auger beetle (*Bostrychopsis jesuita*) attacks ***freshly dead wood*** of *Brachychiton* spp. which must contain starch. ***Beetles*** are about ***12 mm*** long. ***Larvae*** are about ***10-12 mm*** long. Larvae are active September through to April. Trees are usually dead so that no treatment is usually justified. See Trees K 11.

Caterpillars

Caterpillars (Lepidoptera) of > 10 species of butterflies and moths feed on *Brachychiton* spp. (Common and Waterhouse 1981, Common 1990).

Butterflies:* *Common aeroplane (*Phaedyma shepherdi shepherdi,* Nymphalidae), ***eastern flat*** (*Netrocoryne repanda*, Hesperiidae), ***helenita blue butterfly*** (*Candalides helenita helenita*, Lycaenidae), ***pencilled blue butterfly*** (*Candalides absimilis,* Lycaenidae), ***tailed emperor butterfly*** (*Polyura sempronius,* Nymphalidae). See Wattle K 133.

Kurrajong leaf-tier (*Lygropia clytusalis,* Pyralidae) caterpillars are ***pests*** of the ***foliage*** of *Brachychiton* spp., especially kurrajong and Illawarra flame tree (*B. acerifolium*). ***Moths*** have a wingspan of about 25 mm and are pale orange with irregular wavy black bands across them. ***Caterpillars*** are light-green, agile and about ***25 mm*** long. They always feed in a group and web ***leaves*** together to form a shelter (bag) up to 250 mm long which makes trees look ugly (Fig. 259). Caterpillars do some feeding within their shelter but also come out at night to feed on other leaves. They pupate inside the shelter, and moths emerge. Occurs in eastern and inland Australia from December to April. Because the caterpillars are in bags during the day, ***bags*** can be cut off and burnt. If the bags cannot be removed, ***insecticides*** (plus a wetting agent) may be applied to small trees only.

Moth (*Tonica effractella*, Depressariidae) caterpillars tunnel in ***swollen shoots and leaf petioles*** of young *Sterculia, B. paradoxum* and cotton. The tunnel entrance is roomy and covered by a web of silk incorporating faecal pellets. Caterpillars feed on the ***bark regrowth*** in this vestibule in much the same way as fruit-tree borers. The plant responds to this activity by producing a ***gall-like swelling*** which often cracks irregularly as caterpillars near maturity. Caterpillars pupate nearby on the food plant.

Noctuids (Noctuidae): ***Hairy leafeating caterpillar*** (*Xanthodes congenita*) is a minor pest of cotton, hibiscus and *B. paradoxum*. Also a ***moth*** (*Chasmina pulchra*).

Yellow peach moth (*Conogethes punctiferalis*, Pyralidae) caterpillars feed on ***seed capsules*** and ***leaves*** of the flame tree (*B. acerifolium*). See Stone fruits F 133.

See Trees K 13.

Gall wasps (*Megastigmus,* Torymidae, Hymenoptera) have been reared from ***stem, leaf and flower galls*** on a variety of plants, eg *Acacia, Banksia, Brachychiton*, *Citrus*, *Eucalyptus*, *Hakea, Helichrysum,* often in association with other insects. *Megastigmus* is cosmopolitan, and commonly yellow-brown, sometimes with metallic patches. These unusual ***bottle-shaped galls*** are quite common on the undersides of *Brachychiton discolor* (Hockings 1980). Heavily infested ***leaves*** are ***seriously disfigured***. See Trees K 14.

Kurrajong pod beetle (*Idaethina froggatti,* Nitidulidae, Coleoptera) is a driedfruit beetle which only attacks ***kurrajong seed pods***. No control is required as seed germination does not seem to be affected. ***Beetles*** are about ***3 mm*** long, flat, reddish brown, the upper surface and eyes are covered with fine hairs. ***Larvae*** are up to ***5 mm*** long, elongate reddish-brown to yellowish and feed amongst seeds and upon the soft inner parts of the pod. See Fruit F 8.

Kurrajong psyllids (Psyllidae, Hemiptera) ***seriously disfigure*** young growth of kurrajongs.

Kurrajong star psyllid (*Protyora sterculiae*) nymphs aggregate on ***leaves*** and have a star-shaped tuft of white waxy filaments at the end of the body (Fig. 260). ***Adults*** are about 3 mm long, pale green with red eyes, body segments are marked with black. Two pairs of transparent wings are held in a roof-like manner over the back when at rest. Eggs are laid on leaf uppersurfaces in groups of 30-40.

Kurrajong twig psyllid (*Aconopsylla sterculiae*) nymphs are dull yellow with light brown markings and red eyes. They congregate on the ***young bark of twigs***. ***Adults*** are < 2 mm long and more robust than the star psyllid. Body is yellowish to reddish-brown, the head and parts of the thorax are black. Wings are light brown and semi-opaque. Yellow eggs are laid in groups at the tips of young twigs or on the foliage between the forks of branchlets.

Both psyllids secrete ***honeydew*** which is attractive to ants. Parasites and predators normally keep these psyllids in check. Control is seldom required except in ***nursery situations***. See Eucalypt K 62, Trees K 16.

Kurrajong seed weevil (*Tepperia sterculiae,* Curculionidae, Coleoptera) may hide in crevices on the ***bark*** during summer, and like the bark weevil, is ***difficult to detect***. The female bores into the ***side of the pod*** and lays eggs in the seed. 4-5 larvae develop in each pod. ***Larvae*** are stout, legless with reddish-brown heads, they pupate in the empty shell of the seed within the pod. Larvae also develop in the large fleshy galls or abnormal growth on ***twigs***. ***Weevils*** are about ***8 mm*** long, reddish-brown, and emerge in spring. Where seed production is important, pods can be protected by covering them with plastic, or a lower yield accepted. Normally enough undamaged seed is produced, no chemical control is required.

VERTEBRATE PESTS

Rabbits and hares may damage ***young trees*** after planting out. Protect with netting. See Fruit F 13.

Non-parasitic

Environment: Kurrajong will withstand ***frost*** and drought once established. ***Excess water*** is harmful.

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State/Territory Departments of Agriculture/Primary Industry eg

The Kurrajong (NSW Agfact)

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Kurrajong is grown for fodder, shelter and ornamental purposes. Most *Brachychiton* spp. are deciduous, but kurrajong (*B. populneus*) is evergreen, frost hardy and grows in most well drained soils (Wrigley 1988). Drought-stressed trees or those that have been pruned too hard are especially ***susceptible*** to insect attack. Do not ***prune*** > 25% of the crown foliage except in good seasons. ***Propagated*** by seed.

Fig. 259. Bag-shelters of the kurrajong leaf-tier (*Lygropia clytusalis*). Forestry Com. of NSW.

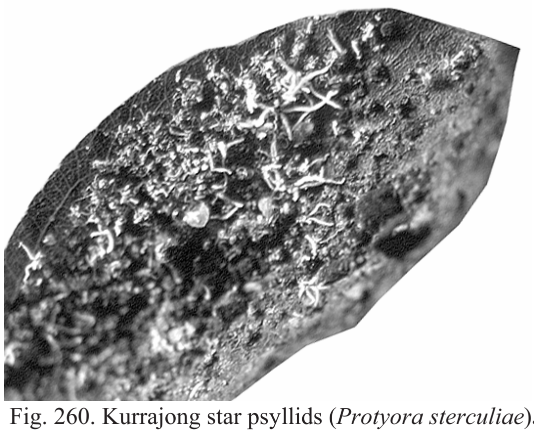

Fig. 260. Kurrajong star psyllids (*Protyora sterculiae*).

Lavender

Lavandula spp.
Family Lamiaceae

PESTS AND DISEASES
Parasitic
- Virus and virus-like diseases
- Fungal diseases
- Nematode diseases
- Insects and allied pests

Non-parasitic

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas alfalfa mosaic virus, has been observed on *L. hybrida* (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Fungal leaf spot (*Septoria lavendulae*) may affect lavender. *Phoma* and *Alternaria* may invade leaves after ***nutritional problems*** and are common before planting out (Nichols 1994). See Annuals A 5.

Root rots, damping off: ***Grey mould*** (*Botrytis cinerea*) may attack shoots and flowers of cuttings in wet seasons. Also ***armillaria root rot*** (*Armillaria luteobubalina*) and ***phytophthora root rot*** (*Phytophthora nicotianae*). See Trees K 7.

NEMATODE DISEASES

Foliar nematode (*Aphelenchoides fragariae*) and ***root knot nematode*** (*Meloidogyne arenaria*) occur on lavender. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Green peach aphid*** (*Myzus persicae*). See Roses J 4.

Caterpillars (Lepidoptera): ***Australian painted lady*** (*Vanessa kershawi*), ***lightbrown apple moth*** (*Epiphyas postvittana*). See Annuals A 8.

Spider mites (Tetranychidae, Acarina): ***Carmine mite*** (*Tetranychus cinnabarinus*), ***twospotted mite*** (*T. urticae*). See Beans (French) M 29, Trees K 16.

Non-parasitic

Environment: Lavender is susceptible to ***severe frosts***. *L. angustifolia* is the hardiest lavender for cold climates. ***Wind*** may damage tall flower spikes. Lavender is often used for ***xeriscape*** plantings. Leaves may blacken in ***wet conditions*** or due to lack of air circulation. ***Sun*** may damage leaves if cuttings are not hardened prior to planting out.

Herbicide toxicity: Over-applications of ***pre-emergence herbicides***, eg oxadiazon, oxyfluorfen, may damage plants. ***Dimethoate*** may cause injury.

Nutrient deficiencies, toxicities: Fertilise with caution as lush growth may be obtained instead of flowers. In ***containers***, excess phosphorus and manganese, especially at low pHs, may result in leaf yellowing between the veins, burning of leaf tips, and even stem dieback. Salts may ***crystallise*** at the leaf tips (Nichols 1994).

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State/Territory Departments of Agriculture/Primary Industry eg
Lavender Growing (Vic Agnote)
Associations, Journals etc.
GrowSearch (database Qld DPI)
Lavender Bombala Conference (Sept. 1995)
The Australian Lavender Growers Assoc (TALGA) The Good Oil
The Essential Oil Producers Assoc. of Australia
See Herbs N 33, Nurseries N 56, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Commercially, lavender is used for oil production, fresh cut flowers, dried, xeriscape plantings and containers. Some species, eg Italian lavender (*L. stoechas*), are noxious weeds in some areas of Victoria. Most problems occur in ***nurseries***, after planting out it has few diseases and pests. ***Propagated*** by cuttings (Nichols 1996). Lavender prefers a sunny position with wind protection, light sandy soils with good drainage and a pH from 6.5-8 (alkaline). Irrigate only when necessary. Keep plantations ***weed-free***. ***Prune*** one half to 2/3rd of each branch after spring frosts and/or when dead-heading but do not cut back to bare wood. Lavender flowers best when regularly hard pruned and shaped after flowering. ***Harvest*** when the middle flowers of the spike are open. When sold in a bunch, stems should be as long as possible. Used as dried flowers rather than fresh, but can be used in fresh arrangements and posies (Jones and Moody 1993).

Lilac

Syringa spp.
Common lilac (*S. vulgaris*)
Family Oleaceae (olive family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot, bacterial blight
- **Fungal diseases**
  - Powdery mildew
- **Insects and allied pests**

Non-parasitic
- Environment
- Graft incompatibility

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas mosaics, ringspots, oak leaf patterns, yellow blotches, witches' broom and veinclearing have been associated with viruses, eg arabis mosaic, elm leaf mottle, lilac ring mottle, tomato black ring virus (Cooper 1993). See Trees K 4.

BACTERIAL DISEASES

Bacterial leaf spot, bacterial blight (*Pseudomonas syringae* pv. *syringae*) causes brown watersoaked spots on ***leaves*** and ***young stems*** of *S. vulgaris*, particularly white-flowered varieties, in early spring. If weather is wet, young leaves and shoots may be ***killed***, girdled stems ***die***. Spots enlarge more slowly on older stems and leaves. Black sunken areas develop on stems, black, dead buds remain on the plant for some time. Avoid ***excessive nitrogen***, prune off affected branches. See Trees K 6, Vegetables M 5.

FUNGAL DISEASES

Powdery mildew (*Oidium* sp.) occurs during spring, summer and autumn. See Annuals A 6.

Others: ***Armillaria root rot*** (*Armillaria luteobubalina*), ***fungal leaf spots*** (various species), ***wood rots***, eg silver leaf (*Stereum purpureum*) and yellowish wood rot (*Polyporus versicolor*).

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Cotton aphid,*** melon aphid (*Aphis gossypii*) may infest lilacs overseas. See Roses J 4, Trees K 10.

Armoured scales (Diaspididae, Hemiptera): ***Apple mussel scale*** (*Lepidosaphes ulmi*), ***olive parlatoria scale*** (*Parlatoria oleae*) and ***San Jose scale*** (*Quadraspidiotus perniciosus*) infest lilac overseas. See Citrus F 39, Trees K 16.

Caterpillars (Lepidoptera): ***Cluster caterpillar*** (*Spodoptera litura*) feeds on lilac. See Brassicas M 40, Trees K 13, Vegetables M 13.

Non-parasitic

Environment: ***Sunscorch*** damage to ***leaves*** is common during hot weather, or when shading trees have been pruned and foliage is suddenly exposed to sun. In late spring, young leaves may be injured by ***near freezing*** temperatures.

Graft incompatibility occurs when lilac is grafted on to privet rootstock (*Ligustrum*). Small ***black spots*** occur in an almost ***regular pattern*** towards ***outer leaf margins***. Usually apparent towards the ***end of the growing season*** in autumn. Symptoms reappear every autumn. New spring leaves do not show any symptoms.

Others: ***Leafcutting bees*** (*Megachile* spp.) may cut neat circular pieces from leaf edges. ***Suckers*** may develop from the rootstock.

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Associations, Journals etc.
Goulburn Lilac Festival

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Lilac prefers cool climates. Site plants in a sunny position and protect them from wind. Soil should be slightly alkaline, mulched and not allowed to dry out during summer. ***Propagated*** preferably by grafting onto ***non-suckering rootstock***. ***Harvest*** long, 1-year old shoots from shrubs at least 6 years old with sharp secateurs, strip leaves to reduce water loss and use a floral preservative. Rehydrating solutions improve water uptake dramatically. Top up water regularly and keep in deep water (Jones and Moody 1993). Lilac is ***ethylene sensitive***. Wilting flowers may be ***refreshed*** by placing stem-ends in hot water for about 60 seconds. During this process the upper leaves and flowers should be protected against rising steam and heat by means of a cardboard collar or barrier of some type. Lilac shoots may be forced in spring and bud opening solutions are available (Nowak and Rudnicki 1990).

Lilly-pilly

Acmena smithii
Family Myrtaceae (eucalypt family, myrtle family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Leaf blotch miner
  - Lilly pilly psyllid
  - Soft scales

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots (various species)
Giant tinder punk (*Phellinus zealandicus*)

NEMATODE DISEASES

In Qld, ***dagger nematodes*** (*Xiphinema*), ***spiral nematode*** (*Rotylenchus*) and other species have been recorded on *Acmena smithii.* Other species infest *Eugenia australis*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Ghost moths (Hepialidae)
Common splendid ghost moth (*Aenetus ligniveren*)
Oecophorid borers (Oecophoridae)
Cryptophasa sordida, *C. pultenae*
Echiomima mythica on *Syzygium floribundum*

See Trees K 12.

Caterpillars (Lepidoptera)

Butterflies: Blues, coppers (Lycaenidae): ***Common tit*** (*Hypolycaena phorbas phorbas*) caterpillars vary in colour, shelter under leaves and are attended by green ants (*Oecophylla smaragdina*). ***Common oakblue*** (*Arhopala micale*) caterpillars are green. ***Skippers*** (Hesperiidae) include ***eastern flat*** (*Netrocoryne repanda*), ***common red-eye*** (*Chaetocneme beata*) (Common and Waterhouse 1991).
Moths: Agriophara spp. (Oecophoridae) caterpillars feed from between leaves of ***Myrtaceae***, eg *Acmena*, *Angophora*, *Eucalyptus*, *Lophostemon*, *Syncarpia*. ***Hook-tip moth*** (*Porela arida*, Drepanidae) caterpillars feed on ***Myrtaceae***, eg *Eugenia*, *Kunzea ambigua*, *Lophostemon confertus*, *Leptospermum flavescens*, *Melaleuca quinquinervia* and *M. armillaris*. ***Bizarre looper*** (*Anisozyga pieroides*) and *Cryptaspasma sordida* (Tortricidae) caterpillars feed in ***fruits*** of *Acmena brachiandra* (Common 1990).

See Annuals A 8, Trees K 13.

Leaf blotch miner

Leaf blotch miner (*Macrarostola formosa,* Gracillariidae, Lepidoptera) in its early stages ***mine*** in leaves of *Acmena smithii*. Later stage caterpillars leave the mine and form a ***shelter*** by rolling the tip of a strip cut from the edges of broader leaves in which it feeds. It finally leaves this shelter and folds the leaf edge inwards to form a hollow and pupates inside. See Azalea K 28.

Lilly pilly psyllid

Lilly pilly psyllid (*Trioza* spp., *T. eugeniae*, Psyllidae, Hemiptera) infests lilly-pilly (*Acmena* spp., *Syzygium* spp.) and bottlebrush. ***Adult psyllids*** are winged, whitish and about ***2 mm*** long. Females lay eggs on leaves (there are several generations each season). ***1st stage nymphs*** move ***freely*** on young leaves and shoots. ***Later stage nymphs settle*** on ***leaf undersurfaces***, sucking sap from new leaves and causing plants to develop oval lumps ***(pimples)*** on the uppersurface and corresponding depressions on the undersurface, with the now scale-like insect inside. Only ***new leaves and shoots*** are attacked and look unsightly. ***Stems*** are also attacked. ***Spread*** by winged adults flying. ***Control*** is of limited value. Infestations are attacked by ***predators***, eg ladybird beetles and birds, and ***parasites***, eg wasps, but not usually before new growth is damaged. ***Susceptible*** species include *A. smithsii,* blue lilly-pilly (*S. coolminianum*), brush cherry (*S. paniculatum*), *S. moorei*. Usually when damage is noticed it is too late to apply ***insecticides*** for that season. In the following year a systemic insecticide may be applied to ***nursery stock*** in spring to protect new growth (McMaugh 1994). See Eucalypt K 62, Trees K 15.

Soft scales

Soft scales (Coccidae, Hemiptera)
Nigra scale (*Parassaisetia nigra*)
Pink wax scale (*Ceroplastes rubens*)
Soft brown scale (*Coccus hesperidum*)
White wax scale (*Gascardia destructor*)
See Citrus F 41, Trees K 16.

Others: ***Seed wasp*** (*Anselmella*, Eulophidae, Hymenoptera) develops in seeds of *Eugenia*. ***Gall-making thrips*** (Thysanoptera) may cause bladder-like galls on *Acmena* and *Syzygium*.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Lilly-pilly is a small self-shaping tree with edible berries. It is suitable for temperate and warm climates. Plant in well drained loam in ***frost-free sites. Propagated*** by seed. Water well in summer.

Magnolia

Magnolia spp.
Family Magnoliaceae (magnolia family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas ***cucumber mosaic virus*** is considered to cause yellow line patterns but this is unconfirmed (Cooper 1993). See Cucurbits M 50, Trees K 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas syringae* pv. *syringae*). Symptoms on leaves are variable but include ***small brown spots*** with yellow ***haloes***. If these spots grow together, splits may develop in the infected leaves. *Magnolia grandiflora, Magnolia* x *soulangeana* Alexandrina and *M.* x *soulangeana* Lennei are ***susceptible***. See Vegetables M 5.

FUNGAL AND ALGAL DISEASES

Algal leaf spot (*Cephaleuros virescens*) may cause minor pale green or reddish ***surface growth*** on leaves of evergreen portwine magnolia (*M. fuscata* = *Michelia figo*). See Avocado F 18.

Fungal leaf spots include ***citrus black spot*** (*Guignardia citricarpa*). Many more species affect magnolia overseas. See Annuals A 5.

Root rots (*Cylindrocladium scoparium*, *Phytophthora* spp.) on *Magnolia* sp. See Trees K 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.) has been recorded on *Magnolia radicans*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Greenhouse thrips (*Heliothrips haemorroidalis*) causes ***silvering of leaves***. See Greenhouses N 24.

Scales (Hemiptera): ***Black scale*** (*Saissetia oleae*, Coccidae), and many other species overseas, may infest magnolia. See Citrus F 41, Trees K 16.

VERTEBRATE PESTS

Birds peck holes in the ***flowers***. See Fruit F 13.

Non-parasitic

Environment: The ***shallow roots*** close to the soil surface should not be disturbed by cultivation or allowed to dry out. Avoid interfering with roots, which should be covered with a mulch to keep them cool, moist and weed-free. ***Abundant water*** is needed in summer but good drainage is essential. ***Lack*** of water, ***excessive*** heat, sun, or salty winds will cause leaves to ***brown***. ***Secondary fungi***, eg *Alternaria alternata*, may invade damaged areas. ***Frost*** may damage buds. ***Wind*** may cause mechanical damage to flowers and large leaves.

Nutrient deficiencies, toxicities: ***Iron deficiency*** may cause yellowing between the veins of new leaves, eg *Magnolia* x *soulangeana.* See Azalea K 29, Trees K 20.

Rusty leaves: ***Leaf undersurfaces*** of the evergreen species or white or southern magnolia, (*M. grandiflora*) are ***naturally*** a rusty colour.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Deciduous magnolias usually prefer a cool moist climate, full sun or light shade, and shelter from ***wind*** to produce the best foliage. Soil should be rich in organic matter and slightly acid. *M. soulangeana* is a deciduous tree and is the most widely grown, flowers appear early in spring before the foliage. *M. grandiflora* is an evergreen tree with large leaves which are used by florists in displays; they are an attractive furry brown on the underside. ***Propagated*** usually by air layering (Salinger 1985).

Maple

Acer spp.
Family Aceraceae (maple family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Powdery mildew
  - Root rots
  - Tar spot
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids

Non-parasitic
- Environment
- Weed potential

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASE

Yellow mosaic, ringspots, stunting, vein yellowing and tatter leaf have been associated with arabis mosaic and tobacco ringspot in *Acer* spp. overseas (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Powdery mildew (*Oidium* sp.) may occur on ***nursery stock*** of box elder (*Acer negundo*) in greenhouses. See Annuals A 6.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*), ***phytophthora root rot*** (*Phytophthora cinnamomi*). See Trees K 4, K 6.

Tar spot (*Rhystima acerinum*) has been recorded in Australia on *Acer* spp. Often occurs on some maples prior to autumn leaf fall. Epidemics of tar spot (*Rhystima* spp.) occur in NY causing ***leaf spots*** and ***defoliation*** of Norway maple (*A. platanoides*) (Hudler et al. 1987). See Trees K 6.

Others: ***Twig blight*** (*Myxosporium acerinum*) has been recorded on red maple (*A. rubrum*) in South Australia (unconfirmed). Overseas ***seedling anthracnose*** (*Discula campestris*) may seriously damage sugar maple (*A. saccharum*) (Stanosz 1993). ***Silver leaf*** (*Stereum purpureum*) affects box elder and red maple.

NEMATODE DISEASES

Root lesion nematodes (*Pratylenchus* spp.) occur on *Acer* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

California maple aphid (*Periphyllus californiensis*) infests maple and ***overwinters*** as eggs in cold climates. In more temperate regions aphids may reproduce continuously. Nymphs ***oversummer*** and are common on Japanese maple (*A. palmatum*) during summer. ***Inspect*** nursery and container plants during the growing season and during winter.

Sycamore aphid (*Drenpanosiphum platanoides*) may infest *Acer* spp. and sycamore (*Platanus occidentalis*).

See Roses J 4, Trees K 10.

Others: ***Caterpillars*** (Lepidoptera), eg case moths (Psychidae) and painted apple moth (*Teia anartoides*). ***Greenhouse thrips*** (*Heliothrips haemorrhoidalis*) cause leaf silvering with dark spots of excreta on Japanese maple. ***Longicorn beetles*** (Cerambycidae) may attack older trees. ***Larvae*** tunnel under the bark causing it to crack. ***Longtailed mealybug*** (*Pseudococcus longispinus*) may infest Japanese maple. ***Twospotted mite*** (*Tetranychus urticae*) causes leaf speckling. Leaves may become brown and papery.

Non-parasitic

Environment: ***Hot dry winds*** and/or ***lack of water*** will cause leaf edges of Japanese maple and other species to brown. ***Reflected sunlight*** from metal roofs may burn trunks causing dieback.

Weed potential: Some species, eg box elder (*A. negundo*), ***seed prolifically*** and invade gardens.

Others: ***Branches break easily*** and trees may be poorly formed. ***Atmospheric pollution*** may cause leaf edges to brown.

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Associations, Journals etc.
GrowSearch (database Qld DPI)

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Most maples are grown for their ***autumn colours.*** They range in size and uses. Japanese maple are ***small trees*** suitable for near swimming pools, bonsai, Japanese gardens, containers and courtyards. Others, eg box elder, grow ***very large*** and are not recommended for small gardens. ***Propagate*** by seed and cuttings. Maples are lime loving, prefer cool moist climates, loamy soil, root systems should not be allowed to dry out. Leaf damage of any type will detract from the autumn colour. Leaf spots may develop in autumn.

Melaleuca

Melaleuca, paper bark (*Melaleuca* spp.)
Family Myrtaceae (eucalypt family, myrtle family)

PESTS AND DISEASES
Parasitic

FUNGAL AND ALGAL DISEASES

Cankers (*Botryosphaeria ribis*, other species) on ***stems*** may cause dieback and is being researched for ***biological control*** of *M. quinquenervia* in Florida (Rayachhetry 1996). See Trees K 5.

Damping off, root rots, wilts: Armillaria root rot (*Armillaria luteobubalina*), ***damping off*** (*Calonectria quinqueseptata*, *Cylindrocladium*, *Phytophthora*, *Pythium*), ***phytophthora root rot*** (*Phytophthora* spp.), ***pythium root rot*** (*Pythium* sp.), ***verticillium wilt*** (*Verticillium dahliae*) (Walker 1994). See Trees K 7, Verticordia K 127.

Fungal and algal leaf spots*:** ***Algal leaf spot (*Cephaleuros virescens*), ***leaf and seedling blight*** (*Calonectria quinqueseptata*), ***fungal leaf spots*** (*Cylindrocladium*, *Seimatosporium dilophosporum*), ***tar spot*** (*Phyllachora* spp.) (Walker 1994). See Annuals A 5, Bottlebrush K 36.

Wood rots (Basidiomycetes): ***Tinder punk*** (*Phellinus* spp.); ***red wood rot*** (*Trametes cinnabarina*, *Pycnoporus coccineus*) (Walker 1994). See Trees K 8.

NEMATODE DISEASES

More than 30 species of nematodes occur on melaleuca, eg ***burrowing nematode*** (*Radopholus*), ***dagger nematode*** (*Xiphinema*), ***root knot*** (*Meloidogyne*), ***sheath nematode*** (*Hemicycliophora*), ***spiral nematode*** (*Helicotylenchus*). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Beetles (Coleoptera)

Leaf beetles (Chrysomelidae): ***Leaf beetles*** (*Cryptocephalus* spp.) feed on foliage of eucalypt, melaleuca and wattle. ***Larvae*** feed on dead leaves on the ground and live in a portable case constructed of faeces and debris, pupation occurs within this case. ***Redshouldered leaf beetle*** (*Monolepta australis*) feeds on foliage. See Trees K 15.

Scarab beetles (Scarabaeidae): ***Christmas beetles*** (*Anoplagnathus* spp.) may defoliate melaleucas. See Eucalypt K 62. ***Flower scarabs*** (*Protaetia* spp.) are minor pests feeding on pollen and new shoots (Jones and Elliot 1986). See Roses J 8.

Borers

Common splendid ghost moth (*Aenutus ligniveren)*
Fruit-tree borer (*Cryptophasa melanostigma*)
Jewel beetles (Buprestidae, Coleoptera)
Longicorn borer (*Platyomopsis armatula*)
Ringbarking weevils (Curculionidae)
See Bottlebrush K 36, Trees K 10.

Bugs (Hemiptera):

Callistemon tip bug (*Pomponatus typica*) is solitary, brown and ***20 mm*** long. ***Adults and nymphs*** suck sap from new shoots of melaleuca causing tips to wither. See Bottlebrush K 37.

Leafspotting mirid bug, myrtle mirid bug (*Eucerocoris suspectus,* Miridae) mainly infests broadleaved melaleuca, eg *M. leucadendron*, *M. quinquenervia, M. viridiflora,* also bottlebrush, eg *Callistemon polandii*, and other Myrtaceae. ***Adults*** are delicate, hard to find, up to ***10 mm*** long, orange with black legs, long black antennae and gauzy wings. ***Nymphs*** are elliptical, orange with bands on legs and antennae. Both suck sap from ***new shoots*** and ***young leaves*** which are damaged by the toxic saliva secreted during feeding. Spots of dead tissue develop where they have fed. There are several generations each year. ***Favoured*** by wet seasons, usually during December-March. Tropical and subtropical regions, mainly coastal. See Bottlebrush K 37, Wattle K 133.

Metallic shield bug (*Scutiphora scutiphora*, Scutelleridae) swarm on melaleuca, *Ficus* (especially fruit) and other plants. ***Adults*** are about ***14 mm*** long, shield-shaped, deep metallic blue or green and mottled with black with some red markings on the thorax. Their feeding may be followed by sap exudation. Tropical and subtropical. See Vegetables M 12.

See Vegetables M 12.

Caterpillars (Lepidoptera)

Dull oakblue (*Arhopala centaurus centaurus*) butterfly caterpillars feed on *M. quinquenervia* and *Eucalyptus intermedia* in NT and north Qld. Larvae and pupae rely on the ***green tree ant*** (*Oecophylla smaragdina*) to remove secreted liquid, they become mouldy in the absence of ants to remove it.

Painted apple moth (*Teia anartoides*) is a sporadic ***serious pest***. A similar pest (*Orgyia athlophora*) occurs in south-western WA. See Pome fruits F 113.

Web moth (Pyralidae) caterpillars spin a webbing of droppings and chewed leaves over stems and leaves. Caterpillars feed at night on leaves and flower buds. Plants become unsightly. See Tea-tree K 124.

Others: Capsule moth (*Bathotroma constrictans*), a ***noctuid*** (*Nola* sp., Noctuidae), ***lightbrown apple moth*** (*Epiphyas postvittana*), ***mottled cup moth*** (*Doratifera vulnerans*), ***Saunders's case moth*** (*Oiketicus elongatus*). ***Aquita tactalis*** caterpillars feed on *M. gibbosa* and other *Melaleuca* spp., ***Myrascia megalocentria*** (Oecophoridae) caterpillars in WA feed on *Melaleuca* spp. ***Porela arida*** caterpillars feed on Myrtaceae, eg *M. quinquinervia*, *M. armillaris, Kunzea*, *Eugenia*, *Lophostemon conferta* (Common 1990).

See Annuals A 8, Trees K 13.

Leafrolling thrips (Phaeothripidae) may cause ***severe distortion*** of young leaves of *M. alternifolia*. See Bottlebrush K 37.

Paperbark sawfly (*Pterygophorus* sp., Pergidae, Hymenoptera) larvae defoliate paperbarks (*Melaleuca* spp.), especially bracket honey myrtle (*M. armillaris*), also *Leptospermum* spp. ***Ringed sawfly*** (*P. cinctus*) larvae may defoliate *M. ericifolia* (Elliot and deLittle 1984). ***Adult sawflies*** are about ***20-25 mm*** across their outspread wings. ***Larvae*** are brownish, ***25-30 mm*** long with true legs. Most damage is caused when larvae pupate in the bark and sapwood of trunks. Trees may be ringbarked. They also pupate in soft timbers, eg in soft pine weather boards. ***Lophyrotoma zonalis*** larvae may defoliate *M. quinquenervia*. See Eucalypt K 62, Tea-tree K 124.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Circular black scale*** (*Chrysomphalus aonidum*) is hard, conical reddish-black with a lighter central peak and about 2-3 mm long. They feed on leaves which may fall. A sporadic serious pest of bottlebrush and melaleuca. ***Mussel scales*** (*Lepidosaphes* spp.), adult females are white and about 1.7 mm long and males are winged. Although common, leaves often seem to tolerate infestation. See Citrus F 39.

Eriococcid scales (Eriococcidae): ***Coccid galls*** (*Apiomorpha* sp.), ***melaleuca hairy gall*** (*Sphaerococcus* sp.). See Eucalypt K 63.

Soft scales (Coccidae): ***Chinese wax scale*** (*Ceratoplastes sinensis*) infests twigs. It is grey-brown, domed and waxy with 6 dark spots around the margins. Nymphs colonise midribs and have conspicuous marginal waxy projections. Large quantities of honeydew are produced. See Citrus F 41.

Others: A ***margarodid scale*** (Margarodidae).

See Trees K 16.

Tip borers (Lepidoptera): ***Callistemon tip borer*** (Lepidoptera) is a minor pest of melaleuca. ***Larvae*** are fleshy cream, about ***10 mm*** long and bore down the centre of young shoots which usually die or break off. In WA, ***tip borers*** cause dieback at tips of new shoots of many species of melaleuca and *Calothamnus* See Bottlebrush K 36.

Weevils (Curculionidae): ***Melaleuca leaf weevil*** (*Oxyops* sp.) and its larvae graze narrow patches of surface tissue of broadleaved melaleuca especially *M. cajuputi*, *M. quinquenervia* and *M. viridiflora* in the tropics. ***Adults*** are pale brown and about ***7 mm*** long, ***larvae*** are fleshy, shiny black and resemble slugs. Damaged areas turn brown and leaves fall. ***Insecticides*** may be applied to the foliage when infestations are first noticed. (Jones and Elliot 1986).

Others: ***Aphids*** (*Twainaphis* sp., Aphididae, Hemiptera) affect melaleuca in WA. ***Eriophyid mites*** (Eriophyidae) cause stunted bunchy growth on *M. alternifolia* and *M. linariifolia*. ***Spine-tailed froghopper*** (*Machaerota finitima*) and ***leafhopper*** (*Rosopaella* spp.) suck sap from eucalypt and melaleuca. ***A tiny orange psyllid*** (Psyllidae) distorts young shoots of melaleuca and bottlebrush. ***Whiteflies*** (Aleyrodidae) feed on succulent growth.

Non-parasitic

Tea-tree oil from *M. alternifolia* must conform to the standard specification (AS K175) for tea-tree oil. Tea-tree oil is ***poisonous*** (Moss 1994) and has a POISON label schedule (S6).

Others: ***In high humidities*** leaves near the ground may blacken. ***Fasciation***, a genetic abnormality, may cause flattened stems. ***Epiphyllous fungal parasites***, eg *Microthyrium melaleucae* on leaves and *Septobasidium clelandii* on calococcus galls (unconfirmed), occur. ***M. quinquenervia*** is a ***serious weed*** in Florida. Sawflies (*L. zonalis*) and other insects and diseases (see above) are being researched as ***biological control agents***.

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State/Territory Departments of Agriculture/Primary Industry eg
Tea Tree Oil (NSW Agfact)
Tea-tree Oil : Plantation Production (NSW Agfact)

Associations, Journals etc
Essential Oil Producers Assoc. of Australia

See Australian native plants N 9, Herbs N 33, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Melaleuca is a large genus of about 140 species in Australia which vary from small to large shrubs and trees and adapts easily to cultivation. Culture ***varies*** for each species, eg some species ***tolerate*** poor drainage, salinity or constantly damp soil. ***Propagated*** from cuttings or seed (Wrigley 1988).

Mint bush

Prostanthera spp.
Victorian Christmas bush (*P. lasianthos*)
Family Lamiaceae

PESTS AND DISEASES
Parasitic
Fungal diseases
Fungal leaf spots
Root rots
Wood rots
Nematode diseases
Root knot
Insects and allied pests
Borers
Non-parasitic

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots (*Cercospora*, *Colletotrichum*, *Coniothyrium*, *Microsphaeropsis*, *Microsphaerella*, *Phomopsis*, *Phyllosticta prostantherae, Septoria,* other species) have been recorded on *P. lasianthos*. *Coniothyrium*, *Microsphaeropsis* and *Mycosphaerella* may also cause leaf spots on other *Prostanthera* spp. *Microsphaeropsis* sp. may also cause ***stem and leaf dieback*** of various species. ***Meliola prostantherae*** may cause ***black leaf and stem spots*** on *Prostanthera* spp. See Annuals A 5, Trees K 6.

Root rots

Armillaria root rot (*Armillaria luteobubalina*) may infect *P. lasianthos*. See Trees K 4.

Phytophthora root rot (*Phytophthora* spp., *P. cinnamomi*, *P. nicotianae*) is the ***most important problem*** affecting mint bushes and is often the cause of them being short-lived. It is recommended that *Prostanthera* be grafted on to the vigorous and easily propagated, ***phytophthora-resistant*** coastal rosemary (*Westringia fructicosa*). Most species of *Prostanthera* are compatible with *W. fructicosa*, several small-leaved species, eg *P. aspalathoides*, which are incompatible may be grafted using a nurse graft of *P. nivea*. See Trees K 6.

Wood rots (Basidiomycetes): ***Ringbarking fuscoporia*** (*Fuscoporia laevigata*) causes a white sapwood rot of *P. lasianthos*. The fruit body forms a rust-coloured, pore-bearing sheath on the ***collar*** of young trees. The fungus may ringbark stems and trees may ***die*** (Marks et al. 1982). ***Other species*** include ***white yellowish wood rot***, rainbow conk (*Polyporus versicolor*). See Trees K 8.

Others: ***Hairy galls*** (species undetermined) may develop on leaves of *P. lasianthos*.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) occur in association with > 10 species of *Prostanthera*. Roots become ***galled***, the whole root system may be severely stunted and invaded by ***fungal diseases***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Fruit-tree borer (*Maroga melanostigma*) caterpillars tunnel in bark and sapwood in ***forks*** and cover their ***short tunnels*** with ***chewed wood*** and webbing. See Fruit F 10, Trees K 12.

Ghost moths (Hepialidae); ***Common splendid ghost moth*** (*Aenutus ligniveren*) and *A. eximius* caterpillars excavate ***tunnels*** up to ***700 mm*** long, often into the ***main root***. See Trees K 12.

See Trees K 10.

Others: ***Aphids*** (Aphididae, Hemiptera) may infest ***shoots*** of *P. lasianthos*. ***Caterpillars*** (Lepidoptera), eg ***leafroller moths*** (Tortricidae), may roll and bind leaves. ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*) is small, white and moth-like and about 1-2 mm long. Nymphs are translucent, greenish and scale-like. Nymphs and adults suck sap from new shoots and leaf undersurfaces. Sooty mould grows on honeydew. ***Unidentified scales*** (Hemiptera) have been observed on *P. incana*.

Non-parasitic

In wet and very humid conditions leaves of *P. phylicifolia*. may blacken and die due to poor transpiration from leaves. ***Iron deficiency*** may cause yellowing of new growth.

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See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Mint bushes are small to large woody shrubs mostly with aromatic foliage and a wealth of flowers in spring (Wrigley 1988). ***Propagate*** by cuttings and grafting. Plant mint bushes grafted on to ***phytophthora-resistant*** rootstock. Mint bushes require well drained sandy or gravelly soil with added organic matter, near to full sun, but protection from hot drying winds, with regular watering in spring and summer. Roots should not be disturbed. Mulch, which should be kept away from stems, will help keep the roots cool and prevent drying out. ***Tip prune*** regularly for the first few years to prevent plants becoming spindly and then annually after flowering.

Oak

Quercus spp.
Family Fagaceae (beech family)

PESTS AND DISEASES
Parasitic
- **Virus diseases**
- **Fungal diseases:**
  - Fungal leaf spots
  - Powdery mildew
  - Root and collar rots
  - Wood rots
- **Parasitic plants**
  - Mistletoe
- **Insects and allied pests:**
  - Borers
  - Golden oak scale
  - Greenhouse thrips
  - Oak aphids
  - Oak leafminer
- **Snails and slugs**

Non-parasitic
- Environment
- Fungi
- Gas damage

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas, ***undetermined viruses*** are considered to cause yellow mottling, veinbanding and ringspotting on leaves, premature break of dormancy and ***progressive dieback*** of trees (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots

Downy leaf spot (*Microstroma album*, Imperfect Fungi) infects oak ***leaves*** causing yellow blotching of uppersurfaces and a glistening white coating on undersurfaces (pustules with large numbers of spores).
Others (many species) including ***Gnomonia veneta*** (*Discula quercina*) may cause ***twig blight*** and ***leaf spotting***. Most leaf spots are of minor importance.

See Annuals A 5.

Powdery mildew (*Microsphaera alphitoides*, *M. quercina*) may affect oaks. Damage to ***nursery stock*** can be ***serious***. Initial symptoms appear late in spring when small brown spots, which rapidly turn white, develop on ***leaves***. As the leaves are covered by fungal mycelia, they become slightly ***distorted*** and young foliage does not enlarge to full size. The fungus also attacks ***young shoots*** and reduces their vigour. Damage to ***mature trees*** is minor. ***Favoured*** by cool, wet or humid conditions. ***Susceptible species*** include English oak (*Q. robur*). Only if considered necessary, ***fungicides*** may be applied to ***seedling trees*** in ***nurseries*** and ***container plants*** at the first sign of disease. See Annuals A 6.

Root and collar rots

Phytophthora root and collar rot (*Phytophthora cinnamomi*). Natural seasonal changes in ***bark*** affect ***susceptibility*** (Robin et al. 1993). Probably other species may also cause root and collar rots. See Trees K 6.
Damping off (*Cylindrocladium* sp., *Phytophthora* sp., *Rhizoctonia* sp.). See Seedlings N 66.

Wood rots: ***Tinder punk*** (*Phellinus robustus*) and ***silver leaf*** (*Stereum* spp.). See Trees K 8.

PARASITIC PLANTS

Mistletoe (*Loranthus* spp., Loranthaceae) may infest ***branches***. See Trees K 10.

INSECTS AND ALLIED PESTS

Borers (various species) may infest ***old*** oak trees. See Trees K 10.

Golden oak scale (*Asterodiaspis variolosa*, Asterolecaniidae, Hemiptera) is frequently kept in check by ***natural enemies*** such as predatory ladybirds. A spray of ***winter oil*** will control this scale without killing the natural enemies. ***Other scales*** may occasionally infest oaks. See Citrus F 40, Trees K 16.

Greenhouse thrips (*Heliothrips haemorrhoidalis*). Leaves become ***silvery***, with black drops of excreta and thrips on ***undersurfaces***. If only a few leaves are affected they may be removed. ***Susceptible species*** include English oak (*Q. robur*) and live oak (*Q. virginiana*). It may be necessary to use an ***insecticide*** on ***nursery*** or ***container stock***. See Greenhouse N 24.

Oak aphids (*Myzocallis castanicola*, *Tuberculatus annulatus,* Aphididae, Hemiptera). *M. castanicola* is the most common. It is ***yellowish***, and is found on both sides of ***leaves*** and on ***stems*** of ***young shoots***. Badly affected leaves may fall. Infested trees appear blackish due to sooty mould growing on the honeydew secreted by the aphids. Control is not usually attempted on large trees but ***seedlings*** or ***nursery stock*** may be sprayed with a ***systemic insecticide*** at the first sign of infestation. See Roses J 4, Trees K 10.

Oak leafminer, oak blotch miner

Oak leafminer is an ***important pest*** in the eastern states of Australia.

Scientific name: Gracillariidae, Lepidoptera:
Oak leafminer (*Phyllonorycter messaniella*)

Host range: At least 17 species of both deciduous and evergreen oaks (*Quercus* spp.), Spanish chestnut (*Castanea sativa*), beech (*Fagus sylvatica*) and birch (*Betula* spp.). ***Overseas*** it has also been recorded on other hosts including other species of oak and *Carpinus betula*. ***In some areas***, apples, feijoa, liquidamber and stone fruits are attacked (McMaugh 1994).

Description and damage: ***Moths*** are tiny and usually rest with their bodies parallel to the surface. ***Caterpillars*** are flattened, up to 5 mm long, with a pale body and dark head. Caterpillars mine in ***leaves*** initially producing fine lines, later small brown ***blotch mines***. See Trees K 3 (Fig. 212). In severe infestations, most leaves on individual trees may be mined. There may be as many as ***20 mines*** per leaf on English oak (*Q. robur*) and over 40 mines per leaf on larger-leaved oaks, eg *Q. aliena*. Although heavy infestations such as these must reduce the photosynthetic capability of trees and result in loss of vigour, trees ***tolerate*** infestations remarkably well. The main affect is ***disfigurement*** of leaves.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with 2-3 generations each year, mainly on deciduous oaks. Moths lay pale yellow eggs on ***leaf undersurfaces***, usually near the midrib. Eggs hatch and caterpillars mine within the leaf. When fully grown, they ***pupate within the mine***. After the moth emerges, the pupal case is often seen protruding from the mine. With cooler weather in autumn, deciduous oaks start to lose their leaves, and emerging moths lay their eggs on leaves of ***evergreen oaks*** during ***winter***, particularly cork oak (*Q. suber*). After caterpillars have mined in evergreen oaks during winter, pupation occurs, and the next generation of moths then switch back to the new foliage of the ***deciduous oaks*** in ***spring***.

Overwintering: As larvae in leaves of evergreen oaks, eg cork oak (*Q. suber*). In NZ, the moth overwinters on evergreen *Q. ilex* and *Q suber*. Most damage is observed during autumn, as the insect is not able to overwinter in large enough numbers to damage spring-summer foliage.

Spread: By moths flying (assisted by wind), by the movement of infested plants or plant material.

Control:

Biological control: Several species of wasps ***parasitise*** caterpillars in mines so there is a degree of natural control.

Resistant varieties:

Only slightly affected: *Q. acutissima*, scarlet oak (*Q. coccinea*), holly or holm oak (*Q. ilex*), pin oak (*Q. palustris*), willow oak (*Q. phellos*), red oak (*Q. rubra, Q. borealis*), cork oak (*Q. suber*).

Moderately affected: Swamp oak (*Q. bicolor*), Turkey oak (*Q. cerris*), *Q. douglassii*, *Q. engelmani*, valley oak (*Q. lobata*), Cypress oak (*Q. robur* Fastigiata).

Severely affected: *Q. canariensis Q. mirbeckii*, Portuguese oak (*Q. lusitanica, Q. faginea*), burr oak (*Q. macrocarpa*), chestnut oak (*Q. prinus*, *Q. montana*), English oak (*Q. robur*), live oak (*Q. virginiana*).

Pesticides: A systemic insecticide may be applied to ***susceptible nursery stock*** in spring and summer to protect new leaves.

Others: ***Beetles*** (Attelabidae) breed in acorns. ***Wasps*** (*Andricus* sp.) on *Quercus* spp. are gall formers or inquilines (live in another's house). ***Phylloxerid*** (*Moritziella corticalis*) occurs on the bark of *Quercus* spp. in Australia. Overseas, ***Phylloxera spp***. also occur on *Quercus* spp.

SNAILS AND SLUGS

Snails and slugs may damage ***nursery stock***. See Seedlings N 70.

Non-parasitic

Environment: ***Inadequate soil moisture*** during hot, windy summer weather may cause a ***marginal brown scorch*** of oak leaves.

Fungi: ***Fly agaric*** (*Amanita muscari*) occurs under oak and other European trees. It is ***very poisonous*** but not usually fatal. ***Death cap*** (*A. phalloides*) was introduced into Australia with deciduous exotic trees, eg oak, and is ***extremely poisonous*** (Shepherd and Totterdell 1988). ***Truffles*** are grown under oak, hazelnut and other trees (Giovannetti et al. 1994).

Gas damage: Leaking underground gas pipes may cause ***marginal scorch*** on leaves. If severe, tree may ***die***. Do not confuse with damage to leaves caused by water stress.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Oaks are large, slow growing, deciduous and evergreen trees. Some deciduous species carry their brown leaves through winter. If necessary, select species ***resistant*** to oak leafminer. ***Propagate*** by seed. Oaks prefer full or half sun, temperate and cool moist climates, and a deep fertile soil for best growth. Fallen acorns can be a nuisance.

Oleander

Nerium oleander
Family Apocynaceae

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Bacterial gall
Fungal diseases
Nematode diseases
Insects and allied pests
Aphids
Caterpillars
Scales
Non-parasitic

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt virus has been recorded on oleander, but is uncommon. See Tomato M 96, Trees K 4.

BACTERIAL DISEASES

Bacterial gall

Scientific name: *Pseudomonas syringae* subsp. *savastanoi* pv. *nerii.*

Host range: A ***common and serious disease*** of oleander.

Symptoms: Leaf galls form on ***both leaf surfaces*** with deep pits developing on the side opposite galls causing leaf distortion. Infected young leaves become twisted. ***Young shoots*** develop longitudinal swellings which split. In infection of ***older stems***, galls tend to be isolated and circular in shape. Symptoms on ***floral parts*** depend on the stage of development at the time of infection, flowers may not be formed, severely infected plants may produce no flowers (Fig. 261).

Disease cycle: All stages take place on the host plant. Bacteria seem to gain entry through ***wounds*** caused by insects feeding or by pruning.

Overwintering: In galls on diseased plants.

Spread: Bacteria are spread from galls by water splash, insects and pruning tools, by vegetative propagation from infected plants and by the introduction of infected plant material.

Conditions favouring: Bacterial gall is widespread throughout the world and occurs wherever oleanders are grown.

Control: Unless control is carried out, disease will spread ***throughout whole plantings***.

Cultural methods: Avoid overhead irrigation to help prevent spread of bacteria. Plants should be kept ***growing vigorously***.

Sanitation: The most effective method is the removal of all diseased plant parts. Make the pruning cuts at least ***100 mm below galls*** on stems. Severely affected shrubs may be pruned back to ground level or removed. Disinfect pruning shears between each cut, and between each shrub, by dipping in 70% methylated spirit or wiping with a rag moistened with methylated spirit. Other disinfectants are available. If prunings are to be destroyed by burning, then they must be burnt outdoors. ***Smoke from burning oleanders is toxic***. See Nurseries N 51, N 52.

Plant quarantine: ***Inspect new purchases*** for any sign of galling, destroy infected plants.

Disease-free planting material: Only propagate from ***gall-free plants***, otherwise take several cuttings from disease-free stems and discard cuttings which later develop galls.

Pesticides: Copper sprays recommended for bacterial diseases are ***non-systemic*** and will only kill bacteria on the ***outside of the plant*** and have no effect on bacteria already inside plant tissue. They are not recommended. Control insect infestations to prevent spread of bacteria.

FUNGAL DISEASES

Overseas, ***phytophthora root rot*** (*Phytophthora*) may be a problem in nurseries.

NEMATODE DISEASES

Root lesion nematode (*Pratylenchus penetrans*) has been recorded on oleander in Victoria. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Oleander aphid (*Aphis nerii*) infests oleander, cotton bush (*Asclepias* sp.) and narrowleaf cotton bush (*Gomphocarpus fructicosus*). Adult aphids are ***yellow and black***. Nymphs and adults suck sap from ***new shoots*** and secrete honeydew on which the sooty mould fungus grows causing disfigurement. Ants are attracted to the honeydew. ***Overwinters*** on host plants. ***Spread*** by aphids flying, assisted by wind. Mainly occurs in autumn and spring.

Others: Green peach aphid (*Myzus persicae*).

See Roses J 4, Trees K 10.

Caterpillars (Lepidoptera)

Eichhorn's crow butterfly (*Euploea eichhorni*, Nymphalidae) caterpillars and pupa, which are said to resemble oleander butterfly, feed on the ***leaves*** of oleander and similar hosts, eg *Ficus eugenioides*, *Hoya australis*, *Gymnanthera nitida* and *Asclepias* spp. in north Qld.

Oleander butterfly (*Euploea core corinna,* Nymphalidae) caterpillars feed ***commonly*** and mainly on oleander, they are not often seen feeding on their native food plants, eg *Ficus* spp., *Hoya australis*, *Ischnostemma*. They also feed on other plants with milky sap, eg Chilean, Madagascar, and star jasmines, *Asclepias*. ***Butterflies*** measure about 70-80 mm across their outspread wings and are of a general dark brown colour marked with whitish spots. Female butterflies lay eggs on leaves. ***Caterpillars*** are greyish or reddish-brown, with several black bands with white margins on the segments and a lighter band along each side of the body, and are up to ***40-50 mm*** long. There are 4 pairs of long, black, fleshy tentacles on the upper surface. Caterpillars feed on ***leaves*** and pupate on the plant. Pupa are about 25 mm long, silvery and extremely beautiful. There are probably ***several generations*** each year. ***Spread*** by butterflies flying, movement of infested plants. Members of a tropical group of butterflies but found as far south as Albury in NSW and in WA. ***Control*** is rarely necessary (Common and Waterhouse 1981).

Orange fruitborer (*Isotenes miserana*, Tortricidae) caterpillars feed between ***joined leaves*** of oleander. See Citrus F 37.

See Annuals A 8, Trees K 13.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Oleander scale,*** ivy scale (*Aspidiotus nerii*) infests ferns, grape, ivy, oleander, olive, orchids, persimmon. ***Female scales*** are 1-2 mm across, white to brown and roughly circular, male scales are smaller and elongate. Scales infest ***foliage and stems***. On persimmon, blemishes may downgrade ***fruit***. ***Parasitic wasps*** (*Aphytis* spp.) and ***predatory ladybirds*** (*Chilocorus* spp., *Rhyzobius* sp.) may be purchased. Also ***purple scale*** (*Lepidosaphes beckii*). See Citrus K 39.

Soft scales (Coccidae): ***Black scale*** (*Saissetia oleae*) (Fig. 262) and ***soft brown scale*** (*Coccus hesperidum*) secrete honeydew attractive to ants and on which sooty mould develops. See Citrus F 41.

See Citrus F 39, F 41, Trees K 16.

Non-parasitic

Sunburnt leaves may be invaded by ***secondary fungi***. ***Poisonous properties:*** The poisonous principle is a drug acting on the heart with an action like digitalis and death is due to heart and/or breathing failure. Most cases of poisoning refer to cattle, but horses, sheep and goats may also be affected (McBarron 1983). All parts of oleander plants, eg flowers and leaves, are ***poisonous to eat***. Children should be cautioned about eating them, however, poisoning is rare as the plant has a foul taste. Plant parts are not poisonous to touch. ***Smoke*** from burning oleander wood is poisonous if inhaled, so it should not be burnt in an enclosed area. Oleander leaves, although toxic, are considered to decompose in ***compost heaps*** into useful non-toxic material.

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State/Territory Departments of Agriculture/Primary Industry eg

Oleander Butterfly (NSW Agfact)

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Oleander is native to the warm parts of Asia, Africa and the Mediterranean regions. In cool areas flowering may be inhibited. ***Examine new purchases*** for the presence of bacterial galls or scales. Propagate only from ***gall and insect-free*** plants. Although oleander will grow satisfactorily under harsh conditions and withstand low temperatures, irrigation in hot and dry environments, will improve performance. Oleander shrubs tolerate ***heavy pruning*** and are easy to grow with little maintenance. They prefer a sunny, well drained site, shade will inhibit flowering. They are ***tolerant*** of soil salinity and drought, and are good for tub growing (but not close to swimming pools or where children play). ***Retail potted oleander*** well established in pots, at the beginning of flowering, to confirm the colour.

Fig. 261. Bacterial gall of oleander (*Pseudomonas syringae* subsp. *savastanoi* pv. *nerii*). Dept. of Agric., NSW.

Fig. 262. Black scale (*Saissetia oleae*) on stems.

Photinia

Photinia spp.
Family Rosaceae (rose family)

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial blight (*Pseudomonas syringae* pv. *syringae*) has been recorded on *Photinia* sp. See Stone fruits F 124.

Fire blight (*Erwinia amylovora*) which may blight leaves, stems and fruits is not known to occur in Australia but occurs in NZ and other countries (Com. of Aust. 1990). See Pome fruits F 108.

FUNGAL DISEASES

Fungal leaf spots: An unidentified species may cause reddish-brown spots on leaves. A minor problem. See Annuals A 5.

Powdery mildew (*Oidium* spp.) is the most ***serious disease*** of *Photinia* and is mainly a problem on ***clipped hedges*** of *P. serrulata*. The fungus attacks new spring growth. ***Young leaves and shoots*** are covered with white powdery growth in spring. ***Shoots*** become spindly, areas of leaves attacked by mildew may become ***pinkish*** and leaves may curl inwards. Severely infected new leaves may wither, powdery mildew on older leaves looks silvery. ***Susceptible*** species include *P. serrulata*. Where possible select species with some ***resistance***, eg *P. glabra* Rubens and *P. glabra* Rubusta. If *P. serrulata* is to be used, plant in a shrubby area where the powdery mildew is not so noticeable and avoid pruning it. Where there are existing *P. serrulata* shrubs, they may either be replaced or tolerated. ***Fungicides*** are not recommended for hedges because they would need to be applied regularly as new growth emerges in spring, and at other times during the year for effective control. ***Fungicides*** may be used in ***nurseries***. See Annuals A 6.

Root rots
Armillaria root rot (*Armillaria luteobubalina*)
Damping off (*Cylindrocladium scoparium*)
See Trees K 7.

INSECTS AND ALLIED PESTS

Insect pests are usually of minor concern.

Aphids (Aphididae, Hemiptera) occasionally may attack new shoots. See Roses J 4.
Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause leaf silvering. See Greenhouses N 24.
Leaf case moth (*Hyalarcta huebneri*) is a sporadic minor pest. See Trees K 13.
Pear and cherry slug (*Caliroa cerasi*) may skeletonise occasional leaves. See Pome fruits F 115.
Scales: ***Armoured scales*** (Diaspididae), eg ***San Jose scale*** (*Quadraspidiotus perniciosus*), ***oystershell scale*** (*Q. ostreaeformis*). ***Soft scales*** (Coccidae), eg ***black scale*** (*Saissetia oleae*). See Citrus F 39, F 41, Trees K 16.

Non-parasitic

Environment: ***Frost*** may injure ***new foliage***. If pruning in mild areas, cut back in winter; in frosty areas leave until after spring flowering. ***Fertilise*** after pruning. ***Heat*** may also injure leaves.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Photinias are widely used as hedge plants for their brilliant red new foliage which can be maintained by regular trimming, watering and fertilising. It is ***tolerant*** of a wide range of conditions, but not the tropics or hot inland areas. Mature leaves will tolerate frost and are quite tough in dry areas. They prefer full sun to semi-shade. *P. glabra* Rubens makes an excellent hedge plant especially in cool moist climates. Main pruning is carried out in late winter, but flushes of the attractive young red leaves can be obtained throughout the year (not in frosty areas), by clipping the plant whenever it has all turned green. *P. serrulata* is ***very susceptible*** to powdery mildew. *Photinia* Superhedge is a vigorous branching *Photinia*, which can grow 2 m in a year and is ideal where a hardy quick growing screen is required. ***Propagated*** by cuttings.

Pine

Pinus spp.
Family Pinaceae

PESTS AND DISEASES
Parasitic
Fungal diseases
Diplodia canker
Dothistroma needle blight
Root rots
Rusts
Wood rots
Wood-stains, sap-stains
Parasitic plants
Nematode diseases
Insects and allied pests
Borers
Bugs
Caterpillars
Grasshoppers and locusts
Greenhouse thrips
Pine aphids
Pine bark beetles
Radiata pine shoot weevil
Scales
Scarab beetles
Sirex wasp
Vertebrate pests
Non-parasitic
Environment
Mycorrhizae
Nutrient deficiencies, toxicities
Poisonous pine needles

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Diplodia canker
Blue stain, dieback, shoot blight

Scientific name: Imperfect Fungi:
Diplodia canker (*Diplodia pinea*)

Host range: Pine (*Pinus* spp.).

Symptoms: Trees from 4-10 years are commonly attacked. *D. pinea* is present wherever radiata pine is grown. ***Stems of leaders*** of young trees become infected through injury and the fungus establishes in the pith and sometimes in the cortex. Tissue is discoloured, resin may flow, lesions and cankers may follow (Fig. 263). If the leader is girdled, it ***dies*** (needles gradually yellow and brown). Side shoots behind the killed tips may grow abnormally long resulting in ***multiple leaders***. Larger areas of a tree will be brown if many dead tips occur together (Lewis and Ferguson 1993).

Overwintering: On needles, twigs, buds, scales.

Spread: Spores by rain drops and wind.

Conditions favouring: Injury due to ***natural occurrences***, eg drought, fire, hail, wind, also insects, pruning, logging. Trees stressed due to poor sites, unreliable rainfall. Warm, wet autumn weather generally > 22^{o}C.

Control:
Cultural methods: Fertilise trees and water in dry weather to keep them growing vigorously to minimise infection and encourage plants already affected, to produce new growth.
Resistant varieties: Radiata pine (*P. radiata*) is ***very susceptible***.
Pesticides: Fungicidal treatments are of doubtful value and impossible on large trees.

Dothistroma needle blight
Pine needle blight

Scientific name: *Dothistroma septospora* (= *D. pini* = *Scirrha pini*). This is the ***most serious needle blight disease*** of radiata pine in Australia and perhaps throughout the world. Other needle blights, eg *Lophodermium* spp. and *Naemacyclus* spp., may cause locally important diseases. Prompt detection and management are essential if vigour is to be maintained.

Host range: *Pinus* spp. especially *P. radiata*, also *P. ponderosa.*

Symptoms: ***In young pines***, the foliage of the lower parts of trees appears orange-red. In severe cases, this may extend right to the growing tip. The needles finally turn red-brown with white patches which may appear ***silvery*** from a distance. ***Older trees***, especially *P. radiata* and *P. ponderosa*, appear ***reddish-brown***, and needle fall will be considerable. This symptom is best seen at the edges of plantings and in clearings especially in humid areas, eg in gullies. ***Needles*** develop pale yellow spots, which later turn bright red to brick-red and form a ***band*** around the needle. Pale red bands may be associated with other fungi. *Dothistroma* has small, black, irregular ***pustules*** (fruiting bodies) which burst through the needle surface within the red area (Fig. 264). *Dothistroma* usually attacks ***new needles*** while *Lophodermium* spp. and *Naemacyclus* spp. attack ***older needles*** which do not contribute much to tree growth.

Lophodermium* needle casts** (*Lophodermium* spp.): Different species affect different species of pines. Fruiting bodies are small, regular, elliptical, shining ***black just below the surface of the needles. When mature they open by a narrow slit, pushing back the leaf surface, exposing glistening ***white contents***. See Fig. 264, Conifers K 50 (Fig. 229).
Naemacyclus* needle casts** (*Naemacyclus* spp.) may affect radiata pine. Fruiting bodies are *whitish*, waxy and rectangular. They open by displacement of the leaf surface and look like white hinged lids or flaps which expose a ***white shiny interior surface. There are no black bands on the needles such as those found with *Lophodermium*.
Others, eg ***needle blight*** (*Sclerophoma pityophila*), may occur on ***dead and dying needles*** of drought affected radiata pine and shore pine, also ***needle drop*** (*Sydowia polyspora*), *Pestalotiopsis royenae*.

Serious attack involves waves of ***defoliation*** each growing season, which can drastically reduce increases in height and diameter and cause young trees to die. The mycelia then penetrate the stomata (breathing holes) of the needles and kill them from the point of attack to the needle tip. The fungus finally produces the black fruiting bodies.

Overwintering: Infected needles on the tree or on the ground.

Spread: ***Spores*** formed on needles are carried to other needles by wind and cloud in moist low level air streams. Disease may spread ***> 100 km*** a season if weather is favourable. Spores are shed on to the lower needles by rain or fog drip, or are picked up in an aerosol form in wet weather and spread by air movements. Entry is through ***stomata*** on needles.

Conditions favouring: An average annual rainfall of about ***1, 200 mm***, evenly distributed throughout the year, and summer temperatures ***< 27°C***, provide ideal conditions. For this reason, many pine forests in Australia where summer temperatures are high and rainfall is low are unlikely to be seriously affected by the disease. However, even here, humid or foggy areas or local wet spots, can harbour disease. Also ***favoured*** by environmental stress, eg nutrient deficiencies, waterlogging, delayed thinning and cold damage, sulphur deficient soils, many years of drought.

Control:

Cultural methods: Thinning, fertilisation, pruning, weed control, careful selection of ***planting sites***.

Plant quarantine: The ***Code of Practice for the Movement of Nursery Stock*** states that the movement of nursery stock from nurseries that are known to have *Dothistroma septosora* in nearby radiata pine plantations, to regions without the disease, is to be discouraged.

Resistant varieties: ***Susceptible species*** include *P. radiata* and *P. ponderosa*. Radiata pine in some areas is only susceptible until 14 years old but in others for at least until 24 years old. ***Breeding*** is continuing to improve resistance.

Pesticides: ***Fungicides***, eg copper, may be used to control *Dothistroma* in ***nurseries*** and in the ***field***. Copper persists in soil for decades. One recommendation is to spray with copper fungicides 4 weeks before lifting to provide good control and is environmentally least damaging. Spraying directly before planting, or at too high a concentration, may kill seedlings before and after planting out.

Root rots

Several root rot fungi have caused losses in pine plantations, sometimes on transplanted seedlings and on older trees, but particularly in areas with infertile soils, poor drainage and waterlogging.

Damping off (*Colletotrichum acutatum*, *Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani*). Also ***grey mould*** (*Botrytis cinerea*). ***Pitch canker*** (*Fusarium subglutinans*) is a ***serious disease*** of pines in North America. See Seedlings N 66.

Graft failure (*Sphaeropsis sapinacea, Cylindrocarpon scoparium*, *Fusarium* spp., *Phytophthora* spp.) and ***thielaviopsis black root rot*** (*Thielaviopsis basicola*) on *Pinus* spp.

Root rots: ***Armillaria root rot*** (*Armillaria* sp.) occurs on some *Pinus* spp., eg *P. elliottii, P. radiata*; also ***ashy stem blight***, charcoal rot (*Macrophomina phaseolina*), ***dieback*** (*Botryodiplodia theobromae*); ***fusarium root rot*** (*Fusarium solani*) on Canary Island pine, Aleppo pine, maritime pine, radiata pine. ***Phytophthora root rot*** (*Phytophthora* spp.) may affect radiata pine on poorly drained sites. Natural resistance varies within radiata pine, which can provide a basis for breeding for resistance (Lewis and Ferguson 1993). See Trees K 7.

Rusts (Uredinales)

Western gall rust (*Endocronartium harknessi*) is present in North America and may cause serious damage if introduced to Australia. Seedlings and young trees may be killed. The disease can kill trees or deform them so badly that the stems are worthless. Breeding is continuing for resistance. ***Quarantine risks:*** The most likely means of introduction is with planting material or on wood of host trees. Unlike many other pine rusts which require an obligate alternate host to complete their life cycles, western gall rust reproduces by direct infection of pine, so the disease would be difficult to eradicate. ***Quarantine precautions:*** All introductions of pine seeds and plants are subject to quarantine. Rust could be accidentally introduced as a seed contaminant. All pine seed is treated on arrival in Australia. Plants must be grown in an official post-entry station for at least 2 seasons and carefully checked for disease (Com. of Aust. 1990).

Others: ***Many other rusts*** infect *Pinus* spp. overseas, eg ***white blister rust*** (*Cronartium ribicola*) (Agrios 1988, Horst 1990).

See Annuals A 7.

Wood rots (Agarcales, Basidiomycetes)

Various species may attack weakened or damaged trees including ***yellow heart rot*** (*Schizophyllum commune*). See Conifers K 46, Trees K 9.

Wood-stains, sap-stains: ***Sap-stain fungi*** are spread by ***bark beetles***. ***Diplodia*** is the most common and widespread blue-stain fungus of radiata pine. ***Ceratocystis spp.*** (= *Ceratostemella* spp.) is spread by ***fivespined bark beetle*** (*Ips grandicollis*). All are primarily fungi of the ***sapwood*** (Lewis and Ferguson 1993). See Trees K 9.

PARASITIC PLANTS

Radiata pine mistletoe (*Loranthus pendula*) occurs in SA. ***Dwarf mistletoes*** (*Arceuthobium* spp., Viscaceae) may infest pines. See Trees K 10.

NEMATODE DISEASES

Many species of nematodes have been found in association with pines especially in nurseries, eg ***burrowing nematode*** (*Radopholus*), ***foliar nematode*** (*Aphelenchoides*), ***root lesion nematode*** (*Pratylenchus*), ***spiral nematode*** (*Helicotylenchus, Rotylenchus*), ***stunt nematode*** (*Tylenchorhynchus*), *Boleodorus, Cephalenchus, Graciliacus, Hemicriconemoides, Morulaimus, Nanidorus, Paratrichodorus,, Scutellonema, Tylenchus*, *Tylodorus.* See Vegetables M 10.

Pine wood nematode (*Bursaphelenchus xylophilus*) is a ***destructive disease*** of pine overseas (Japan, North America, Europe and Hong Kong). The nematode is spread by longicorn beetles (Cerambycidae), eg *Monochamus alternatus* in Japan. ***Quarantine risks***: The importation of any untreated timber or timber articles, especially logs, exhibiting signs of insect infestation, is considered a major risk. ***Quarantine precautions*:** All logs and timber imported into Australia is subject to quarantine. Importation of logs, rough sawn timber, boxes, crates or any other items with bark still attached is ***prohibited***. All logs and timber products are inspected on arrival and fumigated if insects are discovered. (Com. of Aust. 1987)

INSECTS AND ALLIED PESTS

Borers (Coleoptera)

Weevils (Curculionidae): ***Mountain pinhole borer*** (*Platypus subgranosus*). ***Pine bark weevil*** (*Aesiotes notabilis*) larvae burrow into bark. See Conifers K 45. ***Pine stump weevil*** (*Mitrastethus australiae*). ***Walnut pinhole borer*** (*Diapus pusillimus*) larvae bore in moist sound wood of pines and hardwoods. See Walnut F 149.

Others: Pine witchety grub (*Cacodacnus planicollis,* Cerambycidae) and ***pine bark anobiid*** (*Ernobius mollis*, Anobiidae).

See Conifers K 47, Trees K 10.

Bugs (Hemiptera)

Rutherglen bug (*Nysius vinitor*) causes shoots of nursery stock to dieback.

Stink bug (*Omyta controlineata*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Many caterpillars are often only a problem in nurseries or on young trees.

Case moths (Psychidae): ***Faggot case moth*** (*Clania* sp.) caterpillars feed on needles and defoliate small trees. ***Leaf case moth*** (*Hyalarcta huebneri*) infests radiata pine and *P. patula*. ***Lepidosca arctiella*** damages needles in plantations, young trees may be completely defoliated. ***Saunders's case moth*** (*Oiketicus elongatus*) causes moderate damage in plantations.

Cutworms (Noctuidae): ***Bogong moth*** (*Agrotis infusa*) and ***brown cutworm*** (*A. munda)* caterpillars damage ***bark*** on stems and roots and needles near ground level, may cause heavy loss of ***nursery stock***. ***Euxoa radians*** caterpillars may severely damage roots and lower stems of nursery stock. See Seedlings N 68.

Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) caterpillars damage needles, shoots and terminal buds especially on ***nursery stock*** and ***young plantings***. ***E. caryotis*** moderately damages needles in plantations. ***Acropolitis spp.*** feed on leaves. ***Lucerne leafroller*** (*Merophyas divulsana*) causes moderate needle and terminal bud damage to ***nursery stock*** and ***young plantings***. See Pome fruits F 112.

Loopers (Geometridae): ***Pine loopers*** (*Chlenias* spp.) feed on soft bark and shoot tips especially in ***young plantings*** and may predispose trees to Sirex. Generally no control is required. ***Twig looper*** (*Ectropis excursia*) which damages growing tips and terminal buds is widespread in some areas. ***Haploceros sphenotypa*** damages needles moderately in plantations, ***Parathemis lyciaria*** (= *Boarmia lyciaria*) may attack young radiata pine, eucalypt, *Persoonia*, *Acacia mearnsii*. ***Other looper pests occur overseas***, eg *Selidosema suavis* and *Nudaurelia cytheria*. See Avocado F 19.

Native budworm (*Helicoverpa punctigera*) causes ***severe damage*** sometimes to ***nursery stock***. See Sweetcorn M 89.

Oecophorids (Oecophopridae): ***Lichenaula*** and ***Procometis*** caterpillars damage needles and terminal shoots of suppressed or drought-stressed trees. See Trees K 12.

Tussock moths (Lymantriidae): ***Omnivorous tussock moth*** (*Acyphas leucomelas*), ***painted apple moth*** (*Teia anartoides*) is a sporadic pest which causes some damage. ***Painted pine moth*** (*Orgyia australis*) may ***severely damage*** small trees and nursery stock, large trees are only moderately damaged. See Pome fruits F 113.

Others: ***Lewin's bag-shelter moth*** *(Panacela lewinae*, Eupterotidae) may causes severe damage on small trees. ***Processionary caterpillar*** (*Ochrogaster contraria,* Notodontidae) damages needles of young plantings in dry aspects. ***Trigonocyttara clandestina*** may be severe in nursery stock. Also ***Epicoma tristis*** (Thaumetopoeidae) on *Pinus*. ***A hook-tip moth*** (*Digglesia australasiae*, Drepanidae) occurs on radiata pine and spruce (*Picea* spp.).

See Trees K 13.

Grasshoppers and locusts (Acrididae, Orthoptera) may damage needles and shoots in young pine plantations, eg ***Australian plague locust*** (*Chortoicetes terminifera*), ***spur-throated locust*** (*Nomadacris guttulosa*), ***wingless grasshopper*** (*Phaulacridium vittatum*), ***yellow-winged locust*** (*Gastrimargus musicus*). See Vegetables M 13.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) causes yellowing and ***silvering*** of ***needles***, death of lower branches during natural regeneration in mature stands in summer. See Greenhouses N 24.

Pine aphids (Adelgidae, Hemiptera)

Pine adelgid, woolly pine aphid (*Pineus pini*) infests pines, nursery plants are commonly attacked, also pines used for bonsai. See Bonsai N 15 (Fig. 394). Older trees may be attacked and have a ragged unhealthy stunted appearance. ***Adults*** are brown, about 1 mm long and feed at the base of the needles and cover themselves with ***fine white filaments***. ***Shoots, branches and trunks:*** Insects gather on new shoots and suck sap; a white woolly secretion at the base of the plant indicates their presence. White waxy threads may be seen also on branches and on the trunk. Shoots may die back, hence the common name for the problem, **'deadtop'.** They cause death of the terminal shoots. Small plants may be killed and older ones stunted. ***Favoured*** by trees that are under stress, eg low water supply, or those planted too closely together. ***Several insects*** parasitise or prey on the pine adelgid. If possible delay spraying in the hope that they will control the pest. If necessary spray small trees with an insecticide and a wetting agent.

Others: Other *Pineus* spp. may infest radiata pine.

See Roses J 4.

Pine bark beetles

Scientific name: Curculionidae, Coleoptera:
Fivespined bark beetle (*Ips grandicollis*)
Other introduced species also attack pines, eg
Black pine bark beetle (*Hylastes ater*)
Goldenhaired bark beetle (*Hylurgus ligniperda*)
but are not such important pests
Overseas also pine engraver beetle (*Ips pini*)

Host range: *Pinus* spp. including *P. radiata. Ips grandicollis* mainly infests recently felled trees and slash, but may cause spot or group killing trees.

Description and damage: ***Beetles*** are small, cylindrical, about ***3-4 mm*** long and about 1.5 mm wide, reddish-brown, short wing covers each with 5 blunt spines near the rear edge. ***Larvae*** are small, white, slightly curved with brown heads. Larvae of various sizes, pupae and beetles of various colour phases are found just below the bark in the sapwood of host trees and logs. ***Breeding injury and introduction of sap-stain fungi:*** Male and female beetles tunnel through the outer bark introducing blue stain fungi (*Ceratocystis ips, Sphaeropsis sapinea*), which degrade commercial timber. They mate in the nuptial chambers. Each female, after mating, chews a narrow gallery in the cambial tissue and along this makes small niches into which she lays her eggs. When larvae hatch they chew fine galleries away from the egg gallery, forming a characteristic pattern or ***engraving***, beneath the bark (Fig. 265). ***Red-brown frass*** produced by breeding attacks. ***Feeding injury to living trees*** is initiated by beetles. If populations are large, trees usually die. Phloem, cambium and outer sapwood are damaged from the ground upwards along trunks and branches. ***White frass***, or borer dust is produced. ***Trees of all ages*** may ***die in patches***.

Pest cycle: Gradual metamorphosis (egg, larva, pupa, adult) with 3 or more generations per year. Pest cycle takes from 3-6 weeks.

Spread: By transportation of unbarked logs with bark remnants attached and pine bark. By beetles flying. Pine bark beetles are most common around plantations or along roads linking plantations.

Conditions favouring: Poor management practices, eg accumulations of heavy slash after logging, thinning or clear fall operations, which provide suitable breeding sites. Thinning and pruning stressed stands during summer. Drought stressed trees.

Control: Trees should be ***monitored*** regularly. If infestation is suspected contact the local forestry department to confirm identification.

Sanitation: ***Forest hygiene*** to reduce slash through better utilisation or by slash treatments is the most important method of control.

Biological control: Pheromones have been used to ***monitor*** beetles. The ***Australian Ips Biological Control Project*** has released predatory and parasitic insects.

Resistant varieties: ***Susceptible species*** include *P. canariensis, P. elliottii, P. halepensis, P. muricata, P. nigra, P. pinaster, P. pinea, P. radiata, P. taeda*. The Cedros Island race of radiata pine has been reported as almost ***completely resistant*** to attack (Lewis and Ferguson 1993).

Plant quarantine: Regional quarantine prevents or ***slows*** further spread to *Ips*-free areas.

Pesticides: *Ips* can attack logs, usually after 48 hours from falling, and logs can rarely be left on the log dump for more than 72 hours before transportation to the mill. During the flight season, in pine growing areas, it is not possible to stockpile logs in the forest or even the mill, without some form of insecticide preventative treatment.

Radiata pine shoot weevil

(*Merimnetes oblongus*, Curculionidae) damages young shoots of radiata in ***young plantings***. A ***weevil*** (*Neomerimnetes obstructor*) damages needles in ***nursery stock*** or young plantings in newly ploughed pastures. ***Overseas*** other shoot borers occur, eg *Rhyacionia buoliana,* in Chile.

Scales (Hemiptera)

Armoured scales (Diaspididae): ***Mauve pittosporum scale***, pine parlatoria scale (*Parlatoria pittospori*).
Soft scales (Coccidae): ***Soft brown scale*** (*Coccus hesperidum*) attack needles and may be severe, there is also sooty mould.

See Citrus F 39, F 41, Trees K 16.

Scarab beetles (Scarabaeidae, Coleoptera)

Green scarab beetle (*Diphucephala colaspidoides*) ***larvae*** damage young plantings.
A scarab (*Heteronyx obesus*): ***Larvae*** cause tree death in young plantings during drought.

See Eucalypt K 61, Trees K 16, Turfgrasses L 11.

Sirex wasp

Scientific name: Siricidae, Hymenoptera:
Sirex wasp (*Sirex noctilio*)

Host range: Radiata pine is highly susceptible to attack but other *Pinus* spp. are also attacked. Confirm identification at a Department of Forestry. Occasionally dying larches (*Larix* spp.) or spruces (*Picea* spp.) (McMaugh 1994).

Description and damage: ***Female wasps*** are ***25-40 mm*** long and have uniformly iridescent, blue-black bodies with amber wings and legs (Fig. 266). ***Males*** are smaller, have a blue-black body with orange-yellowish areas on the back of the abdomen, yellowish forelegs and blue-black hind legs. ***Larvae*** are ***25 mm*** long, soft and white with well developed chewing mouthparts, very small thoracic legs and a dark spine on the tip of the abdomen. ***Damage:*** The female lays eggs, a ***fungus*** (*Amylostereum areolatum*) and ***phytotoxic mucous*** into sapwood. The mucous allows establishment and invasion of the fungus within the wood on which the larvae feed. The fungus inhibits the flow of sap and water within the tree, causing the foliage to wilt, turn yellow then red then brown. Timber is further downgraded by larvae ***tunnelling in the wood*** and ***exit holes*** of adult wasps. The entire crown turns light green and later brown from April onwards. Beads or dribble of ***resin*** resulting from wounds during egg laying may occur on ***bark***. As the fungus grows from the oviposition drill, fungal stains appear in the cambium as long narrow brown bands along the grain, and eventually the fungus permeates every part of the tree. After the tree dies, wood degrades rapidly.

Pest cycle: In Australia sirex normally completes 1 generation per year (very occasionally over 2 years).

Adults emerge in December to May and only live a few days. Females drill into the outer sapwood of trees to lay eggs and inject a symbiotic fungus (*A. areolatum*) and a toxic mucous. They pupate close to the bark about 3 weeks later. When development is completed in summer or autumn, adult wasps chew their way out through circular holes ***4-7 mm*** across.

Spread: Sirex spreads naturally only 30-50 km per year, by transport of infested logs or timber. Sirex can emerge from air dried timber or copper-chrome-arsenate treated products.

Conditions favouring: Unthinned plantations, trees stressed from fire, drought, wind, logging injury, over-mature pines, unsuitable sites, poor soils, low erratic rainfall, drought.

Control: Although sirex is not considered to be a major threat to healthy thinned plantations which have a full suite of parasites and predators, it may be in some circumstances (Cummine et al. 1996). Sirex populations, damage and its biological control agents should be ***monitored*** regularly. The ***National Sirex Coordination Control*** operates in each state.

Cultural methods/sanitation: Choose planting sites carefully, eg not very steep slopes which cannot be thinned, restrict high pruning and thinning to waste to certain times of the year, time selective thinning to maintain tree vigour throughout the rotation; minimise injury to trees from fire, machinery and silvicultural treatments, early salvage of trees damaged through natural causes, eg wind, hail, lightning and maintain a high standard of hygiene through early felling of dying or diseased trees. Ensure the pines are appropriate to the area being planted and use wide tree spacing to reduce competition from other trees.

Biological control: A ***nematode*** (*Deladenus siricicola/siridicola*) breeds up in vast numbers in the tree while feeding on the fungus, it then enters the sirex larva and begins reproduction when its host pupates. Nematode juveniles sterilise adult sirex females by entering all her eggs. When nematode-infected sirex emerge and attack other trees, they transmit nematodes instead of fertile eggs. Infection levels can approach ***100%*** and lead to collapse of sirex populations. A small number of sirex-infected trap trees in a plantation are inoculated with the nematodes mixed in a gel. A ***wasp*** (*Ibalia leucospoides*) lays its eggs down the drills of sirex and into the developing ***sirex eggs***. ***Wasps*** (*Rhyssa*, *Megarhyssa nortoni nortoni*, *Schlettererius)* drill deep into wood to paralyse and lay their eggs on ***sirex larvae***. The parasites do not usually kill > 40% of a sirex population.

Resistant varieties: White cypress pine (*Callitris columellaris*) is unaffected.

Plant quarantine: Sirex only spreads naturally by 30-50 km per year. Quarantine offers an opportunity to restrict its spread.

Others: ***Spruce spider mite*** (*Oligonychus ununguis*), ***termites*** (Isoptera).

VERTEBRATE PESTS

Kangaroos, wallabies, possums, wombats, native rats, cockatoos, magpies, currawongs, emus may damage ***young pines***. See Fruit F 13.

Non-parasitic

Environment: ***Soil moisture*** may be limited during south western summers causing dead tops. ***Frost, wind and hail*** may damage trees. In nurseries ***sun*** may scorch bark.

Mycorrhizae (ectomycorrhizae) associations are important for efficient nutrient uptake, nursery soil should be inoculated. Mixing in some soil from under established pine stands may be sufficient for trees in home gardens. See Trees K 18.

Nutrient deficiencies, toxicities: ***Phosphorus and nitrogen*** are applied to pines after planting. Excess phosphorus may be toxic. ***Boron deficiency*** causes short, tufted or rossetted needles. Some cultivars of radiata pine are susceptible to ***speed wobbles*** (curved new growth associated with very high growth rates and unbalanced nutrition).

Poisonous pine needles: ***Canary Island pine*** (*P. canariensis*) needles form indigestible masses in the stomach of cattle. Death follows 24 hours or more after access to foliage. The condition is produced by engorgement following a meagre diet (McBarron 1983).

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State/Territory Departments of Agriculture/Primary Industry eg
Sirex Woodwasp (NSW Forest Prot. Series 1)
Introduced Pine Bark Beetles in NSW (NSW Forest Prot. Series 5)

Remember, always check for recent references

Associations, Journals etc.
Australian Forest Grower
Australian Forestry
GrowSearch (database Qld DPI)
National Sirex Fund
National Sirex Coordination Committee

See Conifers K 49,
Trees, shrubs and climbers K 22

MANAGEMENT

Radiata pine is the most important plantation tree for timber in Australia. Pines are also grown for windbreaks on farms, edible nuts and bonsai. They are generally too large for the average home garden. ***Pest management programs*** have been described (Lewis and Ferguson 1993). Most diseases and pests of pines should be controlled by appropriate ***clone selection*** (genetic breeding is important), ***site selection***, ***cultural amendments***, ***thinning*** and ***other practices*** which minimise or avoid the use of pesticides in the field. See Trees K 24. ***Resistant varieties:*** Natural resistance to root rots and *Dothistroma* varies and this might provide a basis for breeding pines. A Special Seed Orchard for ***tolerant varieties*** has been established. ***Disease-free planting material:*** Some diseases are ***seedborne***, eg *Dothistroma*. Nursery stock must be free from or have a minimal tolerance of *Dothistroma* disease and be free from root rots and other diseases before planting out. Diseases must be controlled on ***nursery stock***. ***Propagated*** by seed, cuttings, micropropagation. ***Cultural methods:*** ***Choice of site*** is probably the most important management option to ensure continual regular growth and minimum damage by needle cast and blight diseases, bark beetles and sirex. Recommended fertiliser, thinning regimes and other practices should be followed. Radiata pines generally are planted in sunny sites. ***Weeds*** should be controlled at all stages of growth, eg in nursery stock and after planting out. Weeds include bracken fern, tussock grass and various woody weeds. Radiata pine may itself, be a potential weed around plantations. ***Plant quarantine:*** ***Pests of pine*** in the northern hemisphere pose the greatest insect threat to radiata pine, the ***bark beetles*** are the most likely to escape quarantine controls. There are many *Ips* spp. in the northern hemisphere and also *Dendroctonus* spp. which could cause severe damage if they established in Australia. Several ***shoot insects***, eg *Rhyacionia* spp., pose a serious threat to radiata as they cause serious growth losses and are difficult to control. Fortunately the probability of importing these is small as most forest products are shipped throughout the world as logs or processed wood. ***Exotic diseases*** of potential importance to pine and other conifers grown in Australia include dwarf mistletoe (*Arceuthobium* sp.), needle blight foliage disease (*Cercoseptoria*), needle blight and brown spot needle blight (*Mycosphaerella gibsonii*, *M. dearnessii* respectively) and needle rust (*Coleosporium* spp.), stem or vascular diseases, western gall rust (*Endocronartium harknessii*), pine wilt nematode (*Bursaphelenchus xylophilus*) and root diseases (*Verticladiella* spp., *Heterobasidion annosum*, *Fusarium* spp.). It may be difficult to predict which diseases could be significant in Australia's environment. Evaluations of the likely susceptibility of radiata pine in Australia to western gall rust and pine wilt nematode have been made in an Australian context. ***Herbicides*** are used for weed control in nurseries and in the field. ***Fungicides*** may be used in nurseries to control *Diplodia* and other diseases. ***Pesticides*** selected for use ***in the field*** should avoid undue persistence and other environmental problems. Broadacre aerial spraying of forests should be avoided.

Fig. 263. Diplodia canker (*Diplodia pinea*) on *P. radiata*. G. Minko.

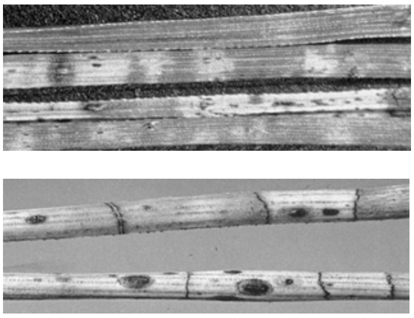

Fig. 264. *Top :* Dothistroma needle blight (*Dothistroma septospora*). G. C. Marks. ***Lower :*** Lophodermium needle cast (*Lophodermium* sp.). B. A. Fuhrer.

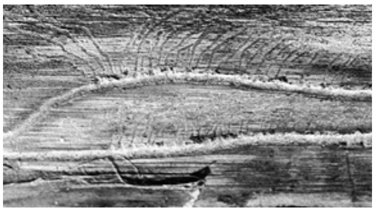

Fig. 265. Damage by fivespined pine bark beetle (*Ips grandicollis*), dead bark has been removed. Two egg galleries have been made by the females; radiating from each gallery are numerous tunnels made by the growing larvae. For. Com., NSW.

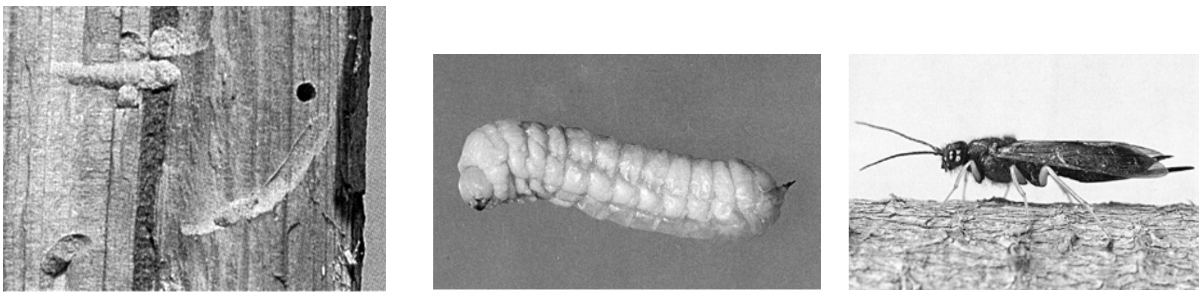

Fig. 266. Sirex wasp (*Sirex noctilio*). ***Left :*** Frass packed larval tunnels. ***Centre :*** Larva (25 mm long) with single spine. ***Right*** *:* Adult female wasp (25-40 mm long). For. Com., NSW.

Pittosporum

Pittosporum spp.
Native or sweet pittosporum (*P. undulatum*)
Family Pittosporaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas, downward leaf rolling of leaves and vein yellowing has been associated with ***virus particles*** in *P. tobira*, mosaic in *P. daphniphylloides*, death of outer bark and branches of *P. tobira*, *P. crassifolium*, *P. viridiflorum* Sims and variegated *P. tobira* (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Fungal leaf spot (*Pleospora* sp., unconfirmed) occurs on **weeping pittosporum** (*P. phillyreoides*). See Annuals A 5, Trees K 6.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*), also ***phytophthora diseases***, eg *Phytophthora cinnamomi* on ***P. tobira***, *Phytophthora nicotianae* on ***P. undulatum*** and *Phytophthora palmivora* on ***P. eugenioides*** and ***P. undulatum***. See Trees K 4, K 6.

Wood rots: ***Yellowish wood rot***, rainbow conk (*Polyporus versicolor*) mostly rots dead pittosporum. See Trees K 8.

INSECTS AND ALLIED PESTS

Pittosporum beetle (*Lamprolina aeneipennis,* Chrysomelidae, Coleoptera) can be a serious pest of *Pittosporum* spp. especially *P. hirtissimum* and *P. venulosum* in some seasons in tropical and subtropical coastal areas. ***Beetles*** are about ***10 mm*** long with shiny black wing covers and a reddish-brown thorax and head. ***Larvae*** have ugly spots and feed in groups. Adults and larvae may feed together and chew large irregular lumps out of ***leaves***. Adults drop to the ground if disturbed. Predators, eg birds and parasitic wasps, exert some control. See Trees K 15.

Pittosporum bug (*Pseudoapines geminata,* Pentatomidae, Hemiptera) is oval, about ***8 mm*** long and black with light markings, they suck sap. See Citrus F 36, Vegetables M 12.

Pittosporum leafminer

Scientific name: Agromyzidae, Diptera: Pittosporum leafminer (*Phytoliriomyza pittosporphylli*) is commonly found on coastal areas of NSW.

Host range: *P. undulatum*.

Description and damage: ***Flies*** are small, about ***3 mm*** long. ***Leaves***: Each discoloured circular sunken area (usually with a diameter of about ***3 mm***) is caused by one fly larva feeding within a leaf (Fig. 267). Maggots concentrate their feeding around the ***midrib***. Although most leaves can be attacked, plants seems to tolerate infestation. ***Twigs***: A closely related fly causes the development of ***galls*** on ***twigs*** of *P. undulatum*.

Pest cycle: Complete metamorphosis (egg, larva (maggot), pupa, adult). Female flies lays their eggs individually below the epidermis on ***leaf uppersurfaces***. Usually the oviposition punctures are made on either side of the ***midrib*** of the leaf, but occasionally may be found singly near the margin of the leaf. The hole where each egg has been laid is surrounded by a narrow violet-brown area. Maggots hatch from the eggs and feed in the mines which become slightly gall-like and so are often called ***mine galls***. When maggots are fully grown, they pupate within the gall and the adult fly eventually emerges from a ***large round hole*** on the undersurface of the mine gall.

Spread: Adults flying. Over long distances by movement of infested plant material.

Conditions favouring: Temperate and subtropical climates, coastal areas of NSW.

Control:
Cultural methods Plant away from thoroughfares so that the perfumed flowers can be appreciated without a close-up view of the leaves.
Resistant varieties: Native daphne or sweet pittosporum (*P. undulatum*) is ***very susceptible***.
Pesticides: Because control is difficult and ***plants seem to tolerate damage***, insecticides are usually only applied to young plants in ***nurseries*** and to ***specimen shrubs***. To prevent damage to leaves, spray new growth regularly. Once leaves are damaged appearance cannot be improved.

Pittosporum longicorn (*Strongylurus thoracicus,* Cerambycidae, Coleoptera) and other longicorn beetles, attack weakened *P. undulatum* and *P. eugenioides* Variegatum. Pittosporum longicorn also attacks native and cultivated figs, citrus, grapevine, passionfruit, red cedar, rock-lily, wisteria. ***Adults*** are ***30 mm*** long, light brown and strikingly marked by a row of white spots on each side of the thorax. Adults emerge mainly in November. ***Larvae*** chew ***oval frass-packed tunnels*** in twigs and limbs, and may leave ***oval openings*** through which sawdust-like material falls. They pupate in the wood in a chamber plugged at each end with fibre rather like wood-wool. See Trees K 11.

Pittosporum psyllid, pittosporum chermid (*Trioza vitreoradiata,* Triozidae, Hemiptera). Nymphs suck sap from ***young leaves***, causing small lumps which detract from their appearance when mature. All cultivars of *P. tenuifolium* are ***susceptible***. See Lilly-pilly K 95.

Scales (Hemiptera)

Armoured scales (Diaspididae)
- Mauve pittosporum scale (*Parlatoria pittospori*)

Margarodid scales (Margarodidae)
- Cottonycushion scale (*Icerya purchasi*)

Soft scales (Coccidae)
- Chinese wax scale (*Ceroplastes sinensis*)
- Pink wax scale (*C. rubens*)
- White wax scale (*Gascardia destructor*)

See Citrus F 39, F 41, Trees K 16.

Thrips (Thripidae, Thysanoptera

Greenhouse thrips (*Heliothrips haemorrhoidalis*) may cause ***leaf silvering***. Black drops of ***excreta*** occur on leaf undersurfaces. See Greenhouses N 24.

Leaf distortion thrips (*Teuchothrips pittosporicola*) attack ***new growth*** of *Pittosporum* spp. especially *P. revolutum,* causing twisted and folded, often reddish, leaves. Shoots may be ***severely deformed***. Thrips feed within the folded leaves (Jones and Elliot 1986). See Bottlebrush K 37.

Others: ***Aphids*** (Aphididae) infest new shoots of *P. eugenioides* Variegatum. ***Weevils*** (Curculionidae) may damage nursery stock of *P. tenuifolium* James Stirling and chew stems of advanced nursery stock after planting out (Fig, 268). See Trees K 17.

Remember, always check for recent references

Non-parasitic

Environment: Leaves of variegated cultivars may develop ***pinkish pigments*** in winter. ***Water stress*** may cause browning of leaf edges.

Natural gumming: ***White blobs of gum*** occur on stems and are often mistaken for scale, areas above may die back.

Potential weed: ***P. undulatum*** is a native plant which has spread beyond its native habitat into bush areas, often coinciding with the clearing of adjacent land and the establishment of housing developments (Mullet and Simmons 1995).

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Associations, Journals etc.
GrowSearch (database Qld DPI)
See Australian native plants N 9,
Trees, shrubs and climbers K 22

MANAGEMENT

Pittosporum are attractive, hardy garden plants that have fragrant creamy flowers and orange seed capsules. They are useful as screen plants. Foliage of variegated forms succeed in a wide range of climates from tropical to highland, but generally withstand only light frosts. They prefer a deep well-drained fertile loam with ample summer water supply, but will ***tolerate*** drought. ***P. tenuifolium*** is grown in NZ for cut foliage. Usually pittosporum are grown in their natural bushy form, but it is possible that longer shoots would be obtained if plants were coppiced, ie cut back at the base and a quantity of shoots encouraged, rather than allowing a main shoot to develop (Salinger 1985). ***Propagated*** generally by seed, but also by cuttings (Larson 1992). ***Potted P. tobira*** must be provided with the required light levels for cultivation and acclimatisation, high mineral nutrition levels preserve good quality, long after being placed in an interior environment (Nowak and Rudnicki 1990). ***Vase life*** of foliage is 1-2 weeks, it may be ***stored*** at 4^{o}C in preservative solution (Larson 1992).

Fig. 267. Leaf galls caused by the pittosporum leafminer (*Phytoliriomyza pittosporphylli*).

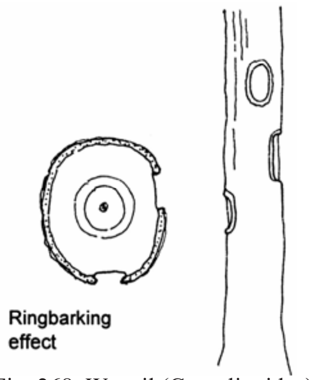

Fig. 268. Weevil (Curculionidae) injury to advanced nursery stock.

Plane tree

Sycamore

Platanus spp.
Family Platanaceae (plane tree family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Anthracnose, leaf scorch
  - Cankers
  - Canker stain
  - Fungal leaf spots
  - Phytophthora root and collar rot
  - Powdery mildew
- **Insects and allied pests**
  - Frosted scale
  - Sycamore aphid

Non-parasitic
- Burr knots
- Environment
- Fruit hairs
- Pesticide injury
- Pollution

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Anthracnose

Leaf scorch

A ***common*** and ***serious disease*** of plane trees.

Scientific name: Ascomycetes:
Anthracnose (*Gnomonia* sp.)
= *Gnomonia errabunda* = *Gnomonia veneta*
= *Gloeosporium nervisequum* = *Discula* sp.

Host range: *Platanus* spp.

Symptoms: Symptoms are most obvious in spring on young ***leaves*** as they unfold. Light brown areas appear along the leaf veins as the leaves develop. These lesions darken and form brown, irregularly-shaped areas around the ***main veins***. Spots may enlarge to include the whole leaf, which looks brown and soon falls. Sometimes the disease is ***mistaken for frost injury***. The ends of ***twigs*** (200-250 mm) may also be killed and either hang on the tree or fall to the ground with the dead leaves. ***Cankers*** form on twigs and limbs which eventually die. ***Larger limbs*** which have died are conspicuous unless pruned away. Severely affected trees show reduced growth.

Disease cycle: In autumn, infected leaves fall and during the winter the fungus lives within the ***fallen leaves***, forming small black microscopic flask-shaped fruiting bodies (perithecia). In spring, ascospores are ejected from the perithecia and depending upon temperature, moisture and light, may start new primary infections on young leaves and twigs. Later conidia are produced and cause all the subsequent infections. Another source of new infections in street trees is the spread of fungus from the ***cankers*** on branches and limbs.

Overwintering: As mycelium and immature perithecia which produce spores in spring, in ***cankers*** in twigs and limbs on the host plant and in ***infected fallen leaves***.

Spread: Both conidia and ascospores are disseminated only ***during rainy weather***. In spring the spores are spread by wind and water splash from ***leaves on the ground***, and from ***cankers*** on the tree to leaves and other locations on the tree.

Conditions favouring: Frequent rains and cool temperatures in spring. Average temperatures during the 2-week period following the emergence of the first leaves of < 12-13^{o}C favour heavy leaf and shoot infections, in spring. If the temperature is > 15^{o}C, little or no injury will occur.

Control: Control measures are ***rarely attempted*** on plane trees growing in parks and nature strips. They are justified, however, on small trees, on particularly valuable specimens or on individual specimen trees in a garden or park.

Cultural methods: Trees suffering from repeated attacks should be fertilised the following spring to increase their vigour.

Sanitation: Where practical, if the tree is valuable and if infection has been heavy the previous year and dieback has occurred, gather and ***destroy/ burn*** all fallen leaves and twigs, ***prune*** the tree back to healthy limbs and burn the prunings. This will destroy the mycelium which produces spores in spring. In the case of some street trees where pruning has been carried out regularly, the inoculum will have been removed with the prunings, reducing the incidence of disease.

Resistant varieties: Oriental plane (*P. orientalis*) has ***low susceptibility***, London plane (*P. hybrida*) is ***moderately susceptible***, sycamore (*P. occidentalis*) is ***highly susceptible***.

Pesticides: Where infection the previous year has been heavy, ***young trees or nursery stock*** may be sprayed with a copper fungicide after pruning to remove infected branches, and before bud burst, to further reduce the inoculum available for re-infection. Should severe infection show signs of developing during spring on a valuable specimen tree, regular applications of a systemic fungicide during cool wet weather may contain further spread of the disease. Only trees < 3 m in height should be sprayed. See Fruit F 5.

Cankers:

Cytospora platani (Imperfect Fungi) and *Leptosphaeria vagabunda* (Ascomycetes) develop on ***trunks and limbs***. See Trees K 5.

Canker stain

London plane blight (*Ceratocystis fimbriata* f. *platani*) is not known to occur in Australia. In the United States, canker stain is a ***serious disease*** of London plane (*P. hybrida*). Sycamore (*P. occidentalis*) is said to have ***resistance*** or only ***mild susceptibility***. It is ***spread*** during ***pruning***, on saws and wounds and in tree paint. About 5 species of Nitidulidae beetles are considered to be ***possible vectors*** (Horst 1990, Pirone 1978). See Elm K 54, Trees K 7.

Fungal leaf spots

Fungal leaf spots (*Alternaria alternata, Phyllosticta platani,* other species) cause minor leaf spotting. Control is usually ***unnecessary***. The control measures suggested for anthracnose on nursery stock could be adopted. See Annuals A 5.

Phytophthora root and collar rot

(*Phytophthora cinnamomi*): The fibrous ***root system*** rots causing a decline and finally death of the tree. Occasionally the fungus progresses from the root system to the trunk causing a ***collar rot.*** The outer bark of the trunk at the collar cracks, trunks may swell and twist, and some branches in the crown may die. Such advanced disease development can cause a dramatic reduction in tree growth. Tree coring instruments may be used to remove and subsequently isolate the fungus so that it can be positively identified and appropriate treatment carried out. See Trees K 6.

Powdery mildew

Powdery mildew (*Oidium obductum*) affects *Platanus* spp. ***Young*** leaves and shoots become covered with a white, powdery mat of mycelium and spores (conidia) making them curled and distorted. ***Buds*** may wither, immature ***fruits*** are also attacked. Leaves and young twigs may ***die***. It rarely attacks older foliage and if it does, there is little injury. The fungus ***overwinters*** in bud scales and on fruits. ***Susceptible*** species include Oriental plane (*P. orientalis*). It may be necessary to spray ***nursery stock*** with a fungicide to control powdery mildew. Large specimen trees are not sprayed. See Annuals A 6, Trees K 7.

Others:

Armillaria root rot (*Armillaria luteobubalina*) only occurs very occasionally on plane trees. ***Twig spot*** (*Steganosporium* spp.) causes dieback of twigs, black tar-like fruiting bodies develop in the ***cankers*** on the twigs. Control measures are not usually necessary.

INSECTS AND ALLIED PESTS

Frosted scale (*Eulecanium pruinosum,* Coccidae, Hemiptera) produces large quantities of honeydew with associated sooty mould. ***Predatory ladybirds*** usually control infestations, both the adults and larvae feed on this scale. One spray of winter oil during winter will usually keep this scale in check and is not detrimental to the predatory ladybirds. Other scales can also infest plane trees. See Citrus F 41, Stone fruits F 132, Trees K 16.

Sycamore aphid (*Drenpanosiphum platanoides*) may infest sycamore (*P. occidentalis*) and maples (*Acer* spp.). See Roses J 4, Trees K 10.

Non-parasitic

Burr knots: Many species of *Platanus* produce ***vegetative knots*** on the trunk, especially close to the ground, which can produce shoots. If the main trunk was removed they would grow actively. They have the same function as ***lignotubers*** on eucalypts. See Eucalypt K 65.

Environment: Plane trees are cool climate plants and have large leaves. They thrive better in places where there is some ***summer irrigation.***

Fruit hairs of London plane (*P. hybrida*) and sycamore (*P. occidentalis*) in several large Chinese cities, are reputed to be responsible for causing ***extreme irritation*** to the eyes, noses, ears and throats of pedestrians. Many of these trees are overmature, and consequently produce an abundance of fruits, the hairs from which cause ***extreme discomfort***. By cutting back these trees to lower or middle trunk branches, the tree crown can be rejuvenated to some extent, depending on pruning intensity. During the following 5-7 years of canopy regeneration and after that, fruit production is greatly reduced and the amount of hairs in the atmosphere is equally diminished.

Pesticide injury: Hormone herbicides such as 2,4-D, may cause leaf cupping. See Trees K 20.

Pollution

Gas injury: Leaf tips and margins brown, centres of leaves generally remain green. Oriental plane (*P. orientalis*) and London plane (*P. hybrida*) have ***intermediate tolerance*** only.

Atmospheric conditions: ***London plane*** (*P. hybrida*) ***tolerates*** smoke and poor atmospheric conditions better than most other trees. See Trees K 21.

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State/Territory Department of Agriculture/Primary Industry eg

Leaf Scorch of Plane Trees (Vic Agnote)

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Platanus spp. are beautiful large shade trees, with large fan-shaped leaves turning yellow in autumn. They are ***adaptable*** to most climates. London plane (*P. hybrida*) has been widely used for street and park plantings for > 2 centuries in cities such as London, ***tolerating*** smoke and poor atmospheric conditions better than most other trees. Oriental plane (*P. orientalis*) is also a magnificent tree for shade in parks and wide roads. In smaller streets its root systems are often too vigorous and the tree may need heavy lopping.

Poinsettia

Euphorbia pulcherrima
Family Euphorbiaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Poinsettia mosaic virus: ***Leaves*** may be mottled or symptomless. ***Bracteoles*** may be distorted and fail to become fully red or cream. ***Nursery stock*** may be ***100%*** infected. ***Overwinters*** in infected poinsettia plants. ***Spread*** by grafting, vegetative propagation, by movement of infected nursery stock, not by contact between plants, not by seed, not by pollen, not by a vector (Buchen-Osmond et al. 1988). See Trees K 4.

BACTERIAL AND FUNGAL DISEASES

Bacterial leaf spot *(Xanthomonas campestris pv. poinsetticola)* causes brown angular leaf spots with halos (Bodman et al. 1996). ***Bacterial soft rot*** (*Erwinia carotovora* var. *carotovora*) may rot injured stems. See Vegetables M 5. ***Grey mould*** (*Botrytis cinerea*) commonly colonises senescent and damaged tissue, especially of double varieties. See Greenhouses N 22. ***Damping off*** (*Cylindrosporium scoparium*, *Phytophthora*, *Pythium*) occurs on roots damaged by insects. See Seedlings N 66. ***Poinsettia scab*** (*Sphaceloma poinsettiae*) causes pale, raised lesions on stems and petioles, also causes distortion of new growth, leaf spots and leaf fall. ***Rhizopus soft rot*** (*Rhizopus stolonifer*) uncommonly causes a soft rot of stems and foliage, black fruiting bodies develop on fluffy white mycelium. ***Roots and stem rots***, eg ***Phytophthora spp.***, ***Pythium spp., sclerotinia rot*** (*Sclerotinia sclerotiorum*); ***rhizoctonia stem rot*** (*Rhizoctonia solani*) may be controlled biologically (Cartwright and Benson 1995). See Trees K 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) and other species attack *E. pulcherimma* and other *Euphorbia* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Whiteflies (Aleyrodidae, Hemiptera): ***Poinsettia whitefly***, silverleaf whitefly (*B. tabaci*-type B = *B. argentifolia*) is widespread and infests poinsettia, field crops, ornamentals, vegetables; a greenhouse pest. It is a ***vector*** for the tomato spotted wilt virus and at least 60 viruses overseas. Also ***cotton whitefly***, tobacco whitefly (*Bemesia tabaci*). See Greenhouses N 24.

Others: ***Castor oil looper*** (*Achaea janata*, Noctuidae). ***Twospotted mite*** (*Tetranychus urticae*) may infest poinsettia in greenhouses.

Non-parasitic

Crud (cause undetermined) is a light brown gritty exudate of calcium sulphate at the nodes of young plants and on petioles. Secondary organisms may invade damaged areas. ***Iron deficiency*** is common and species growing on Heron Island all show symptoms of iron deficiency. ***Dimethoate*** or ***media wetting agents*** (at higher than recommended rates) may injure plants. Sap may ***irritate*** skin and eyes; leaves and stems when ***eaten*** by humans do not always cause serious symptoms (Frohne and Pfander 1983).

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GrowerTalks
GrowSearch (database Qld DPI)
Poinsettia whitefly (Bemesia tabaci type B) (NSW Agnote)

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Poinsettia is a popular garden or potted plant and cut flower. ***Propagated*** by cuttings from disease- and pest-free stock plants. ***Harvest cut flowers*** when fully mature and pollen is shed. Flowers are sensitive to ethylene and chilling injury. After harvest, sear stems in boiling water to stop latex flow (latex hinders water uptake causing wilting), place in lukewarm water with preservative solution, repeat each time stem is cut, change water regularly (Jones and Moody 1993). ***Retail potted plants*** when fully mature. Adequate light ensures longevity of coloured bracts. High temperatures cause bracts to drop (Nell 1993).

Poplar

Populus spp.
Family Salicaceae (willow family)

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Bacterial canker
Fungal diseases
Fungal leaf spots
Poplar leaf curl
Rust
Nematode diseases
Insects and allied pests
Borers
Caterpillars
Poplar gall aphid
Non-parasitic
Environment
Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Overseas, yellow spots extending along fine leaf veins have been attributed to ***poplar mosaic virus*** in *P. euromericana* Gelrica. High temperatures mask leaf symptoms. Branchwood strength may be affected. ***Spread*** by vegetative propagation, by grafting, not by seed, not by pollen, not by aphid vectors, not by pruning tools. ***Several other viruses*** may affect poplar overseas (Cooper 1993). See Trees K 4.

BACTERIAL DISEASES

Bacterial canker (*Pseudomonas syringae* pv. *syringae*) affects western balsam (*Populus trichocarpa*) (Fahy and Persley 1983). In Europe poplar canker (*Pseudomonas syringae* pv. *populea*) causes cankers from ***20-120 mm*** across on trunks. Excessively cankered shoots may die back during early summer. See Stone Fruits F 124.

FUNGAL DISEASES

Fungal leaf spots

Anthracnose, poplar leaf blight (*Marssonina castagnei*, Imperfect Fungi) affects white poplar (*Populus alba*), some hybrids and cultivars. Brown ***leaf spots*** may enlarge to ***10 mm*** across. ***Favoured*** by wet conditions, eg overhead irrigation, common at the side of golf greens where sprinklers provide moisture. A greyish dot (fruiting body) develops in the centre of each spot. Leaf spots may join together to cover whole leaves which yellow and fall prematurely. Spots develop on ***leaf stalks*** but rarely on small twigs. ***M. brunnea*** attacks *P. deltoides* and other species. Leaf spots are initially red-brown, with age they bleach, are about ***1 mm*** across, but do not join together. Elliptical spots up to ***2 mm*** long develop on ***leaf stalks***. ***Additional species*** occur overseas. See Fruit F 5.

Anthracnose, scab (*Sphaceloma populi*, Ascomycetes) on Lombardy poplar (*P. nigra* Italica). ***Leaf spots 3-4 mm*** across along veins may join together into large damaged areas. Spots may develop on ***leaf stalks***. See Roses J 2, Violet A 56.

Control is not practical on large trees. In ***nurseries***, prune off badly affected shoots; ***fungicides*** may be applied to new leaves as they unfold to prevent infection. See Annuals A 5, Trees K 6.

Poplar leaf curl, poplar leaf blister (*Taphrina aurea*) is a minor but common ***leaf infection*** of most poplars. On rare occasions ***catkins*** may be infected. ***Blisters*** up to ***10 mm*** across appear on leaf uppersurfaces. On the corresponding areas on the undersides there is a concave shape in which ***orange-red spore masses*** form. Leaves do not fall and shoots are little damaged. ***Favoured*** by wet areas, young trees and nursery cuttings. Control measures are not necessary. Trembling poplar (*P. tremula*) and white poplar (*P. alba*) have some ***resistance***. See Stone fruits F 126.

Rust (Uredinales, Basidiomycetes) is the most serious problem affecting poplars. ***American poplar rust*** (*Melampsora medusae*) preferentially attacks cottonwood (*P. deltoides*) and its hybrids. ***European poplar rust*** (*M. larici-populina*) prefers Lombardy poplar (*P. nigra* var. *italica*) and its hybrids, some genetic selections show a high degree of resistance. ***Leaf uppersurfaces*** are flecked with yellow. Yellow-orange pustules 1-2 mm across (containing uredospores) develop on ***leaf undersurfaces***, sometimes joining together (*M. larici-populina*). Heavy infection causes leaves to wither and fall prematurely, often only a few terminal leaves remain on upper branches. New leaves may appear, but these also become infected and fall early. Repeated attacks weaken or even kill small trees or nursery stock. Shoots die back, possibly due to secondary diseases. In severe rust infection the yellow leaves are spectacular from a distance. Rust may completely defoliate ***nursery stock***. ***Bees*** are attracted to rust spores which they carry off to the hive, possibly in the belief that they are pollen grains. In North America and Europe, both rusts require 2 hosts to complete their ***disease cycle.*** In Australia, they seem to be able to ***survive from season to season*** as uredospores on fallen infected leaves. Uredospores are ***spread*** from infected leaves on the ground and on the tree by wind. ***Favoured*** by high humidities and temperatures in summer and autumn. As rust is only severe in some years, affected trees should only be removed when dead. Their life span may be reduced by a few years. A fungus (*Cladosporium* sp.) is a ***hyperparasite*** of *M. larici-populina* but does not provide economic control. The use of ***resistant varieties***, eg white poplar (*P. alba*), trembling poplar (*P. tremula*) is the only practical control. ***Nursery stock*** and small trees may be sprayed with a ***fungicide*** applied when rust pustules first appear. See Annuals A 7, Trees K 7.

Others: ***Cytospora canker*** (*Cytospora chrysosperma*) occurs on black poplar (*P. nigra*) and other species. ***Root rots***, eg ***armillaria root rot*** (*Armillaria* spp.), ***verticillium wilt*** (*Verticillium dahliae*). ***Silver leaf*** (*Stereum purpureum*) during mild wet winter may affect white poplar (*P. alba*) and Lombardy poplar (*P. nigra* var. *italica*).

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) has only been recorded once on poplars in Australia. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Small fruit-tree borer (*Cryptophasa albacosta*)
Fig longicorn (*Acalolepta vastator*)
See Trees K 10, K 11, K 12.

Caterpillars (Lepidoptera)

Archernis mitis (Pyralidae) occurs in Qld and northern NSW. Caterpillars live gregariously amongst ***webbed leaves*** of *P. deltoides* and pupate in the webbed bunch. The pupae are able to produce audible stridulatory sounds. See Tea-tree K 124.

Ivy leafroller (*Cryptoptila immersana*) caterpillars feed ***between leaves*** and are green. See Ivy K 88.

See Trees K 13.

Poplar gall aphid (*Pemphigus bursarius*, Aphididae, Hemiptera) causes ***leaf stalk galls*** on its ***primary host*** (Lombardy and other poplars) but ***feeds on roots*** of its ***secondary host*** (weeds, eg curled dock, dandelion). Purse-shaped ***galls*** (25-30 mm long) develop on ***leaf stalks*** of poplar in response to aphids feeding. Wingless aphids and their woolly wax are found inside the galls. In summer and autumn winged aphids leave the gall by an opening at the end and migrate to weeds to feed on roots. In spring they move back to poplars. Also spread by the movement of infested nursery stock. No control is necessary (McMaugh 1994). See Roses J 4.

Others: Larvae of the exotic ***leaf beetle*** (*Zeugophora* sp., Chrysomelidae, Coleoptera) mine in leaves of ***Salicaceae***, especially *Populus*. ***Scales*** (Hemiptera), eg ***black scale*** (*Saissetia oleae*), ***greedy scale*** (*Hemiberlesia rapax*), ***oystershell scale*** (*Quadraspidiotus ostreaeformis*), ***San Jose scale*** (*Q. perniciosus*) may infest poplar. Other scales infest poplars overseas.

Remember, always check for recent references

Non-parasitic

Environment: ***Wind*** may cause holes and tears in ***leaves*** on exposed slopes and open plantings. Trunks of Robusta cultivars are susceptible to snapping. Italica cultivars are especially resistant to wind storm damage. ***Late frosts*** may burn young leaves and soft new growth in nurseries. The use of late flushing varieties will overcome this problem.

Nutrient deficiencies, toxicities: Poplars are susceptible to ***deficiencies***, eg potassium deficiency, and ***salt toxicity***. Leaf edges brown.

Others: Poplars may grow to be ***very large trees***, their roots may cause extensive damage to ***pipes*** and ***sucker profusely***. Do not plant in small areas, near underground pipes or drains. Avoid species which sucker profusely. ***Honeybees*** apparently collect the ***sticky*** protective layer which covers the buds of some clones, causing complete destruction of buds, deformation and loss of growth. ***Large galls*** (cause undetermined) may develop on the ***trunks*** of some poplars.

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Marssonina castagnei : A Disease of White Poplar (Vic Con. Forests & Lands)
Poplar Rust (NSW Forestry Co.)
Some Notes on Poplar Growing in NSW (NSW For Com)
Farm Trees Series NSW Agric.
Establishment Techniques for Farm Trees
Farm Planning for Tree Establishment
Tree Planting for Gully Erosion Control
Soil Conservation Service of NSW Trees for the Southern Tablelands.
Associations. Journals etc.
FAO International Poplar Commission
New Zealand National Poplar Commission
See Trees, shrubs and climbers K 22

MANAGEMENT

In Australia poplars are mainly grown for ornamental purposes. They are not suitable for tropical areas and are usually grown in temperate climates in deep, fertile, well drained soils. A good water supply is required. They will tolerate occasional flooding and temperatures < 0^{o}C (McMaugh 1994). Select species with ***resistance*** to rust and *Marssonina* leaf spots, size and suckering and other local problems.

Protea

Protea spp.
Family Proteaceae (waratah family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Witches' broom occurs in South Africa and is considered to be caused by a mycoplasma which is spread by an eriophyid mite (*Aceria proteae*) (Von Broembsen 1989). See Trees K 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas syringae* pv. *syringae*) causes minor leaf spotting on *P. cynaroides* and other species in ***nurseries*** and ***field plantings*** during cool moist conditions. Sunken dead areas are surrounded by a crimson coloured halo. Flowers with spotted foliage are not marketable. See Vegetables M 5.

FUNGAL DISEASES

*Fungal diseases of **leaves and stems** are probably the **most serious problems** affecting proteas.*

Cankers (various species) are common on ***stems*** of *Protea* spp. They can girdle stems and usually follow injury. Plants may die. ***Phomopsis shoot and stem canker*** (*Phomopsis* spp.) causes shoot and stem cankers of *Protea* in Qld. ***Botryosphaeria canker and tip blight*** (*Botryosphaeria* spp.) is a problem on proteas in South Africa and Hawaii. ***Others:*** *Botryodiplodia, Phoma.* See Trees K 5.

Fungal leaf spots

Anthracnose diseases: ***Colletotrichum tip dieback*** (*Colletotrichum gloeosporoides*) is an ***serious disease*** of young and old proteas cultivated for cut flowers, including *P. coronata, P. compacta*, *P. cynaroides*, *P. magnifica*, *P. neriifolia*, *P. longifolia*, *P. obtusifolia*, *P. repens*, *P. stockoei* in the ***field*** and in ***nurseries***. ***Young shoot tips*** may die back, plants may die. Diseased tissues become dark grey to black and ***orange spore masses*** may develop on dead tissue. Lesions may extend down into older tissues ***(cankers)*** and whole branches may die. Brown leaf spots ***(anthracnose)*** develop. In older plants only the terminal growth is usually affected. ***Favoured*** by high humidities especially in summer rainfall areas, extended periods of leaf wetness and warm (20-25^{o}C) conditions. Seedborne.

Elsinoe disease, elsinoe scab (*Elsinoe*) is a ***serious disease*** of ***foliage and stems*** of *Leucodendron, Leucospermum*, *Mimetes* and *Serruria* in Vic, Qld and WA and *Petrophile linearis* in Qld, and may be ***difficult to control***. It has been recorded on *Protea* Pink Ice, and *Petrophile teretifolia* (Ziehri et al. 1996). Raised red scabby lesions develop on ***current season's stems***, heavily infected branches become twisted and distorted. Pits may develop on stems. ***Latent infections*** may occur in nurseries without showing symptoms. Resistant species have not been identified (Pascoe et al. 1995). See Fruit F 5.

Batchelomyces leaf spot (*Batchelomyces proteae*) occurs on ***P. cynaroides*** in wet and warm conditions causing unsightly lumpy red markings. Blooms are unmarketable due to the yellow, red to purple spots on ***leaves***. Probably seedborne.

Coleroa sp. causes leaf spots on ***older foliage*** of *Protea* spp. It only attacks young foliage when plants are growing poorly. The fungal fruiting bodies are like pepper grains and are arranged in roughly ***circular spots*** on leaves.

Dreschlera blight (*Dreschlera* spp. = *Helminthosporium* spp.) is a minor disease of most commercial cultivars of *Leucospermum* especially *L. cordifolium* causing rapid ***death of young shoots***. Affected leaves yellow and die.

Others: ***Alternaria*** on *Leucospermum* and *Leucodendron* attacks flower bearing shoots. ***Guignardia leaf spot*** (*Guignardia* sp.) occurs on waratah and *P. cynaroides*. ***Others*** in South Africa, eg *Leptosphaeria protearum* on protea; *Mycosphaerella proteae* and *Stigmina protearum* occur on *Leucospermum* and *Leucodendron*.

See Annuals A 5, Trees K 6.

Grey mould (*Botrytis cinerea*) may be a problem on *Leucodendron*, *Leucospermum*, *Protea* and waratah, causing ***leaf, shoot and flower blights***, curling and dieback of shoot tips, and irregular brown spots on ***leaves and flowers***. As flower buds are produced near shoot tips, flower production is reduced. ***Favoured*** by cool, wet weather during winter. It is controlled with foliar sprays. Grey mould may cause ***damping off diseases*** and ***postharvest*** storage problems as well. See Greenhouses N 22.

Postharvest diseases: ***Grey mould*** (*Botrytis cinerea*) and ***rhizopus soft rot*** (*Rhizopus* sp.) on *L. cordifolium* is controlled by dipping flowers in fungicide and drying thoroughly before packing. See Annuals A 5, A 11.

Root rots

Damping off (*Botrytis cinerea*, *Colletotrichum gloeosporiodes*, *Cylindrocladioum*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia,* other species). See Seedlings N 66.

Root rots: ***Armillaria root rot*** (*Armillaria luteobubalina*) may ***kill plants*** in established plantations of protea, *Leucodendron* and *Leucospermum* if planted in cleared diseased bush areas. See Trees K 4. ***Phytophthora root rot*** (*Phytophthora* spp., *P. nicotianae, P. cinnamomi*) is a ***major disease*** in WA where commercial proteas are grown in cleared bushland. *P. cinnamomi* may kill ***> 50%*** plants in a crop. *Leucadendron* and *Leucospermum* are ***very susceptible***. Above ground symptoms of leaf yellowing and poor growth are similar to those of nutrient deficiency and drought. Affected plants have no fibrous or proteoid roots. ***Roots*** are black and shrivelled and a dark lesion is often present below the bark at soil level. Most losses occur within 2 years of planting. Select a well drained site and avoid conditions where soil is saturated for long periods. ***Tolerant proteas*** include *P. neriifolia*, *P. repens.* ***Susceptible species*** include *P. magnifica*, *P. compacta*, *P. cynaroides*. See Trees K 6.

Rosellinia white root rot (*Rosellinia* sp.) is uncommon but may be ***serious in some areas***. It affects protea, waratah, many forest trees, eg pine, eucalypt, fruit trees, woody weeds and potatoes. A basal stem, crown or collar rot occurs with or without root rot. Abundant ***white fungal growth*** can be seen usually on the surface of affected parts. ***Favoured*** by soil rich in organic matter which possibly spreads it in litter layers. It has occurred in newly cleared land adjacent to forests. See Pome fruits F 110.

Others: ***Rhizoctonia stem rot*** (*Rhizoctonia solani*) affects *Leucodendron*. ***Verticillium wilt*** (*Verticillium dahliae*) is a minor disease of protea.

See Trees K 6, Vegetables M 7.

Wood rots: ***Silver leaf*** (*Stereum purpureum*) is a ***serious disease*** of protea and *Leucodendron*. Other wood rots of protea occur overseas. See Trees K 8.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) affect *P. mellifera* and *P. obtusifolia*. In Hawaii, root knot severely limits growth of *L. cordifolium* and *P. neriifolia*, causing stunting, yellowing of lower leaves and death of young shoots, branches and entire plants. Roots develop ***galls***. Others include ***spiral nematode*** (*Helicotylenchus dihystera*) and *Paratrichodorus minor*. *Hemicycliophora* sp. occurs on *P. neriifolia*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers of various kinds attack banksia, waratah and *Leucospermum*. ***Larvae*** of beetles and moths can attack stems of woody plants and once established they are difficult to kill. They may cause ***severe damage*** to wildflower or protea plantations. See Trees K 10.

Caterpillars (Lepidoptera)

Leafminer (Incurvariidae) and possibly other moth caterpillars may mine in ***leaves*** of *Protea* spp. See Eucalypt K 62.

Lightbrown apple moth (*Epiphyas postvittana*) is an ***important pest*** of proteas especially *Leucodendron*. See Pome fruits F 112.

Macadamia twig-girdler (*Xylorycta luteotactella*) caterpillars are ***25 mm*** long, mottled brown, with rows of dark brown spots on the back with bristles rising from the spots, may ringbark ***stems*** or destroy ***leaves***. See Macadamia F 77.

See Annuals A 8, Trees K 13.

Weevils (Curculionidae, Coleoptera): Larvae of ***Fuller's rose weevil*** (*Asynonychus cervinus*) and ***garden weevil*** (*Phlyctinus callosus*) live in the soil where they feed on the roots of grasses and broadleaved plants. Adults excavate small, deep, rounded holes scattered over the surface of ***stems***. Stems may be ***ringbarked***. See Trees K 17.

White palm scale (*Phenacaspis eugeniae*) is a common ***armoured scale*** (Diaspididae) affecting protea in ***nurseries*** and in the ***field*** and is unacceptable to ***export markets***. Field control is difficult and post-harvest elimination costly. Even if postharvest treatments are effective, scale coverings often remain. Scale should be controlled during the growing season. ***Monitor*** scales so that treatments can be applied at crawler stages. Small localised infestations can be ***spot treated*** before populations get out of control. See Palms H 4.

Others: ***European earwig*** (*Forficula auricularia*) nibbles ***foliage*** giving it a ragged appearance. ***Green peach aphid*** (*Myzus persicae*) may infest ***new shoots***. ***Mites*** (Acarina), eg European red mite (*Panonychus ulmi*), twospotted mite (*Tetranychus urticae*). ***Scarab beetles***, eg black beetle (*Metanastes vulgivagus*), may damage proteas. ***Termites*** (Isoptera) have caused significant damage in some protea plantations. ***Thrips*** (Thysanoptera) may infest ***flowers***.

VERTEBRATE PESTS

Various animals and birds especially parrots may damage proteas. See Fruit 13.

Non-parasitic

Blackening of leaves is a ***postharvest disease*** of *P. compacta, P. exima, P. magnifica, P. repens* and *P. neriifolia*, caused by the production of black oxidation compounds due to physical damage, water or temperature stress. Do not harvest when excessively hot, place cut stems in water as soon as possible, cool quickly. Treat as recommended. Keep in strong light and ***do not mist flowers*** or foliage (Jones and Moody 1993).

Environment: Some species, eg *P. grandiceps* Princess and *P. repens* Sugar bush, ***tolerate*** severe ***frosts*** while buds of others, eg *L. cordifolium*, are ***susceptible***. Many species are ***drought hardy*** but if quality flowers are desired then irrigation and fertilisation are necessary.

Nutrient deficiencies, toxicities: Proteas have coraloid ***proteoid*** roots which have a large surface area for absorption of minerals. See Trees K 18. ***Too much phosphorus*** causes yellowing/bronzing of leaves tips and susceptibility to fungal disease. There may be leaf fall and with substantial overdoses, plants may die. ***Excess nitrogen*** will result in poor growth. ***Deficiencies*** of iron, magnesium, potassium and other elements, may occur. See Trees K 20.

Pesticide injury*:* ***Oil sprays*** may damage hairy leafed protea. ***Copper sprays*** may damage protea. Before spraying, test spray a few plants.

Others: ***Ants*** are attracted by honeydew secreted by sucking insects or nectar in flowers. Control of scale and aphids will reduce the attractiveness of plants to ants. Reduce ***spider populations*** by controlling weeds and other pests, eg caterpillars. Spiders are ***predators*** and if prey is scarce will go elsewhere in search of food. Treatments for other pests will have some effect on spiders. ***Populations*** of spiders and scales are greatest on *P. grandiceps* and least on *P. cordifolium*.

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State/Territory Departments of Agriculture/Primary Industry eg

Growing Proteas (WA Farmnote)
Growing Proteas Commercially (NSW Agfact)
Insect Pests of Wildfllowers and Proteas (WA Farmnote)
Major Diseases of Proteaceous Plants (Vic Agnote)
Pests of Proteaceous Plants (Vic Agnote)
Phosphorus Toxicity in Native and Proteaceous Plants (Vic Agnote)
Post-harvest Handling of Proteas (Vic Agnote)
Protea Growing (Vic Agnote)
Picking, Packing, Processing (Video Tel 08 389 3057)

Associations, Journals etc.

Australian Floriculture Conferences
Australian Protea Growers Assoc (APGA)
Flower Export Council of Australia (FECA)
GrowSearch (database QLD DPI)
International Protea Assoc (IPA)
Proteaflora Enterprises, Monbulk, Vic
Protea Growers Assoc of WA (PGA of WA)
Protea National

See Australian native plants N 9, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Select flower species to match flower production with peak demand periods. Young plants may be lost in their first year, sudden death of older plants can occur. Avoid cultivars ***highly susceptible*** to *Phytophthora,* leaf spots or local problems. *Protea* Pink Ice is vigorous, frost hardy, evergreen, tolerant of wide range of soil types and climates. Proteas may be grafted onto ***Phytophthora-resistant rootstock***. Many diseases are seedborne. Select seed and cuttings from ***disease- and pest-free plants and treat seed***; diseases and pests are difficult to control on established plants. ***Design sites*** for layout and practices which minimise disease development. ***Avoid planting sites*** with a history of disease, eg *Armillaria, Phytophthora, Rosellinia*. ***Pre-plant*** clear land thoroughly of root debris, etc. Fallowing may be necessary. ***Analyse soil*** for diseases, nematodes and nutrients. Treat if necessary. Use mulches with care as they may increase problems, eg weevils, *Rosellinia*. Provide a well drained acid soil, open sunny and breezy positions preferably with north to east aspect. ***Minimise*** overhead irrigation. Proteas flourish ***in poor soil*** and do not tolerate phosphorus (a few exceptions) or respond well to large amounts of nitrogen. Avoid excessive root disturbance. Protect from afternoon summer sun. Avoid staking even of tallish single stem species. Follow ***nursery hygiene*** procedures for disinfecting water, etc. See Nurseries N 51. ***Prune out*** and burn diseased stems and whole plants. Most species need to be ***pruned*** properly if more flowers are to be produced (there are some differences in the pruning required for individual species). ***Control weeds*** to limit earwigs and other insects. Planting in single rows allows better access for mowing, picking and spraying. Growers should produce relatively ***clean plants*** in the ***field***, so that postharvest treatment of cut flowers is more effective. The presence of pests, eg scale, thrips, may jeopardise ***quarantine regulations*** and ***export markets***. Flowers of *Protea* Pink ice may need to be disinfested. ***Pesticides*** may protect young plants from *Phytophthora*, leaf spots, etc. in nurseries but may be uneconomical in the field. Seek advice to avoid the development of ***resistance*** to pesticides. ***Harvest*** early in the day just as buds are opening, do not leave in the sun, immediately place in water in an adjacent cool shed. For export they are packaged by variety, graded, etc. They dry well; air-dry naturally, standing in water or spread on wire benches or treat with glycerine. ***Vase life*** may be lengthened by using flower preservative in the water. Proteas take up much water. Keep leaves dry and in strong light to avoid leaf blackening, do not mist (Jones and Moody 1993). An overview of the industry is outlined by Coombs (1995).

Silk tree

Silk tree, pink silk tree (*Albizia julibrissin*)
Family Mimosaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Phytophthora root rot
- **Nematode diseases**
  - Root knot nematode
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Wattle mealybug

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASE

Virus-like particles are associated with yellow ***stripes bordering leaf veins*** of *Albizia julibrissin* in the USA (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Phytophthora root rot (*Phytophthora* sp.) has been recorded on silk tree (*A. julibrissin*) and crested or cape wattle (*A. lophantha*), and *P. cryptogea* on *Albizia* sp. See Trees K 6.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne javanica*) has been recorded on *Albizia distachya* and *A. lophantha*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers are ***the most serious problems*** affecting silk tree (*A. julibrissin*) and unless trees are well cared for culturally, inspected regularly and infestations properly treated each year from the time a tree is several years old, they may become severely infested and may die within 15-20 years of planting. Various ***moth*** (Lepidoptera) and ***beetle*** (Coleoptera) borers may infest silk trees including:

Fruit-tree borers (Oecophoridae)
- Fruit-tree borer (*Maroga melanostigma*)
- Small fruit-tree borer (*Cryptophasa albacosta*)

Longicorn beetles (Cerambycidae, Coleoptera)
Wood moths (Cossidae, Lepidoptera)

See Trees K 10, K 11, K 12, Wattle K 132.

Caterpillars (Lepidoptera) of several butterflies and moths may infest silk trees.

Common grass yellow (*Eurema hecabe phoebus*, Pieridae) caterpillars feed on mainly ***featheryleaved wattles*** and *A. lebbeck*. See Wattle K 133.
Hook-tip moth (*Digglesia australasiae*, Drepanidae) caterpillars feed on *Acacia* spp., *Albizia* spp., *Exocarpos cupressiformis*, *Pinus radiata* and spruce (*Picea*).
Moth (*Neola semiauranta,* Notodontidae) caterpillars feed on Mimosaceae, eg many *Acacia* spp., *Dodonaea* spp. and the introduced *A. lophantha*.
Others: ***Painted apple moth*** (*Teia anartoides*), ***sandal-box hawk moth*** (*Coenotes eremophilae*, Sphingidae) and ***tailed emperor butterfly*** (*Polyura pyrrhus sempronius*, Nymphalidae).

See Trees K 12, Wattle K 133.

Wattle mealybug (*Melanococcus albizziae,* Pseudococcidae, Hemiptera) is a ***sporadic pest*** of mainly wattles but also some species of *Albizia*. It is usually controlled by ***parasites and predators***. See Wattle K 135.

Non-parasitic

Environment: Although silk trees are reasonably hardy, they must be irrigated and fertilised appropriately if they are to ***withstand borer infestations***.

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Silk trees are grown for their attractive flowers and fine fern-like leaves. Because of the ***susceptibility*** of silk trees to borers, it is recommended that they should not be planted as specimen trees. ***Fertilise and water*** appropriately to retard borer attack. ***Inspect trees regularly*** and treat any borer damage when first observed. *Albizia* spp. ***tolerate*** light frosts and short periods of dry conditions. They grow well in a wide range of climates, preferably in a warm, sunny position and well drained soil. Some species, eg Indian siris (*Albizia lebbeck*), will grow in areas receiving as little as 400 mm rainfall. ***Propagated*** by seed.

Tamarisk

Tamarix spp.
Athel tree (*T. aphylla*)
Family Tamaricaceae

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
- **Nematode diseases**
- **Insects and allied pests**
  - Borers
  - Caterpillars
  - Scales
  - Weevils

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Overseas, ***cankers*** (various species of fungi) may cause dieback of tamarisk. ***Powdery mildew***, ***root rots*** and ***wood rots*** also affect tamarisk. Fungal diseases in Australia are not well documented.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne* sp.) has been recorded on *T. aphylla*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers

Auger beetles (Bostrichidae, Coleoptera) derive their name from their habit of boring ***circular holes***. Several species may attack tamarisk. ***Large auger beetle*** (*Bostrychopsis jesuita*) is glossy black and from 15-22 mm long (Fig. 269). ***Larvae*** are curved, thickset, white, about 10-12 mm long, with 3 pairs of thoracic legs . The vertical tunnels in the sapwood in which they have been feeding become ***tightly packed with frass*** and undigested residue of eaten wood. Tunnels are about 5 mm across. Larvae feed on starch in the sapwood, pupate close to the surface and emerge through ***round exit holes***. Larvae are active September to April. Usually dead or dying trees are attacked so that no treatment is usually justified. Plant a replacement tree or another species suitable for the site. See Trees K 11.

Fruit-tree borers (Oecophoridae, Lepidoptera)
Fruit-tree borer (*Maroga melanostigma*)
Small fruit-tree borer (*Cryptophasa albacosta*)
Caterpillars are multicoloured, hairy and make short tunnels usually in a ***branch fork***. They feed on callus tissue which grows around the tunnel entrance. See Fruit F 10, Trees K 12.

Others: Elephant weevil (*Orthorhinus cylindrirostris*).

Caterpillars (Lepidoptera)

Darkspotted tiger moth (*Spilosoma canescens*, Arctiidae).
Tussock moths (Lymantriidae)
Painted apple moth (*Teia anartoides*)
Omnivorous tussock moth (*Acyphas leucomelas*)

See Trees K 13.

Scales (Hemiptera)

Armoured scales (Diaspididae)
Latania scale (*Hemiberlesia lataniae*)
Apple mussel scale (*Lepidosaphes ulmi*)
Soft scales (Coccidae)
Black scale (*Saissetia oleae*)

See Citrus F 39, F 41, Trees K 16.

Weevils (Curculionidae, Coleoptera) chew bark from small branches (Fig. 270). See Trees K 17.

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State/Territory Departments of Agriculture/Forestry/ Primary Industry eg
Borers and Termites in Trees (Forestry Commission of NSW. Series No. 4)
See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

The athel tree (*T. aphylla*) will grow in a variety of harsh conditions. It ***tolerates*** hot, dry conditions, moderately saline soils, severe pruning and salt-laden winds, but it should be protected from frost while young. It has a deep and penetrating root system. The ***large auger beetle*** attacks dead or dying trees.

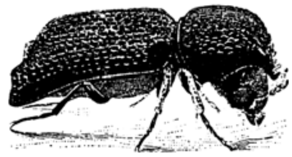

Fig. 269. Large auger beetle (*Bostrychopsis jesuita*) 12-22 mm long. Dept. of Agric., NSW.

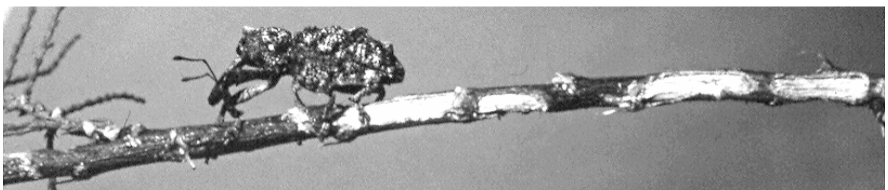

Fig. 270. Tamarisk stem damaged by elephant weevil (*Orthorhinus cylindrirostris*) (20 mm long). Identity unconfirmed.

Tea-tree

Leptospermum spp.
Family Myrtaceae

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Cylindrocladium* collar and stem rot, leaf spot, shoot blight** (*Cylindrocladium* spp.) attacks nearly all parts of ***Myrtaceae plants, especially young plants.
Fungal leaf spots: ***Tar spot*** (*Phyllochora egenula*) (Walker 1994). See Annuals A 5, Bottlebrush K 36.
Root rots: Armillaria root rot (*Armillaria luteobubalina*) and ***phytophthora root rot*** (*Phytophthora cinnamomi*). See Trees K 4, K 6.
Others: Cankers (various fungi) on stems may cause dieback. ***Tinder punk*** (*Phellinus* spp.) may cause wood rotting.

NEMATODE DISEASES

Root knot nematode (*Meloidogyne incognita*), ***root lesion nematode*** (*Pratylenchus brachyurus*), *Helicotylenchus, Hemicriconemoides, Morulaimus, Paratylenchus*, *Scutelloma* on *Leptospermum* spp. (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***An Australian species*** (*Anomalaphis* spp.) occurs on ***Myrtaceae***, eg *Agonis*, *Astartea*, *Leptospermum*. See Roses J 4.

Borers

Fruit-tree borer (*Maroga melanostigma*) caterpillars cover their tunnels with brown chewed wood pieces and webbing. They feed mainly on ***small branches*** and may ringbark and kill ***branches***. See Trees K 12.
Ghost moths, swift moths (Hepialidae), eg ***common splendid ghost moth*** (*Aenetus ligniveren*) and *A. lewini*. See Trees K 12.
Others: Longicorns (Cerambycidae) tunnel in small branches and twigs causing them to die. ***Jewel beetles*** (Buprestidae) and ***wood moths*** (Cossidae). See Trees K 10, K 11, K 12.

Bugs (Hemiptera): ***Crompus oculatus, C. opacus*** (Lygaeidae) and other species suck sap from ***seeds*** of ***Myrtaceae***, eg *Callistemon*, *Leptospermum*, *Metrosideros*. See Bottlebrush K 36.

Caterpillars (Lepidoptera): More than 20 species of moths infest *Leptospermum* spp.

Case moths (Psychidae): ***Faggot case moth*** (*Clania tenuis*), ***leaf case moths*** (*Hyalarctica huebneri*, *H. nigrescens*) and ***Saunders's case moth*** (*Oiketicus elongatus*) caterpillars feed on *Leptospermum* spp. ***Narycia guildingi*** feeds on ***Myrtaceae***, eg *Leptospermum*, *Kunzea*. See Trees K 13.
Loopers (Geometridae): These include ***twig looper*** (*Ectropis excursia*), also *Aelochroma melarhodata*, *Chlorodes boisduvalaria*, *Dichromodes*, *Eochrois dejunctella, Epidesmia tricolor, Euloxia meandrari, Lophothalauna habrocosma, Onycodea traumataria*. See Avocado F 19.
Web moths (Pyralidae) are ***serious pests*** of narrowleaved ***Myrtaceae***, eg *Astartea, Baeckea, Beaufortia,* Geraldton wax, eucalypt, *Kunzea, Leptospermum, Melaleuca, Reglia, Thryptomene,* some ***Proteaceae***, *Acacia*, *Indigofera*, other plants. The host range of each species is often not precisely known. ***Teatree moth*** (*Catamola marmorea*), ***teatree web moth*** (*C. thyrisalis*) and other moth caterpillars live gregariously between webbed leaves. ***Moths*** are small, dull. ***Caterpillars*** are slender, dull, about ***25 mm*** long with many black hairs. They spin a protective ***silky webbing*** over the stems and leaves of the plants on which they feed. Webbing is coated with plant debris and pellets of excreta (Fig. 271). Caterpillars shelter together during the day in the webbing and ***feed at night*** on ***foliage*** and ***young flower buds***, making plants unsightly, reducing and preventing flowering. If the webbing is disturbed they may quickly drop down on silken threads and disappear into leaf litter at the plant base. ***Complete metamorphosis*** (egg, caterpillar, pupa, adult), with probably several generations each season. ***Spread*** by moths flying and to a limited extent by the movement of infested plants. ***Favoured*** by temperate and tropical climates. ***Control*** caterpillars in spring to prevent a buildup in numbers. If only a few plants are infested, caterpillars may be ***squashed by hand***. Dead shoots and webbing may be ***pruned off and burnt***. Light infestations may be hosed off, caterpillars tend to return quickly. If necessary spray plants and soil immediately underneath in spring after removing webbing. If this 1st spring generation is controlled further sprays may not be necessary that season. ***Bacillus thuringiensis*** (Dipel®) may be effective for light infestations but it may be necessary to apply white oil and other insecticides.
Others: Hook-tip moths (*Porella* spp., Drepanidae), also *Epicoma constristis* and *E. melanosticta, Aquita tactalis, Amelora milvaria, Marane melanospila, Marasca bracteate*, *Thudaca mimodora*.

See Trees K 13.

Paperbark sawfly (*Pterygophorus* sp.) ***larvae*** may ***defoliate*** *Leptospermum* in summer and autumn (Fig. 272) and cause ***permanent damage*** when they pupate in the bark of ***trunks*** (can be mistaken for phloem-cambium borers). If many larvae burrow into bark, trees may be ringbarked. They also pupate in soft timbers, eg soft pine weather boards. ***Prune off*** small branches with larvae. Remove damaged areas and keep plants bushy. See Melaleuca K 99.

Plague thrips (*Thrips imaginis*) feed in ***flowers*** causing premature browning. Their sap sucking reduces ***fruit and seed formation***. They are sporadic pests, in huge numbers some seasons and absent or uncommon in others. See Roses J 6.

Scales (Hemiptera)

Armoured scales (Diaspididae):
White palm scale (*Phenacaspis eugeniae*)

Eriococcid scales (Eriococcidae): ***Teatree scale***, ***manuka blight*** (*Eriococcus orariensis*) feeds on broom tea-tree or manuka (*L. scoparium*) which can be weakened or killed, kanuka (*L. ericoides*) is hardly affected. Scale insects feed in bark crevices and under loose bark. Large numbers cause ***serious damage*** and plants become covered with sooty mould. White male pupal cases may be seen on the blackened surfaces. Teatree scale is ***difficult to eradicate***. In Australia, scale numbers are kept low by ***natural enemies*** and they do not always cause much damage. In NZ there are few successful natural competitors and damage can be ***severe***; applications of ***insecticides*** and ***petroleum oil*** may be necessary. Presence of scale on export material could affect export trade from NZ. See Citrus F 41, Eucalypt K 63.

See Citrus F 39, F 41, Trees K 16.

Others: ***Free-living psyllids*** (*Acizzia* sp.), ***redshouldered leaf beetle*** (*Monolepta australis*). Also ***green scarab beetle*** (*Diphucephala colaspidoides*), ***gall midges*** (Diptera), ***gall wasps*** (Eupelmidae), ***green planthopper*** (*Siphanta acuta*).

Non-parasitic

Fungi: A blackish ***epiphyllous parasite*** (*Meliola leptospermi*) may grow on leaves. ***Sooty mould*** (*Capnodium* sp.) may grow on honeydew secreted by scales and other sap sucking insects.

Insects and mites: A ***scorpion fly*** (*Harpobittacus,* Mecoptera) feeds on nectar as it forages for prey in blossoms and ***adult flies*** (*Pelecorgynchus*) hover in flowers. Also ***soldier beetles*** (Catharidae, Diptera), ***beetles*** (*Pseudohydrobius*), ***teatree itch mite*** (*Eutrimbicula samboni*).

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Associations, Journals etc.
Society for Growing Australian Plants
See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Tea-trees are small trees and shrubs and are generally not suitable for the tropics, but they will withstand almost any other conditions. Some ***tolerate*** salty winds. Broom tea-tree or manuka (*L. scoparium*) from which most cultivars used for flowers originate, is ***susceptible*** to teatree scale (*Eriococcus oranensis*). Cultivars for cut flowers must have long straight stems. Kanuka (*L. ericoides*) is ***resistant*** to teatree scale. Breeding programs aim to develop cultivars with long straight stems for use as cut flowers and with resistance to teatree scale. Only plant ***scale-free propagation material***. ***Propagate*** by cuttings or seed. Cultivars grown for display or cut flowers must be provided with good soil, water in dry weather and be tip-pruned regularly if they are to look their best. ***Harvest*** long shoots of *L scoparium*. Long shoots of wild material have been cut for export, double flowered cultivars are preferred, eg Floradora, Red damask. The shoots are cut as the lower flowers open. Flowers can be ***stored*** at 4°C for 1- 2 days and will last 3-10 days under room conditions (Salinger 1985). Flowers drop easily, treat as for Geraldton wax (Jones and Moody 1993). See Geraldton wax K 74.

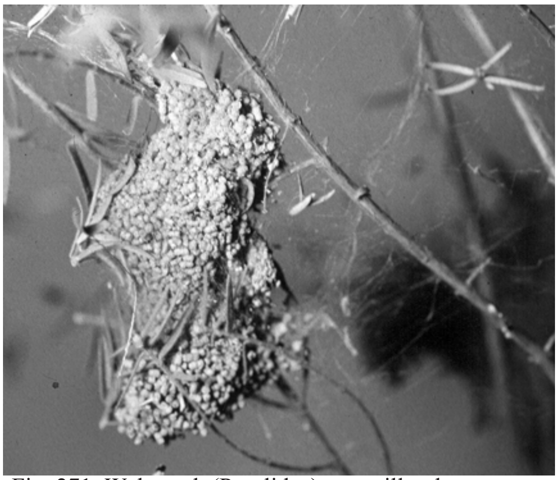

Fig. 271. Web moth (Pyralidae) caterpillar damage to melaleuca.

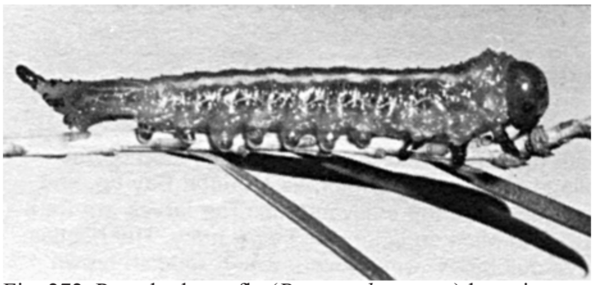

Fig. 272. Paperbark sawfly (*Pterygophorus* sp.) larva is up to 30 mm long. Forestry Com. of NSW.

Thryptomene

Australian Lace Flower

Grampians
Thryptomene spp.
Grampians thryptomene (*Thryptomene calycina*)
Family Myrtaceae (eucalypt family, myrtle family)

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Damping off
  - Grey mould
  - Phytophthora root rot
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Ringbarking weevil
  - Thrips

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Damping off (*Pythium* spp., *Phytophthora cinnamomi*) may occur ***before and after*** planting out. See Seedlings N 66.

Grey mould (*Botrytis cinerea*) may cause ***flower blight*** of *T. baeckeacea.* See Geraldton wax K 73, Greenhouses N 22.

Phytophthora root rot (*Phytophthora cinnamomi*) is the ***most serious disease*** of thryptomene. *T. calycina* is ***very susceptible*** and thousands of plants have been killed in both the wild and in plantations. *T. saxicola* and *T. hyporhytis* appear to be ***more resistant*** than *T. calycina* and *T. micrantha*. *T. oligandra* has shown some resistance but it is not as frost hardy as the other species. ***Grafting*** on to the more tolerant *T. saxicola* may be a possibility. See Trees K 6.

Others: ***Cankers*** (various fungi) on stems may cause dieback. ***Cylindrocladium collar and stem rot, leaf spot, shoot blight*** (*Cylindrocladium* spp.) attacks nearly all parts of ***Myrtaceae*** especially ***young plants***. The disease is most common during wet weather and poor ventilation. ***Other fungi*** probably also cause shoot blights.

INSECTS AND ALLIED PESTS

Aphids (Aphididae): An ***Australian species*** (*Anomalaphis* sp.) may infest new shoots. See Roses J 4.

Caterpillars (Lepidoptera)

Leaf case moth (*Hyalarcta huebneri*, Psychidae) feed on ***leaves***. See Trees K 13.
Web moths (Pyralidae) may damage ***flowering stems*** of *T. calycina* causing a complete absence of ***flowers*** and making plants look ***unsightly***. See Tea-tree K 124.

Ringbarking weevil (Cucurlionidae, Coleoptera) is a ***serious pest*** of *Thryptomene* (Wood 1988). Larvae feed on the stem below ground level causing shrubs to ***die***. See Geraldton wax K 73.

Thrips (Thripidae, Thysanoptera): ***Onion thrips*** (*Thrips tabaci*) and other species, feed on the ***nectar*** and ***pollen*** of ***flowers*** and pose disinfestation problems on flowering stems that are to be ***exported***. See Onion M 68, Roses J 6.

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State/Territory Departments of Agriculture/Primary Industry eg
Cultivation of Thryptomene calycina (Vic Agnote)
Associations, Journals etc.
GrowSearch (database Qld DPI)
See Australian native plants N 9, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Thryptomene is an Australian genus of woody shrubs of variable height, some tropical species being quite tall. Thryptomene is an excellent cut flower. In cultivation it requires reasonably good drainage, full sun to part shade and a good mulch (Wrigley 1988). It is a cold climate shrub and ***frost hardy*** (-7^{o}C in normal rainfall). Research is ***selecting cultivars*** which have ***varying flowering characteristics,*** eg peak flowering, size and colour of flowers, evenness of flowering, foliage colour and ***resistance*** to *P. cinnamomi*. Only propagate from ***disease and pest-free plants*** and plant in ***phytophthora-free*** media/soil. ***Propagation*** is by tip cuttings when the plant is not in flower, propagation by seed is difficult. Avoid water stress between November-April. Regular ***trimmings*** encourage side shoots and flowers and compact plants. ***Weed control*** is not usually necessary. ***Harvest*** when 20-30% of flowers are open and cool to preferably between 1-4^{o}C. Thryptomene may be ***stored*** for 2-5 days in water at 1^{o}C. Stems must be recut after storage. Keep well watered using preservative solution, flowers may be misted (Jones and Moody 1993).

Verticordia

Feather flowers

Verticordia spp.
Rapier feather flower (*V. mitchelliana*)
Family Myrtaceae

PESTS AND DISEASES
Parasitic
- **Fungal diseases**
  - Grey mould
  - Powdery mildew
  - Root and stem rots, shoot blights
- **Nematode diseases**
- **Insects and allied pests**
  - Ringbarking weevil

Non-parasitic
- Environment

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Grey mould (*Botrytis cinerea*): *Verticordia* is ***very susceptible***, do not buy bunches with the characteristic grey fungal hyphae produced by *Botrytis cinerea.* See Greenhouses N 22.

Powdery mildew (*Oidium* sp.) may occur on *Verticordia* ***seedlings*** (Wood, P. M. 1988). See Annuals A 6.

Root and stem rots, shoot blights

Cylindrocladium collar and stem rot, leaf spot, shoot blight (*Cylindrocladium* spp.) attacks ***Myrtaceae***, eg *Verticordia*. All parts may be attacked. ***Young plants*** are most susceptible.
Phytophthora root rot (*Phytophthora cinnamomi*). See Trees K 6.

See Trees K 7.

Others: ***Cankers*** (various fungi) on stems may cause ***dieback***.

NEMATODE DISEASES

Hemicriconemoides obtusus and *Scutelloma* sp. have been recorded on *Verticordia* sp. in WA (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Ringbarking weevil (Cucurlionidae, Coleoptera) is the ***most serious pest*** of *Verticordia* (Wood, W. 1988). It attacks other ***Myrtaceae***, eg Geraldton wax (*Chamelaucium uncinatum)*. In some plantations **> 50%** *Verticordia* plants have been ***killed***. ***Weevils*** lay eggs near the base of the plant and ***larvae*** start feeding on the stem just below ground level, eventually ***ringbarking*** the plant. Damage is not obvious until ***branches start dying*** from water stress. ***Insecticides*** provide good control. See Geraldton wax K 73.

Others: ***Whiteflies*** (Aleyrodidae, Hemiptera) and ***web moths*** (Pyralidae, Lepidoptera).

Non-parasitic

Environment: Once established, *V. mitchelliana* is reasonably ***drought and frost tolerant***, but will not tolerate excessive moisture or humidity.

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Associations, Journals etc.
GrowSearch (database Qld DPI)
Nuytsia
Kings Park Research Notes

See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Verticordia is a ***highly ornamental genus*** of some 50 species but few are considered reliable in cultivation. Plant in ***perfectly drained sites*** in full sun and mulch. All species make ***excellent cut flowers*** and a market has been created from flowers cut from ***natural bush***; care must be taken not to over cut (Wrigley 1988). An overview of the industry has been outlined by Coombs (1995). ***Propagated*** by semi-hardwood tip cuttings and tissue culture because seed is difficult to germinate (the percentage of fertile seed is low). ***Harvest*** bunches with fresh leaves and make sure that they are ***Botrytis-free.*** Leaves often abciss before the flowers drop. Use a preservative solution with double sugar, but do not store for more than 7 days. Some species are very sensitive to ethylene. Some species will dry successfully (Jones and Moody 1993).

Viburnum

Viburnum spp.
Family Caprifoliaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Fungal leaf spots
  - Grey mould
  - Phytophthora root rots
  - Powdery mildew
- **Insects and allied pests**
  - Aphids
  - Greenhouse thrips

Non-parasitic
  - Environment
  - Pesticide injury
  - Protective mutualism

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Specimens of *Viburnum tinus* with virus-like symptoms have been collected in Australia but not confirmed. Overseas, variegation, light green to white patches, vein yellowing and necrosis occurring in *V. tinus* and *V. opulus* may be attributed to ***alfalfa mosaic virus***. In Australia alfalfa mosaic virus is ***spread*** by various aphids, by grafting, not by contact between plants, by seed, by pollen to seed. Commercial growers should destroy plants with symptoms and not use them for propagation. ***Satsuma dwarf virus*** infects *V. odoratissimum* in Japan (Buchen-Osmond et al. 1988, Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Fungal leaf spots (various species) may cause ***leaf spotting*** on viburnum. See Annuals A 5.

Grey mould (*Botrytis cinerea*) may cause leaf spots, shoots and ***inflorescences*** may be ***killed***. See Greenhouses N 22.

Phytophthora root rots (*Phytophthora* spp., *P. cinnamomi*) have been recorded on *Viburnum* spp. *P. cryptogea, P. nicotianae* and *P. palmivora* have been recorded on *V. tinus.* See Tree K 6.

Powdery mildew (*Oidium* spp.) may affect *V. tinus* and *V. opulus* in ***shady situations***. See Annuals A 6.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Probably other aphids, eg ***foxglove aphid*** (*Aulacorthum solani*). Overseas also ***viburnum aphid*** (*Brachycaudus viburnicola*) and other species. Aphids cluster at tips of branches, ***distorting new leaves***. See Roses J 4, Trees K 10.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) commonly infest ***leaf undersurfaces*** which become disfigured with dark dots of thrips excreta. ***Leaf uppersurfaces*** appear ***silvery***. In heavy infestations, thrips may also feed on leaf uppersurfaces. Other *Viburnum* spp. may develop different symptoms, eg ***wrinkled, distorted young leaves***. Do not confuse with aphid injury. See Greenhouses N 24, Trees K 3 (Fig. 215).

Others: ***Twospotted mite*** (*Tetranychus urtica*), ***white palm scale*** (*Phenacaspis eugeniae*).

Non-parasitic

Environment: ***Sun*** may burn leaves of green varieties. Yellow sections of ***variegated leaves*** are ***very susceptible***.

Pesticide injury: Overseas, some viburnum, eg Korean viburnum (*V. carlesii*), are very sensitive to ***sulphur*** and may be injured even by spray drift (Pirone 1978).

Protective mutualism: Beneficial mites live in naturally occurring tuft ***domatia*** (tiny pits, pouches, pockets, hair tufts) on ***leaf undersurfaces*** of *V. tinus* where they are protected from environmental stress and their own predators. Leaves of many other plants also have domatia, eg cashew, walnut. These mites are thought to feed on plant parasitic insects, mites and fungi, decreasing plant damage, but this has not been conclusively demonstrated (O'Dowd and Willson 1991-92).

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See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Viburnums are evergreen or deciduous, and prefer full sun to semi-shade. There are more than 100 species and many more named varieties. They are grown for their ***fragrant flowers*** and ***berries***. They grow in most climates except the tropics. These plants have few serious problems. ***Prune*** both evergreen and deciduous types after flowering.

Waratah

Telopea spp.
New South Wales waratah (*T. speciosissima*)
Floral emblem of NSW
Family Proteaceae (waratah family)

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Fungal leaf spots (various species) including ***black spot of citrus*** (*Guignardia citricarpa*), are not uncommon. They do not kill plants, but they ***reduce bloom quality*** and increase susceptibility to other problems. See Annuals A 5, Trees K 6.

Root rots are ***major diseases*** of waratah.

Damping off (*Phytophthora*, *Pythium, Rhizoctonia*) can be ***severe***, ***killing all seedling stock***. ***Grey mould*** (*Botrytis cinerea*) and *Colletotrichum* may also cause damping off. Fungicides are usually required. See Seedlings N 66.
Phytophthora root rots (*Phytophthora* spp., *P. cinnamomi*) are favoured by poor drainage and the high fertility and irrigation needed for commercial flower production. *T. speciosissima* and *T. truncata* seem to be ***most susceptible***. *T. mongaensis* has ***some tolerance***. *T. oreades* is intermediate in resistance to root diseases generally, its resistance to *Phytophthora* is unclear. See Trees K 6.
Others: Armillaria root rot (*Armillaria luteobubalina*); ***Fusarium* sp.** is considered to cause a partial death syndrome (unconfirmed).

See Trees K 7.

Others : ***Cankers*** (various species) and ***wood rots*** (various species) may affect waratahs.

NEMATODE DISEASES

Root lesion nematode (*Pratylenchus crenatus*) on *T. speciosissima.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers: Various species may damage ***older waratahs***. See Trees K 10.

Caterpillars (Lepidoptera)

Lightbrown apple moth (*Epiphyas postvittana*) may ***roll leaves*** of *Telopea* spp. See Pome fruits F 112.
Macadamia cup moth (*Mecytha fasciata,* Limacodidae) caterpillars are oval, smooth, bright green, flat with a pale-yellowish mid-dorsal stripe and up to ***35 mm*** long. They often rest so that the stripe lies along the main vein of the leaf. They feed mainly on ***mature leaves*** of ***Proteaceae***, eg macadamia, *T. speciosissima*, *Banksia serrata*, *B. marginata*, *Lambertia formosa*, *Persoonia levis* and *Xylomelum pyriforme,* and can ***defoliate young plants***. See Macadamia F 77.
Macadamia leafminer (*Acrocerops chiomosema*) caterpillars may ***mine in leaves***, disfiguring them. See Macadamia F 78.
Macadamia twig girdler, waratah bud-borer (*Xylorycta luteotactella*) caterpillars bore into ***terminal buds***, especially in winter, damaging inflorescence. ***Fungicides*** are used on a preventative basis. See Macadamia F 77.

Garden weevil (*Phlyctinus callosus,* Curculionidae, Coleoptera) is grey, about ***5-6 mm*** long and chews holes scalloped from ***centres and margins of leaves***. On waratahs they also feed on ***stems***, excavating small deep rounded holes over the surface. Stems of young plants may be ***ringbarked***. See Trees K 17.

White palm scale (*Phenacaspis eugeniae,* Diaspididae, Hemiptera) may ***debilitate plants***, depressing growth and yield, increasing susceptibility to other pests and diseases both in the ***field*** and in ***greenhouse conditions***. Prompt control is necessary, because infestation can spread very quickly. Effective chemical control is possible, although phytotoxicity can occur in hot conditions. See Palms H 4.

Others: ***Field crickets*** (*Teleogryllus*) may ringbark growing shoots of young plants. ***European earwig*** (*Forficula auricularia*) chews leaves and flowers.

VERTEBRATE PESTS

Rabbits, hares and wallabies destroy seedlings, shrubs and young trees, barriers are required. ***Birds*** generally disfigure and destroy flowers and may feed on terminal buds. Sulphur-crested cockatoos, damage ***unopened flower buds*** of waratah on the bushes on which they perch; parrots are attracted to large flowers with copious amounts of ***nectar***. See Fruit F 13.

Non-parasitic

Environment: ***Blackening or browning of bract tips*** after harvest is thought to be related to environmental stress especially water stress. ***Wind***

damage is a ***major contributor*** to both ***bract browning*** and ***short vase life***. Maintain an adequate water supply and protect from strong winds during bud development and opening. While windbreaks and bloom bagging help, the extra cost may not be justified. Planting sites should be sunny or slightly shaded. The only long term solution lies in breeding new selections with ***some resistance*** to bract browning.

Nutrient deficiencies, toxicities: ***Phosphorus toxicity:*** Excess phosphorus will be toxic. ***Proteiod roots*** of waratah tend to be superficial, deep mulching is advantageous as it protects surface roots from high temperatures and excessive desiccation during summer. Proteiod root development is considered to be inhibited by high nitrogen and phosphorus. See Protea K 121, Trees K 20.

Spiders in ***flower heads*** make it difficult to satisfy ***phytosanitary requirements*** for export. Spiders feed on insect pests. ***Weeds*** should be controlled and ***postharvest treatments*** may be necessary.

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State/Territory Departments of Agriculture/Primary Industry eg

Banksia Cultivation in South Australia. (SA Agric)
Growing Waratahs Commercially (DPI Agnote)
Major Diseases of Proteaceous Plants (Vic Agnote)
Pests of Proteaceous Plants (Vic Agnote)
Phosphorus Toxicity in Native and Proteaceous Plants (Vic Agnote)
Protea Culture (Proteaflora Enterprises)

Associations, Journals etc.

GrowSearch (Qld DPI)
Proceedings of Seminar. Production and Marketing of Wildflowers (Uni. of Western Australia, Nov. 1982)

See Australian native plants N 9, Protea K 121, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Waratahs are grown for their brilliant red bracts and the red styles. Only NSW waratah (*T. speciosissima*) is grown for cut flowers. ***Select clonal material*** for vigour, flower production, flower quality and vase life. Select also for marketability, ie their ability to pack and travel well, and not develop blackening or spotting of the bracts or produce excessive nectar. Plants must establish rapidly and vigorously regrow after harvesting of flowers. Species vary in ***resistance*** to root diseases. Only propagate from ***plants free from*** leaf spots and scales, if using seed, check that leaf spots are not seedborne. ***Propagated*** by cuttings, leaf and bud cuttings, by seed (seedling material is highly variable and not recommended), tissue culture. ***Waratah grow best*** on acid, ***well-drained*** sandy loam of low fertility. Mulch with leaf litter or similar materials, provide adequate irrigation especially when plants are young, drip irrigation is preferable to overhead watering. ***Sites*** should be sunny or slightly shaded. Use slow release fertiliser. Container waratahs for cut flowers should be grown either in a sheltered environmental in the open or in a shade house to facilitate pest, disease and weed control, irrigation and fertilisation. There is a ***lack of information*** on nutrition, and the hormonal control of flush growth and dormancy. Flowers are borne on the ends of main stems, plants grow vigorously and are upright so they may be attached to wires. If plants are ***pruned*** or flowers cut, more terminal shoots, and therefore more flowers, will be produced the following year. All new shoots, whether flowers are harvested or not, should be cut back close to their point of origin to keep plants manageable in both height and flower production. Growers may have ***disease identification problems*** in that many different problems cause similar symptoms. ***Systemic fungicides*** are often used to control root rots. ***Weeds*** provide breeding sites for earwigs, weevils, spiders and crickets. ***Mulching*** aids ***weed control*** and protects ***proteoid roots***. However, mulching alone does usually provide adequate weed control and herbicides are usually required, eg spot treatments with glyphosate. Weed matting is unsuitable for waratahs. ***Harvest*** when 1-5% of flowers are open (waratah flowers are made up of up to 300 individual florets surrounded by coloured bracts), avoid flowers with a blue tinge (a sign of ageing and ethylene damage). Flowers must be cut before the style opens and the lower bracts expand. ***Cool flowers rapidly*** but do not chill, flowers must be dry and cool before packing. Place flowers in a preservative solution (no sugar as solutions containing sugars promote nectar production that can lead to fungal infection). Waratahs are very sensitive to ethylene (Jones and Moody 1993).

Wattle

Acacia spp., *Racosperma* spp.
Family Mimosaceae

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial wilt (*Pseudomonas solanacearum*) has been recorded on *Acacia difficilis* and *A. mountfordiae*. See Tomato M 98, Vegetables M 6.

FUNGAL DISEASES

Fungal leaf and phyllode spots (more than 170 species) may cause minor or ***serious diseases*** of wattles, phyllodes may fall, plants have a sparse appearance (Pascoe and Sutton 1987). ***Favoured*** by wet seasons. Leaf spots may be common on ***nursery stock***.

Colletogloeum leaf spots (*Colletogloeum* spp.) have been identified on *Acacia* spp., each of the many species identified occurs on a different species of *Acacia* (Pascoe and Sutton 1987).
Others, eg *Diplodia*, *Mycosphaerella*, *Phaeoseptoria*; *Septoria aureocorana* on *A. saligna*; *Wettsteinina phyllodiorum* on *A. myrtifolia* (Pascoe 1987).

See Annuals A 5, Trees K 6.

Powdery mildew (*Leveillula taurica, Oidium* spp.) infects wattle. See Annuals A 6.

Root and collar rots

Damping off (*Cylindrocladium scoparium*), ***grey mould*** (*Botrytis cinerea*). See Seedlings N 66.
Root and collar rots: Armillaria root rot (*Armillaria* sp.). Also ***phytophthora root rot*** (*Phytophthora* spp., *P. cinnamomi*, *P. cryptogea* and *P. nicotianae* var. *parasitica*) and ***root and collar rot*** (*Ganoderma* spp.). Wattles are considered to have some ***resistance*** to *Phytophthora*. See Trees K 7.

Rusts (Uredinales)

Gall rusts (*Uromycladium* spp.): *U. tepperianum* commonly attacks wattles with ***phyllodes*** and *U. notabile* commonly attacks ***bipinnate wattles***. One species of wattle may be affected with several species of rust. ***Silver wattle*** (*A. dealbata*) by *U. aplinum, U. bisporum, U. notabile,* ***Sydney golden wattle*** (*A. longifolia*) by *U. maritimum, U. tepperianum,* ***golden wattle*** (*A. pycnantha*) by *U. simplex, U. tepperianum,* ***blackwood*** (*A. melanoxylon*) by *U. robbinsonii, U. tepperianum* (Marks et al. 1982). Galls develop on ***leaves, flowers or stems,*** trees look unsightly (Fig. 273). Severe infections may ***kill trees*** and inhibit seed production, eg *A. mearnsii*. Largest galls are produced by *U. tepperianum* and are 30-150 mm across and are brown due to the spore masses on them. Other *Uromycladium* spp. produce different symptoms, eg witches' brooms, twisted stems. Galls may be invaded by ***insects***, some of which are parasites of the insects which live in the rust galls, eg small brown beetles (*Doticus pestilens*, Anthribidae). Note that some insects themselves cause galls on stems. ***Overwinters*** on galls on hosts. ***Spread*** by windborne spores (uredospores), by introduction of infected plant material. ***Favoured*** by weakened trees in poor soils or exposed situations. ***Fertilise*** slightly affected trees to improve tree vigour and reduce infestation. ***Remove*** severely diseased trees (they are a source of infection). If only a few trees are lightly infested trees, prune off and destroy galls when observed. *Acacia* spp. vary in ***susceptibility***. *U. tepperianum* has been used to control *A. saligna* a weed in South Africa (Shearer 1994). If ***fungicides*** are applied in nurseries, prune off galls before spraying.
Other rust genera (Fig. 274): A ***native rust fungus*** (*Atelocauda digitata*) is potentially a ***serious problem*** on *A. mangium* in Qld. (Dargavel and Semple 1990). ***Also*** *Aecidium torquens, Uromyces* spp. See Annuals A 7.

Stem cankers and galls: ***Canker*** (*Botryosphaeria* sp.) may cause dieback. ***Cushion-like galls*** (*Leptosphaeria* sp.) develop on branches of Cootamundra wattle (*A. baileyana*). One gall may be up to 10 mm across. See Trees K 5.

Wood rots (Basidiomycetes) are common on wattle (Marks et al. 1982) and include:

Wood rots include:
- Beech hoof (*Heterobasidion hemitephrum*)
- Cramp balls (*Daldinia concentrica*)
- Ring-barking fuscoporia (*Fuscoporia laevigata*)
- Timber rot (*Fomes nigro-laccatus*)
- Tinder punk (*Phellinus* spp.)
- Weeping polypore (*Grifola campyla*)
- Woody toadstool (*Amauroderma rude*)

Some wood rots decay stumps, eg ***stump removers*** (*Ionotus* sp., *Polyporus* sp., *Poria medullaris*, *Trametes* sp.)
Some wood rots attack weakened trees, or trees injured by borers:
Pink limb blight (*Corticium salmonicolor*)
Red wood rot (*Pycnosporus coccineus*)
Yellow heart rot (*Schizophyllum commune*)
Yellowish wood rot (*Polyporus versicolor*)

See Trees K 8.

Others: ***Sooty blotch*** (*Gloeodes pomogena*) grows on ***twigs*** of wattles. See Pome fruits F 110.

PARASITIC PLANTS

Devil's twine (*Cassytha* spp.), ***mistletoe*** (Loranthaceae). See Trees K 9, K 10.

NEMATODE DISEASES

More than 40 species of nematodes have been recorded in association with *Acacia* spp. (Mcleod et al. 1994) including ***burrowing nematodes*** (*Radolphus* spp.), ***dagger nematodes*** (*Xiphinema* spp.), ***root knot nematodes*** (*Meloidogyne* spp.), ***sheath nematode*** (*Hemicycliophora* spp.), ***stubby root nematodes*** (*Paratrichodorus* spp.), *Carpophodorus, Cephalenchus, Colbranium truncatum, Hemicriconemoides*, *Morulaimus, Scutellonema, Tylodorus*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Beetles (Coleoptera)

Leaf beetles, flea beetles (Chrysomelidae): ***Fireblight beetle, wattle blight*** (*Pyrgoides orphana*) is a ***serious pest*** of wattles especially silver wattle (*A. dealbata*) and black wattle (*A. mearnsii*). ***Beetles*** are small, greenish, tortoise-shaped beetles about ***6 mm*** long with cream and brown longitudinal stripes on the wing covers. ***Larvae*** are green with dark lateral stripes, stoutish and about ***6 mm*** long, tapering to a point at the tail. Beetles and larvae feed in groups on the ***foliage*** (Fig. 275), but ***green bark*** may be eaten by the adults after all the foliage has been consumed. Trees look scorched (fireblight) after an outbreak. ***Overwinter*** as larvae feeding. ***Favoured*** by temperate climates in spring and autumn, eg Tasmania. ***Pyrgoides sp.*** is similar to *P. orphana* but brighter. It causes minor damage to phyllodinous native willow (*A. mucronata*). ***Redshouldered leaf beetle*** (*Monolepta australis*) and ***swarming leaf beetles*** (*Rhyparida* spp.) may swarm on foliage. The larger ***brown leaf beetle*** (*Dicranosterna immaculata*) is sometimes found on black wattle (*A. mearnsii*), the pale green larvae have convex swollen abdomens. The smaller ***blue-green metallic leaf beetles*** (*Calomela* spp.) may strip young wattle growth. Olive-green larvae cling close to the stem, often rendering their detection difficult. See Trees K 15.

Scarab beetles (Scarabaeidae, Coleoptera): ***Christmas beetles*** (*Anoplagnathus* spp.) and ***green scarab beetle*** (*Diphucephala colaspidoides*) chew foliage. ***Flower scarabs*** (*Protaetia* spp.) are stout, active, brown beetles ***15-20 mm*** long. They feed on the ***pollen*** in flowers and on ***wattle shoots*** causing wilting and dieback. See Trees K 16.

Borers

Auger beetles (Bostrichidae, Coleoptera): ***Large auger beetle*** (*Bostrychopsis jesuita*) is a common and sometimes ***serious pest*** of wattle. Larvae bore ***round vertical tunnels*** filled with frass in the sap and heartwood of large branches and the trunk. See Trees K 11.

Fruit-tree borers (Oecophoridae, Lepidoptera) ***commonly*** damage wattle. Tunnels in ***tree forks*** are covered with chewed wood and droppings. Caterpillars make only a short tunnel into the wood, so are easy to control. Caterpillars of the ***wattle web-covering borer*** (*C. rubescens)* feed on small branches which break where they feed. Caterpillars are about 25 mm long and are fleshy, sparsely hairy and greenish. See Fruit F 10, Trees K 12.

Ghost moths, swift moths (Hepialidae), eg ***common splendid ghost moth*** (*Aenetus ligniveren*), larvae bore tunnels in trunks and roots. See Trees K 12.

Jewel beetles (Buprestidae): ***Cobra-shaped larvae*** bore oval, frass-filled tunnels in sapwood. See Trees K 11.

Longicorn beetles (Cerambycidae, Coleoptera): ***Wattle root longicorn*** (*Eurynassa australis*) larvae are often called witchety grubs. ***Wattle longicorn*** (*Uracanthus triangularis*) affects wattles and other trees. ***Beetles*** are large slender fawn-grey about 30 mm long with a shiny triangular brown patch on each wing cover. Antennae are about 40 mm long. ***Larvae*** are fleshy, cream, legless and about ***30 mm*** long. They bore ***round tunnels*** in trunks and large branches. Branches die back. Temperate to tropical regions, coastal and inland. ***Wattle ringbarking beetle*** (*Ancita marginicollis*) infests *Acacia* spp., *Alphitonia* spp., others. ***Adults*** are stout grey mottled beetles about 15 mm long with prominently banded antennae about 30 mm long. They graze on ***bark*** in spring and early summer. Ringbarked branches die or break. Tropical and subtropical regions. ***Others:*** *A. crocogaster, Probatodes plumula, Platyomopsis, Rhitiphora, Penthea.* See Trees K 11.

Weevils (Curculionidae, Coleoptera): ***Diamond beetle,*** Botany Bay diamond beetle (*Chrysolopus spectabilis*) is a minor pest of wattles especially *A. aulacocarpa*, *A, concurrens*, *A. leiocalyx* and *A. sophorae*. ***Weevils*** are large, attractive, solitary insects about ***20 mm*** long, they are mostly black with patches of metallic green or blue and are one of the few brightly coloured weevils. Weevils chew ***new shoots***. ***Larvae*** are fleshy, legless, chew ***round tunnels*** in ***roots and stems*** and may ***kill*** trees. Subtropical and warm temperate regions. Control is usually unnecessary. ***Elephant weevil*** (*Orthorhinus cylindrirostris*) affects ***dead or dying*** wattles. Emerging adults leave circular holes about 5 mm across in trees and logs. ***Fruit-tree root weevil*** (*Leptopius squalidus*) is grey, about 20 mm long and grazes the surface of wattle leaves. ***Larvae*** are fat, legless, up to ***20 mm*** long and tunnel in ***roots*** (especially deep roots) of the same species. A related species (*L. tribulus*) also attacks wattle roots. ***Vine weevil*** (*Orthorhinus klugi*) attacks black wattle trees.

It is similar to the elephant weevil except smaller, about ***6-7 mm*** long, and reddish-brown. Exit holes are round and about 2-3 mm across. See Grapevine F 60, F 63, Trees K 12.

Wood moths, goat moths (*Xyleutes* spp., Cossidae, Lepidoptera) may ***limit the life*** of many wattles to between 5-15 years. ***Witjuti grubs*** *(Xyleutes* spp.,) form a silk-lined tunnel in the soil and feeds externally on the roots of the witchetty bush (*A. kempeana*) in central Australia or *A. ligulata* in SA. ***Wattle goat moth*** (*X. encalypti = X. eucalypti*) infests wattles, eg silver wattle (*A. dealbata*), black wattle (*A. mearnsii*), blackwood (*A. melanoxylon*). ***Moths*** are large, grey or light brown with stout bodies with narrow, hairy or scaly wings with wingspans up to 250 mm. ***Caterpillars*** are large, fleshy, yellowish or pinkish, up to ***150 mm*** long with true legs. Caterpillars may ***tunnel*** in the sapwood and heartwood in ***trunks*** and ***roots*** for ***several years*** and can weaken the structural strength of large trees. If trunks or roots are split open, tunnels are full of chewed wood. Large limbs die and eventually whole trees may die prematurely. There is ***1 generation every few years.*** Moths fly during rainy weather and each female lays numerous eggs on the bark, covered with a glutinous secretion beneath which the newly hatched caterpillars live for 1-2 days before dispersing. The 1st-instar caterpillars spin great quantities of silk and disperse themselves on silken strands. Before pupation, the tunnel to the exit hole is enlarged and the bark covering is almost severed. Pupation takes place in the tunnel close to the bark surface and the felted pad closing the tunnel is pushed out. ***Yellow-tailed black cockatoos*** tear away at the bark and large volumes of wood searching for the caterpillars. See Trees K 12.

See Trees K 10, K 11, K12.

Bugs (Hemiptera)

Acacia spotting bug (*Rayieria tumidiceps,* Miridae) infests several species of ***phyllode-type wattles***, especially Sydney golden wattle (*A. longifolia*) and red-stemmed wattle (*A. rubida*). ***Adults*** look like ***mosquitoes*** and may be difficult to see, are about 10 mm long, elongated with long slender legs and antennae. The body is yellow-brown, wings brown. Bugs suck sap from ***leaves*** and inject some of their saliva causing either ***dark spots*** on the leaves or ***rectangular brown areas*** between the ***veins*** (Fig. 276). Severely affected leaves may die and fall. Dieback of shoots may occur, trees and shrubs may have a general rusty brown appearance. ***Gradual metamorphosis*** (egg, nymph, adult) with probably several generations each season. ***Spread*** by adults flying, wind and by the movement of infested plants. It is difficult to control with insecticides because the bugs have usually left the plant before damage is noticed. ***Susceptible species*** should not be used as specimen trees. If only a few shoots are affected they can be ***pruned off. Insecticides*** may be applied to ***nursery stock*** in early spring to protect new leaves.

Crusader bug (*Mictis profana,* Coreidae) is ***20-25 mm*** long, brown with a well defined yellow St Andrew's cross on its back. Nymphs and adults suck sap from new spring growth causing it to wilt, brown and die. See Trees K 12.

Others: Jewel bugs (Scutelleridae), ***shield bugs*** (Pentatomidae) and others may feed on wattle.

See Vegetables M 12.

Caterpillars *(Butterflies) (Lepidoptera)*

More than 20 species feed on the foliage of wattles (Common and Waterhouse 1981).

Blues, coppers, hairstreaks (Lycaenidae) include various ***blue butterflies*** (*Jalmenus* spp.), various ***jewel butterflies*** (*Hypochrysops* spp.), various ***lineblues*** (*Prosotas* spp., *Nacaduba* sp.), ***grass blue butterfly*** (*Zizina labradus*) and *Theclinesthes miskini*, *T. scintillata, Miletus ignita*.

Grass yellow butterfly (*Eurema hecabe*, Pieridae) is small, bright yellow and is most active in autumn during egg laying. ***Caterpillars*** are small, slender, green with a conspicuous white lateral band and about ***15 mm*** long. They feed ***voraciously*** on mainly featherleaved wattles. eg *A. baileyana*, *A. muelleriana*, *A. rubida*, *A. spectabilis* and *Albizia lebbeck*. They feed at night, resting on ***leaf undersurfaces*** during the day. They can defoliate quite large wattles, it may be necessary to treat ***nursery stock*** and small wattles.

Tailed emperor butterfly (*Polyura sempronius*, Nymphalidae) is large and handsome. ***Caterpillars*** are large, fleshy, about ***80 mm*** long, green with yellow longitudinal bands, they feed on mature leaves of featheryleaved *Acacia.* Also *P. pyrrhus*. See Trees K 13.

Others: *Pseudalmenus chlorinda*.

See Trees K 13.

Caterpillars *(Moths) (Lepidoptera)*

More than 50 species feed on *Acacia* (Common 1990). The following caterpillars mainly feed on ***foliage*** but some bore in ***trunks and roots***.

Anthelid caterpillars (*Anthela* spp., Anthelidae) occasionally cause ***serious damage***. ***Hairymary caterpillar*** (*A. nicothoe*) feeds on foliage of silver wattle (*A. dealbata*), caterpillars may cause ***irritation*** if handled. See Trees K 13.

Case moths (Psychidae): ***Ribbed case moth*** (*Hyalarcta nigrescens*) is a minor pest of wattle. The ***case*** is a spindle-shaped grey silken bag about 50 mm long, with 4 prominent longitudinal ridges and is often fastened around stems. This may girdle the twig. See Trees K 13.

Hawk moths (Sphingidae): ***Sandal-box hawk moth*** (*Coenotes eremophilae*).

Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*), ***macadamia nutborer*** (*Cryptophlebia ombrodelta*). See Pome fruits K 112.

Loopers (Geometridae): ***Bizarre looper*** (*Anisozyga pieroides*) feed on ***phyllodinous species*** of *Acacia*. Sporadic attacks may be ***severe*** on *A. fimbriata*. ***Caterpillars*** are about ***25 mm*** long, brown with flanged body segments looking like twisted dead leaves and are rarely noticed. Control is rarely necessary. ***A geometrid moth*** (*Euchloris submissaria*) is a delicate green moth with the margins of the wings and a stripe on the thorax a buff-white. The ***caterpillar*** is slender, round, light brown, when disturbed it remains perfectly erect and motionless, but when it crawls it is very active. It feeds on the ***foliage***. ***Green stick looper*** (*Chlorocoma assimilis*) causes minor damage to various species of ***phyllodinous wattles***. ***Moths*** are green, about 30 mm across the wings. ***Caterpillars*** are slender, hard green with a pointed head with a ***single pair of prolegs*** and about ***55 mm*** long. Solitary caterpillars that feed at night or on cloudy days. When not feeding it assumes a stiff, obliquely erect posture.

Also *C. dichloraria*. ***Green wattle loopers*** (*Thalaina* spp.) feed mainly on wattles, sometimes on *Cassia*, are rarely a problem and are often difficult to see. ***Moths*** have satin white wings often with distinctive brown markings on the forewings and about 40 mm across. ***Caterpillars*** are green with a rounded head about ***50 mm*** long and have a ***single pair of prolegs***, often with good camouflage. Caterpillar are solitary but they can ***completely defoliate trees***. Temperate and subtropical regions. ***Others: Cherry looper*** (*Chloroclystis approximata*), ***pome looper*** (*C. testulata*) and *C. destructa,* ***apple looper*** (*Phrissogonus laticostata*), ***twig looper*** (*Ectropis excursaria*), brown looper (*Pholodes sinistraria*). ***Microdes squamulata*** caterpillars web leaves together to form shelter in silver wattle (*A. dealbata*), *A. decurrens, A. mearnsii, A. baileyana, A. buxifolia,* other plants. See Avocado F 19, Trees K 13.

Processionary caterpillar, bag-shelter moth, (*Ochrogaster* spp., Thaumetopoeidae) may be a ***serious pest*** of a few species of wattle, particularly the myall (*A. pendula*) and *A. salicina* in inland areas. ***Caterpillars*** are up to ***50 mm*** long and are covered with long sharp stiff reddish-brown ***hairs*** which cause ***intense skin irritation*** on contact. Caterpillars shelter during the day ***in large brown silken bags,*** which they construct from twigs and webbing and which become filled with excreta and cast skins, and feed on ***foliage at night***. Depending on the species, bags may be at the base of the tree or higher up in the tree. Bags should not be handled as they contain irritating hairs. Caterpillars move from tree to tree in long processions each with its head in contact with the caterpillar preceding it. There is ***1 generation each year but attacks last for years.*** Moths appear in early summer and lay their eggs on leaves or twigs. Depending on the species, caterpillars pupate within the bag shelters on the tree or the soil. Limited population control is achieved by ***parasitic*** wasps and flies, and birds. Depending on tree height it may be possible to clip bags off and burn during the day when caterpillars are inside, or destroy caterpillars when they are moving over the soil.

Tussock moths (Lymantriidae): ***Painted apple moth***, painted wattle moth (*Teia anartoides*) caterpillars are about ***30 mm***, densely covered with brown hairs and have ***4 tufts of white hairs*** on their backs, and a pair of black, horn-like tufts projecting from the head. They may eat ***whole leaves*** (fine leaved plants) or ***skeletonise leaves*** by eating the upper surface layer (broadleaved plants eg *A. pycnantha*). Also *T. athlophora.* See Pome fruits F 113. ***Others: Painted pine moth*** (*Orgyia australis*) and ***omnivorous tussock*** moth (*Acyphas leucomelas*) on acacia, pine, etc.

Noctuids (Noctuidae): ***Caster oil looper*** (*Achaea janata*), ***granny moth*** (*Dasypodia selenophora*), ***looper caterpillars*** (*Chrysodeixis* spp.). See Sweetcorn M 89.

Snout moth (*Entometa australasiae*, Lasiocampidae) are stout yellowish-buff moths with red marks on the hindwings. ***Caterpillars*** feed on black wattle (*A. decurrens*) and other wattles and are about ***35 mm*** long, greenish-grey with 2 transverse bars on the thorax which are obvious only when caterpillars are crawling. The sides are fringed with long hairs and as the caterpillar rests along the branch by day, the hairs eliminate shadows (excellent camouflage).

Web moths (Pyralidae), eg ***tree lucerne moth*** (*Uresiphita ornithopteralis*) caterpillars, web leaves and feed on foliage. See Tea-tree K 124.

Others: A ***flower caterpillar*** (*Nemophora topazias,* Incurvariidae) forms a case from ***flower parts*** of *Acacia* and feeds on fallen flowers on the ground. Pupation takes place in the case. Also a ***moth*** (*Neola semiauranta,* Notodontidae) on Mimosaceae, eg many wattles, *Dodonaea* spp. and the introduced *A. lophantha*. ***Hook-tip moth*** (*Digglesia australasiae*, Drepanidae) caterpillars feed on *Acacia* spp., *Albizia* spp., *Exocarpos cupressiformis*, *Pinus radiata*, spruce (*Picea*).

Control is often unnecessary, there are exceptions. For many hand picking is often sufficient. Insecticides are rarely necessary. See Trees K 13.

Froghoppers and spittle bugs, leafhoppers, tree hoppers (Hemiptera)

Froghoppers and spittle bugs (Cercopoidae, Hemiptera) are minor pests of wattles. Nymphs of spittle bugs live in spittle and of froghoppers in liquid-filled tubes. Both nymphs and adults suck sap from the small stems but generally appear to cause little injury. Control is not necessary. They are kept in check by ***parasites and predators***. Hosing will remove many from branches. See Trees K 14.

Leafhoppers (many species) may ***damage*** *A. fimbriata*, *A. floribunda* and other species. Size varies from ***3-7 mm*** and colour also varies depending on the species. They secrete honeydew, ants attend and sooty mould grows on the honeydew. See Trees K 15.

Treehoppers (Membracidae, Hemiptera): ***Green treehopper***, green wattle hopper (*Sextius virescens*) is a ***sporadic pest*** of featheryleaved *Acacia* spp. especially black wattle (*A. decurrens*). ***Adults*** are small cicada-like, green, about ***9 mm*** long with a prominent, brown-tipped spine on either side of the thorax, the head is tucked down beneath the body. ***Nymphs*** are wingless and greenish. Both suck sap from ***young shoots*** which may ***die***. They secrete honeydew which attracts ants and on which sooty mould grows. Females lay their eggs in ***slits*** in the ***bark*** of twigs. As plants grow, slits become more noticeable, gum freely and may be unsightly. ***Prune off*** damaged twigs. Usually controlled by natural enemies. Spraying is not usually necessary. ***Spiny treehopper*** (*Sertorius australis*) infests wattle and eucalypts. Adults are solitary, small, brown, cicada-like, about ***8 mm*** long, with a hard, short but sharp spine on either side of the head. Nymphs gather in colonies on young shoots. Usually controlled by natural enemies. See Trees K 15.

Gall insects

Flies, midges (Cecidomyiidae, Diptera) are sporadic minor pests. ***Blossom gall fly*** (*Cecidomyia acaciaelongifoliae*) infest wattles especially *A. floribunda*, *A. longifolia*, *A. pycnantha* and *A. sophorae*. Maggots feed on ***flower heads***, disrupting seed formation. Fruits are replaced by irregular gall-like growths which are twisted masses of tubes. Galls may be pruned off and burnt to prevent flies emerging. ***Gall fly*** (*Asphondylia* sp.) lays eggs in ***flowers*** of Wally's wattle (*A. pataczekii*), maggots cause galling of the flower heads, preventing seed formation.

Thrips (Phlaeothripidae, Thysanoptera): ***Several genera*** are ***sporadic pests*** of phyllodinous wattles, especially myall (*A. pendula*). Galls on ***phyllodes*** may be hollow, smooth, bubble-like, or irregular and spiny. ***Hollow galls*** imprison thrips until the galls dry and split. Over 1 000 individual thrips have been recovered from a single gall. Unlike most gall formers thrips continue to reproduce inside the gall. Infested trees are ***unsightly***. Occurs mostly in subtropical and temperate inland areas. Mainly controlled by parasitic wasps and predatory mites. ***Rhopalothripoides froggatti*** thrips are so small that they breed in the ***nectaries*** on the leaves of pinnateleaved wattles.

Wasps (Hymenoptera): Larvae of ***seed chalcids*** (Eurytomidae) infest seeds or feed in galls. Usually larvae of these wasps feed within the distorted tissue of the gall. ***Wattle apple-gall wasp*** (*Trichilogaster acaciaelongifoliae,* Pteromalidae) is a minor pest. See Trees K 3 (Fig. 209). ***T. trilineata*** also causes ***flower galls***. ***Wasps*** about 2 mm long lay eggs in spikes. Green galls about 10 mm across develop in flower heads in response to larvae feeding inside. Pupation takes place within the gall, and on emergence from the pupa, the adult wasp chews its way out of the gall. ***Other species*** of tiny wasps cause ***blossom galls*** on *A. longifolia.* ***Other wasps parasitise*** gall-making insects by laying their eggs directly into larva in the gall, their larvae feeding on the gall insect. ***A wasp*** (*Eurytome gahani*) merely lives in galls on *A. decurrens* which have been made by other insects or diseases.

See Eucalypt K 61, Trees K 14.

Mealybugs (Hemiptera)

Wattle mealybug (*Melanococcus albizziae,* Pseudococcidae) is a ***sporadic pest*** which sucks sap from fernyleaved wattles (*A. howittii*, *A. ericifolia*) and *Albizia* spp. ***Adults*** are soft, oval, reddish-brown, ***scale-like,*** about ***3-4 mm*** long. They secrete white, cottony threads in a margin and gather in colonies along ***branches*** (Fig. 277). They secrete large quantities of honeydew which attracts ants and on which sooty mould grows. Severe infestations may kill trees. ***Nymphs*** are whitish and are obvious against stems blackened with sooty mould in spring. Infested twigs may be ***pruned off***. Wattle mealybug is usually controlled by ***natural predators and parasites***. Only spray if necessary when crawlers are present in spring and autumn.

Woolly giant mealybug (*Monophlebulus pilosior*, Margarodidae) is a solitary native species which sucks sap from wattles, water gum (*Tristaniopsis laurina*). It is oval, ***pinkish-orange*** with black marks, up to ***25 mm*** long and secretes long thin white waxy threads over the body (Fig. 278). Control is unnecessary.

See Greenhouses N 25.

Psyllids (Psyllidae, Hemiptera)

Cootamundra wattle psyllid (*Acizzia acaciaebaileyanae*) is ***free-living*** and causes withering of young foliage and dieback of shoots of Cootamundra wattle (*A. baileyana*). Also feeds on mature phyllodes of *A. anceps*. See Trees K 16.

Other free-living psyllids: *Psylla* spp. feed on leaf tips, mature leaves and twigs of many wattles (Morgan 1984). Flower buds and young shoots of *A. fimbriata* may be distorted by a species of psyllid. Foliage is bunched (Hockings 1980). See Trees K 16.

Scales (Hemiptera)

Armoured scales (Diaspididae):
Oleander or ivy scale (*Aspidiotus nerii*)
Purple or mussel scale (*Lepidosaphes beckii*)
Red scale (*Aonidiella aurantii*).
Scales are attacked by many parasites, predators and fungi. On lightly infested shrubs they provide control. See Citrus F 39.

Soft scales (Coccidae): ***Chain scales*** (*Pulvinaria* spp.) attack many native species and may be hard to control. ***A chain scale*** (*P. maskellii)* may infest *A. coriaceae* of inland regions. ***Adult females*** have a white or cottony egg mass, ***nymphs*** have an oval, flat, greenish or almost transparent covering 1-2 mm long and feed end to end, usually along the ***midrib of leaves*** (chain scale). Nymphs retain their legs and are mobile until they become adults, so they can move out on the stems and leaves changing their feeding positions. They secrete honeydew which attracts ants and on which sooty mould grows. Active predators include ladybirds and lacewings. ***Wattle tick scale*** (*Cryptes baccatus*) is a native scale which can weaken or kill healthy fernyleaved and phyllodinous wattles, eg black or green wattle (*A. decurrens*), Sydney golden wattle (*A. longifolia*), blackwood (*A. melanoxylon*), *A. limearis, A. floribunda, A. mollisima* and *A. aneura,* and *A. pendula* in inland areas. ***Adults*** are ***large*** and ***berry-like***, 5-8 mm across, initially whitish, later dark brown, 30-40 cluster on small branches (Fig. 277). They congregate in clusters and can cause ***dieback*** or ***kill*** healthy trees. They secrete honeydew which attracts ants and resulting sooty mould may discolour bark. Effective control can be difficult. If necessary, prune infested branches off. See Citrus F 41.

Eriococcid scales (Eriococcidae) may infest some wattles, deforming branches. See Eucalypt K 63, Citrus F 41.

Margarodid scales (Margarodidae): ***Cottony cushion scale*** (*Icerya purchasi*) infests wattles, especially fernyleaved wattles, eg *Acacia dealbata*. ***Females*** have a conspicuous, ***white fluted egg sac*** covered with cottony threads up to ***10 mm*** long. See Australian native plants N 12 (Fig. 387). Males are winged. Females cluster along midribs and ***veins*** on ***leaf undersurfaces***, on ***bark*** and ***small branches*** and even on the ***trunk***. Honeydew is secreted copiously, attracting and encouraging sooty mould. Usually controlled by ***parasites and predators***, eg ladybirds. Colonies can be squashed between fingers or by jets of water. See Citrus F 41.

Seed insects: Many insects feed on seeds. Various ***gall flies and wasps*** infest seed (see above). ***Various seed moths*** (Lepidoptera) breed in the seed pods of wattles. A ***seed weevil*** (*Melanterius* sp., Bruchidae, Coleoptera) lays eggs on ***seed pods*** of silver wattle (*A. dealbata*), the larvae eat the developing seed. See Trees K 16.

Wattle leafminer (*Acrocercops plebeia,* Gracillariidae, Lepidoptera) infests ***phyllodinous wattles*** especially young Queensland silver wattle (*A. podalyriifolia*) during spring, summer and autumn. ***Moths*** are small, about 15 mm long. ***Caterpillars*** are about ***10 mm*** long and mine inside ***leaves*** first making a fine line, later a large pinkish blister which turns brown and flakes off. Phyllodes may fall prematurely, trees look ugly. Caterpillars pupate inside leaves. ***Insecticides*** may be applied in ***nurseries*** early in spring to prevent damage to new leaves. Caterpillars of ***A. antimima*** mine in *Lomatia myricoides*. See Azalea K 28.

Others: ***Eriophyid mites*** (Eriophyidae) may feed on new shoots causing shoots to bunch. ***Spiny leaf insect*** (*Extatosoma tiaratum*) is large, bright-green or brown and up to ***120 mm*** long.

VERTEBRATE PESTS

Native animals may browse on ***young wattles***. Regeneration strategies must include fencing until seedlings reach 1.5 to 2 m high. Trunks infested with ***borer larvae*** may be further damaged by cockatoos seeking the larvae. See Fruit F 13.

Non-parasitic

Environment: Some *Acacia* spp. are damaged by ***frost***. Some species of *Acacia* are sensitive to ***high humidities***, eg *A. aculeatissima*, *A. amblygona*, *A. conferta*, *A. tindaliae*. Leaves cannot transpire, become waterlogged and blacken.

Fungi, bacteria and insects: ***Lichens*** (symbiotic algae and fungi) may grow on branches and trunks. ***Nitrogen-fixing bacteria*** (*Rhizobium* spp.) are associated with the roots. ***Non-parasitic fungi***, eg **Meliola brisbanensis**, may grow among the hairs on leaf undersurfaces when humidity is high. The fungal mycelium often looks black. ***Honeydew*** produced by mealybugs, psyllids, scales, and other sap sucking insects, attracts ***ants***, ***sooty mould*** may grow on it, making plants look black. ***Cicadas*** (Cicadidae, Hemiptera), eg ***redeye*** (*Psaltoda moerens*), makes numerous egg laying slits in wattle shoots killing them, and may occur in Tasmania in epidemic proportions. ***Wattle cicada*** (*Cicadetta oldfieldi*). See Trees K 13, K 19.

Nutrient deficiencies, toxicities: Deficiency and toxicity symptoms are ***extremely variable*** and depend on the species of *Acacia*. See Citrus F 43.

Potential weeds: The exotic ***prickly acacia*** (*A. nilotoca*) is a ***major weed*** of grassland in north west Qld. Attempts are being made to control it biologically (Marohasy 1995). ***Native wattles***, eg Cootamundra wattle (*A. baileyiana*), may be a weed in some areas.

Others: ***Fasciation*** may result in flattened stems. See Daphne K 53. Leaves of Deane's wattle (*A. deanei*) and coast myall (*A. binervia*) produce ***toxic cyanogenetic compounds*** which, if eaten by sheep and cattle are toxic. Coastal myall is also toxic to pigs and goats (McBarron 1983).

Remember, always check for recent references

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State/Territory Departments of Agriculture/Primary Industry eg

Iron Deficiency (Vic Agnote)

Associations, Journals etc.

GrowSearch (database Qld DPI)

**See Australian native plants N 9,
Trees, shrubs and climbers K 22**

MANAGEMENT

Wattles are grown for tannin, dyes, quick shelter, fodder, ornamental trees and shrubs, mine site regeneration, sand stabilisation, ground covers, cut flowers and foliage and potted plants. Select species suitable for the ***purpose*** and suited to the ***local area.*** Some species have some ***tolerance or resistance*** to acacia spotting bug, various scales, salt, lime, damp conditions. Some tolerate a wide range of pHs, others tolerate only acid or alkaline conditions. Only plant ***disease and pest-free*** nursery stock in disease and pest-free soils. ***Propagated*** by scarified or boiling water-treated seed, cuttings and grafting (Glocke and Sedgeley 1995). Plants may take 2-3 years to reach flowering stage when started from seed. ***Cultural methods:*** Choose sites with good drainage. Fertilise and irrigate to minimise borer damage. ***Sanitation:*** ***Regular pruning*** will promote more prolific flowering and will help prolong plant life. Regularly tip prune young plants to encourage compact bushes, prune after flowering, unless seeds are required. Prune to repair damage caused by wind, disease or insects. Large older wattles should be pruned with care. Some species tolerate heavy pruning and will re-shoot vigorously, eg *A. decurrens*. ***Pesticides:*** Petroleum oils and soap sprays are widely used for scale control. Many pesticides are registered for use on wattle. ***Harvest*** when 50% of the flowers are open at the beginning of flowering, cut foliage with firm undamaged leaves, avoid foliage with wilted tips (Jones and Moody 1993, Nowak and Rudnicki 1990). ***Vase life*** is short, approximately 4-6 days. In Europe, standards have been set by the United Nations Economic Commission for Europe (ECE) for the marketing and commercial quality of cut flowering branches of *Acacia* species. There are several grades depending on stem length and glomerules open and other factors. Branches must be cut cleanly at the base. As the woody stems seldom take up water, prolonged ***storage*** and transport is not recommended. Flowers dry out quickly so it may be necessary to pack flowers in foil.

Fig. 273. Gall rust (*Uromycladium* sp.) on wattle.

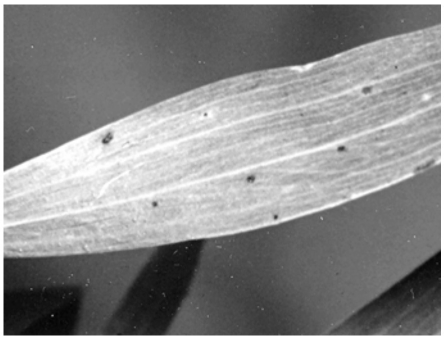

Fig. 274. Rust (Uredinales) on *A. longifolia*.

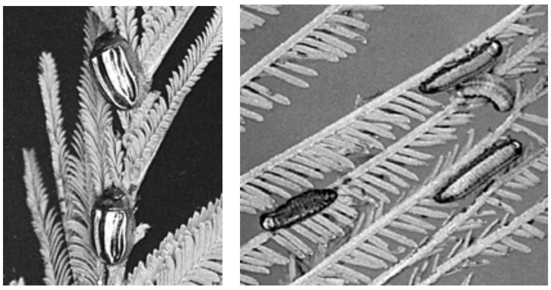

Fig. 275. Fireblight beetle (*Pyroides orphana*).
Left : Beetles. ***Right :*** Larvae. Both 6 mm long.
H. J. Elliott.

Fig. 276. Acacia spotting bug (*Rayieria tumidiceps*) damage. ***Left :*** Round dark brown spots.
Right : Rectangular brown areas between veins.

Fig. 277. ***Left :*** Wattle mealybug (*Melanococcus albizziae*).
Centre : Wattle tick scale (*Cryptes baccatus*) (young scale).
Right : Wattle tick scale (*Cryptes baccatus*) (older scale).

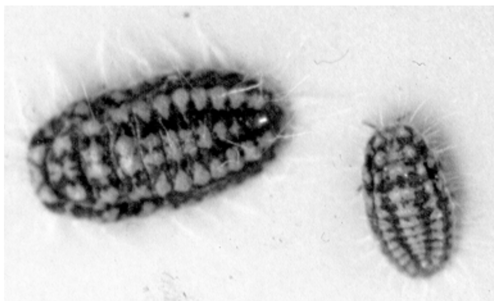

Fig. 278. Woolly giant mealybug (*Monophlebulus pilosior*) is up to 25 mm long.

White cedar

Melia azedarach var. *australasica*
Family Meliaceae

PESTS AND DISEASES
Parasitic

FUNGAL DISEASES

Armillaria root rot (*Armillaria luteobubalina*)
Phytophthora rot (*Phytophthora nicotianae*)
See Trees K 4. K 6.

NEMATODE DISEASES

Stubby root nematodes (*Paratrichodorus* spp.) may infect white cedar (*Melia azedarach* var. *australasica*) in Qld. See Vegetables M 10.

INSECTS AND ALLIED PESTS

White cedar moth (*Leptocneria reducta,* Lymantriidae, Lepidoptera) ranges from Cooktown to southern NSW. ***L. binota*** ranges across northern Australia (Common 1990). Caterpillars of both species feed on leaves of white cedar. ***Moths*** of *L. reducta* have a light brown body, brown blotched forewings and pale hindwings. Wingspans vary from 40-60 mm. Moths lay their eggs on the tree in clusters. ***Caterpillars*** are up to ***40 mm*** long, dark brown with yellow heads and masses of long grey and black hairs about 15 mm long which cause ***skin irritation.*** Caterpillars hide during the day at the base of the tree in a silk shelter and spread out to feed on ***foliage at night***. When they have defoliated one tree, they walk in single file to another white cedar tree ***(processionary caterpillars)***. They may stray into buildings risking dehydration and predation. Trees may be completely defoliated in spring and autumn. ***Complete metamorphosis*** (egg, caterpillar, pupa, adult) with 2 generations in a year, one in spring and another in autumn. The autumn generation is larger and more destructive. ***Overwinters*** as flimsy silken cocoons mixed with body hairs either under bark, in crevices, posts and buildings or amongst dead leaves or rubbish on the ground. ***Spread*** by moths flying and caterpillars crawling. ***Natural control*** is achieved through weather extremes, predation and parasitic wasps and flies which prevent successful pupation. ***Removal by hand*** is an option but hairs cause irritation. A sack or piece of ***hessian tied around the tree*** provides a place for caterpillars to shelter during the day. Examine the hessian each day and destroy the caterpillars. ***This banding is effective*** if sustained during the hazardous period. Alternatively, spray trunks and lower leaves in the evening with ***insecticide***. See Pome fruits F 113.

Others: ***Large auger beetle*** (*Bostrychopsis jesuita*, Bostrichidae, Coleoptera) larvae may bore in ***trunks***. ***Macadamia leafminer*** (*Acrocercops chionosema*, Gracillariidae, Lepidoptera) caterpillars may ***mine in leaves***.

SNAILS AND SLUGS

Snails and slugs may be a pest of young trees, severe ringbarking kills plants. See Seedlings N 70.

Non-parasitic

Poisonous properties: The poisonous principle is not known. ***Berries*** contain the most poison with lesser amounts in the ***bark*** and ***young leaves***. Fresh leaves are reported by some authors to be harmless. Most commonly, ***pigs*** are poisoned but also ***sheep, cattle, dogs and children*** with a history of access to ripe fruits. ***Symptoms*** include vomiting, diarrhoea, convulsions, depression, colic, paralysis and coma. ***Prevent access*** to the fruits and do not plant white cedar trees near stockyards. Recorded cases of poisoning extend between April and November with most cases July-October (McBarron 1983).

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See Australian native plants N 9,
Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

White cedar is one of Australia's ***rare deciduous trees***. It is useful for street and park planting in moderately warm or dry climates. It maintains a convenient size and is very showy when covered with spring blossoms. Only in tropical parts does it become a tall tree. Fruit attracts birds, particularly parrots. It is very hardy in most situations and will grow in a wide range of climates and in almost any well drained soil. It ***tolerates*** very dry conditions. ***Severe frosts*** may cause leaf fall but the tree usually recovers. ***Propagated*** by seed.

Willow

Salix spp.
Family Salicaceae (willow family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Rickettsia-like organisms have been associated with brooming, narrowing, yellowing of ***leaves*** and predisposing of leaves to winter injury overseas (Cooper 1993). See Trees K 4.

FUNGAL DISEASES

Cankers

Black canker, willow black canker, willow blight (*Physalospora miyabeana*) in the USA, starts in the ***leaf blades***, the fungus proceeds through petioles into ***twigs***, it also causes ***cankers*** on larger stems, followed by defoliation. ***Pinkish spore masses*** of *Gloeosporium* (Imperfect stage) are formed on dead twigs and branch cankers and then perithecia, which ***overwinter*** (Horst 1990). Dead twigs and branches should be pruned out during dormancy.
Stem canker (*Glomerella miyabeana*) causes stem cankers and dieback of branch tips in Australia.
Others: Cytospora canker (*Cytospora* sp.), *Botryosphaeria, Colletotrichum*.

See Trees K 5.

Fungal leaf spots

Anthracnose, willow anthracnose (*Marssonina salicicola*, Imperfect Fungi) affects willow, especially weeping willow (*Salix babylonica*), but also basket willow (*S. pupurea*) and cricket-bat willow (*S. coerulea*). ***Leaves*** may develop small, circular, black-coloured spots. ***Young shoots*** may develop black, elliptical lesions, later they enlarge and the epidermis splits, exposing a ***whitish fruiting body*** (acervulus) that is surrounded by black tissue, the lesions may be ***canker-like***. When weather conditions are favourable, ***tip dieback*** is common and shoots are defoliated. ***Spread*** by windborne spores (conidia) that infect the young, growing shoot tips in spring. Anthracnose may occur ***sporadically*** and be of ***nuisance value*** only in the drier areas; however, in wetter areas it can be ***severe*** and spoil the form and vigour of trees. See Fruit F 5.
Others: *Cercospora salicina*, *Sphaceloma murrayae*.

See Annuals A 5.

Root rots: ***Armillaria root rot*** (*Armillaria* spp.), ***phytophthora rot*** (*P. cinnamomi*) on *S. caprea* in USA. See Trees K 7.

Rusts (Uredinales, Basidiomyctes)

European willow rust (*Melampsora epitea*) affects basket willows (*S. pupurea*, *S. viminalis*), pussy willow (*S. discolor*). Towards the end of summer, uredospores (summer spores) appear on ***leaf undersurfaces***, in ***orange-coloured pustules***. Infected leaf tissues rapidly collapse, leaving a small, dark lesion in which ***overwintering spores*** (teliospores) form. Heavy infection produces ***severe defoliation***, which weakens trees. The extent of disease varies from year to year. There is little information on the ***secondary hosts***, which are suspected to be species of *Larix* and *Saxifraga*. ***Overwinters*** as teliospores which develop on fallen leaves. Spores (uredospores) are ***spread*** by wind during summer. ***Favoured*** by wet summers. The only practical method of control is the use of ***resistant*** species or varieties. ***Fungicides*** would only be applied in ***nurseries*** if disease is severe.
Oriental willow rust (*Melampsora coleosporioides*) especially affects weeping willow (*S. babylonica*) and twisted willow (*S. matsudana*). Unlike the other *Melampsora* spp., the ***orange-coloured uredinia*** (spore sacs) are ***tiny***, 0.2-0.5 mm across, and large numbers of pustules appear on ***leaf undersurfaces***. Heavy infection causes ***premature defoliation***. ***Dark brown overwintering fruiting bodies*** (telia) appear in the same fruiting bodies (uredia) that produced the uredospores.

See Annuals A 7.

Wood rots: ***Silver leaf*** (*Stereum purpureum*), ***yellow heart rot*** (*Schizophyllum commune*), ***yellowish wood rot*** (*Polyporus versicolor*). See Trees K 8.

PARASITIC PLANTS

Mistletoe (Loranthaceae) may occur on willows. See Trees K 10.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) have been recorded on white willow (*Salix alba*), weeping willow (*S. babylonica*), *S. caprea*, *S. matsudana.* ***Root lesion nematodes*** (*Pratylenchus* spp.) have been recorded on weeping willow, ***dagger nematode*** (*Xiphinema* sp.) on *S. matsudana*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Borers: ***Longicorn beetles*** (Cerambycidae), eg ***fig longicorn*** (*Acalolepta vastator*) larvae, may feed in the trunks and branches of weeping willow, especially ***older weakened trees*** planted in drier sites or when water supply is removed. Trees may split and fall in high winds. See Trees K 11.

Carrot aphid (*Cavariella aegopodii*): Willow (*Salix* spp.) is the ***primary host*** and various Apiaceae, eg carrot, parsley or fennel, are ***secondary hosts***. Eggs hatch in spring on willow where several generations occur, eventually winged aphids fly to secondary hosts. In cold climates in autumn, winged forms return to the primary host and overwintering eggs are laid. See Carrot M 45.

Caterpillars (Lepidoptera), eg ***painted apple moth*** (*Teia anartoides*) and an ***anthelid caterpillar*** (*Anthela varia*), may feed on ***leaves***. See Trees K 13.

Scales (Hemiptera) may infest leaves and stems.

Armoured scale (Diaspididae)
Red scale (*Aonidiella aurantii*)
San Jose scale (*Quadraspidiotus perniciosus*)

See Citrus F 39, Trees K 16.

Willow leaf sawfly (*Pontania proxima*, Hymenoptera) causes ***leaf galls*** on crack willows (*S. fragilis*). Appearance is spoilt but there seems to be little effect on growth (McMaugh 1994).

Others: ***Glandiferous phylloxerid*** (*Phylloxerina salicis*, Phylloxeridae, Hemiptera) occurs on the ***bark*** of willow.

VERTEBRATE PESTS

All willows, except bitter willow (*S. purpurea*), are palatable to domestic livestock, rabbits, hares, possums, macropods, etc. so protection is necessary ***during establishment***. See Fruit F 13, Trees K 18.

Non-parasitic

Environment: A ***good water supply*** is necessary for satisfactory growth, however consistently waterlogged soils are not suitable.

Potential weed: ***Crack willow*** (*S. fragilis*) is a significant environmental weed. ***Broken pieces*** can be carried downstream where they readily take root. In recent years, ***hybrids*** have been imported into Australia which could produce ***seed*** spread by wind and water causing serious problems in rivers and swamps (Cremer 1994). Willows already are a ***major pest*** of waterways. ***Before control is attempted***, the impact of removal must be considered. Removal can increase erosion, willows may be replaced with more desirable species. Depending on size, willows may be removed by ***mechanical means*** or by ***herbicide treatments***.

Root/drain problems: Willow roots may ***block drains***, where this is likely to be a problem, drains of plastic or other materials, may be considered.

Others: ***Twisted willow*** (*S. matsudana*) derives it name from the twisted nature of its stems.

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State/Territory Departments of Agriculture/Primary Industry eg
Growing Willows (NSW Agfact)
Willow : A Multi-purpose Tree (NSW Agfact)
Willow Control (CSIRO/NSW Agric)
Willow Identification (NSW Agric)
Associations, Journals etc.
New Zealand National Poplar Commission

See Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Willows are grown for windbreaks, shade, fodder, erosion control, timber, baskets, floral arrangements and for ornamental plantings. ***Hybrids*** grow faster, retain leaves longer and leaf again rapidly; however, many will eventually ***seed*** and pose ***environmental problems in waterways***. ***Propagated*** by cuttings and by seed. Willows will grow well in most climates except very dry ones and ***usually grow near water***. They tolerate quite cold conditions. A good water supply is necessary but not consistently waterlogged soils. Sometimes they are planted in damp regions so that their roots take up water and dry the soil. The roots interlace to form a tough network that holds soil together and prevents soil erosion. ***Control measures*** should only be undertaken after consideration of the ***impact of removal***, ***alternative species*** and other ***legal requirements***. ***Environmental legislation*** protect rivers and water courses from erosion and pollution from herbicides. ***Vase life:*** Cut stems on an angle with a very sharp knife or secateurs, change vase solution every 2 days. Place deep in water and top up regularly. Warm water may be beneficial in easing water up stems (Jones and Moody 1993).

Turfgrasses

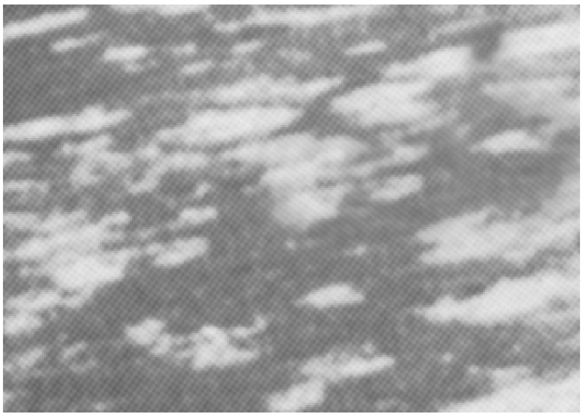

Fig. 279. Spring dead spot (*Leptosphaeria korrae*) on couch-grass (*Cynodon dactylon*). Many other soilborne fungi also infect roots and other parts of turfgrasses resulting in dead patches or rings on turf.

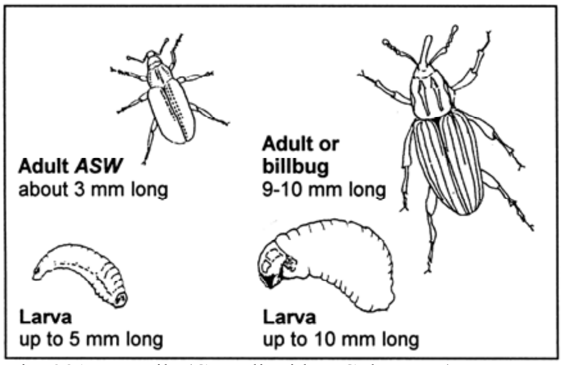

Fig. 281. Weevils (Curculionidae, Coleoptera).
Left : Argentine stem weevil (ASW) (*Listronotus bonariensis*). ***Right :*** Billbug (*Sphenophorus brunnipennis*).

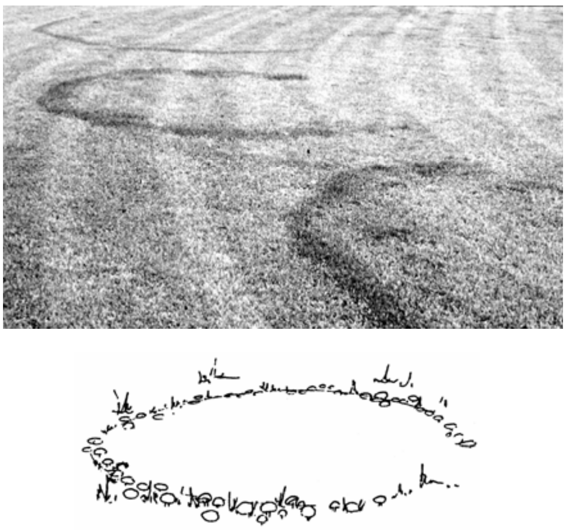

Fig. 284. Fairy rings. ***Upper :*** The fungus decays organic matter and releases soil nitrogen which stimulates the growth of grass. ***Lower :*** Mushrooms develop at the outer edge of the fungal ring in the soil.

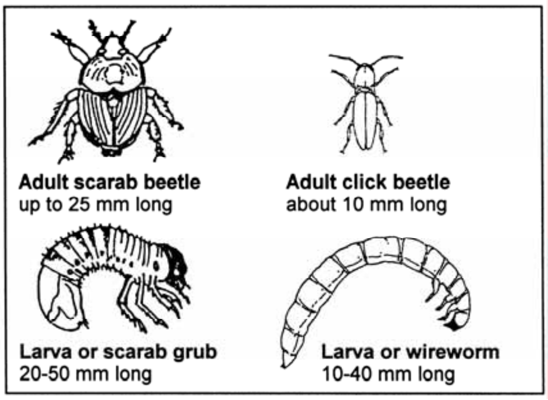

Fig. 280. Beetles (Coleoptera). ***Left :*** Scarab grubs (Scarabaeidae). ***Right :*** Wireworms (Elateridae).

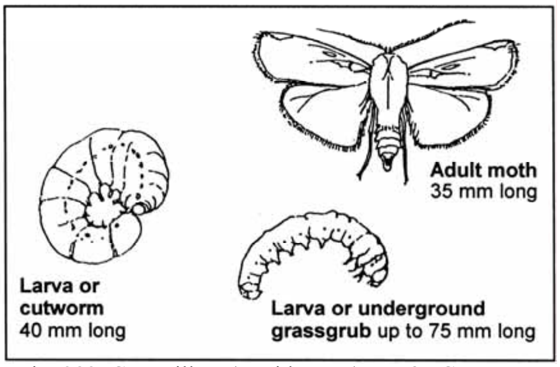

Fig. 282. Caterpillars (Lepidoptera). ***Left :*** Cutworms (*Agrotis* spp.). ***Right :*** Underground grassgrub (*Oncopera* sp.).

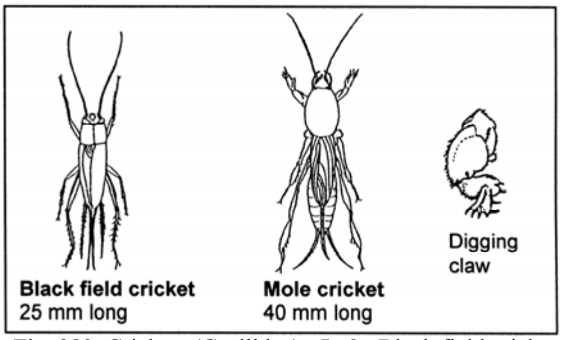

Fig. 283. Crickets (Gryllidae). ***Left :*** Black field cricket (*Teleogryllus commodus*). ***Right :*** Mole cricket (Gryllotalpidae).

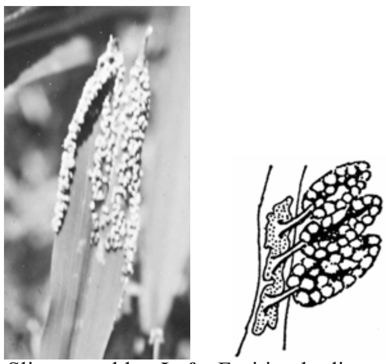

Fig. 285. Slime moulds. ***Left :*** Fruiting bodies on grass. ***Right :*** Spores inside fruiting bodies.

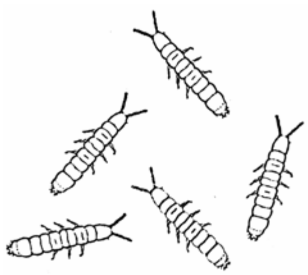

Fig. 286. Springtails (Collembola) are mostly < 6 mm long.

Fig. 287. Lawn mower damage to collar of tree.

Fig. 288. Thatch between the soil surface and grass.

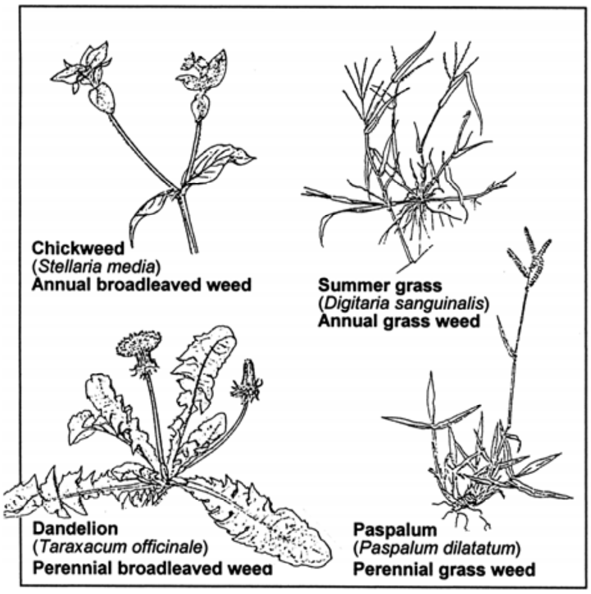

Fig. 289. Weed types in turf.

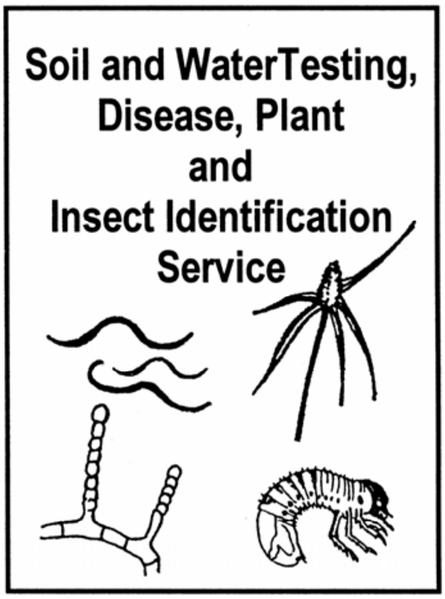

Fig. 290 Diagnostic tests.

DIAGNOSING TURFGRASS PROBLEMS

Diagnosis of ***soilborne*** fungal diseases and pests can be difficult. Only a few pests and diseases cause significant damage to lawns and commercial turf in a particular locality, and often their control is over-emphasised at the expense of good cultural practice. Make a list of the diseases, pests and weeds in your region and when they are likely to occur. You then know in advance when they are likely to be a problem and when treatment (if any) should be carried out. The following steps assist accurate diagnosis:

Identify turf species and cultivar. Most cultivars are only susceptible to a few diseases and pests (Table 5).

Examine individual turf plants, eg stems, leaves, runner and roots. ***Foliage problems***, eg leaf spots, rusts and leafeating caterpillars, leafhoppers, mealybugs and mites are easily identified. ***Root, runner and soil problems***, eg soil fungi, mealybugs, ground pearls which make turf look unhealthy, are more difficult.

Examine diseased turf areas or, if this is not possible, ***ask questions*** about pattern, size, number and colour of diseased patches, and site conditions. ***Evaluate*** vigour, amount and type of cover, check soil and thatch, mowing program and irrigation regime. ***Examine history*** of materials applications, eg pesticides and fertilisers, recent soil tests, month of occurrence (Table 6), weather (specific conditions might favour particular diseases).

Look up a reference (book or database) to confirm or assist diagnosis and provide information on control. If diagnosis is still not certain, then seek assistance.

Seek expert assistance either to identify the problem or confirm a visual diagnosis, eg send core samples for analysis to a recognised testing laboratory. Analyses include ***soil analysis*** for ***chemical properties*** (pH and total soluble salts, major and minor element analysis) and ***physical properties*** (particle size distribution, drainage and compaction studies, profile wettability), ***biological analysis*** for root system evaluation, disease diagnosis, insect and weed identification and germination tests, and ***leaf analysis*** or other tissue analysis, and ***water analysis.***

Turfgrasses

Family Poaceae

PESTS AND DISEASES

Parasitic

- **Virus and virus-like diseases**
- **Bacterial diseases**
- **Fungal diseases**
  - Anthracnose
  - Brown patch
  - Damping off
  - Dollar spot
  - Downy mildew
  - Fungal leaf spots
  - Fusarium diseases
  - Kikuyu yellows
  - Powdery mildew
  - Red thread
  - Rusts
  - Sclerotium stem rot
  - Spring dead spot
  - Take-all
- **Parasitic plants**
- **Nematode diseases**
- **Insects and allied pests**
  - African black beetle
  - Ants
  - Argentine stem weevil
  - Caterpillars, grassgrubs, lawn grubs, webworms
  - Crickets
  - Flies
  - Leaf beetles, flea beetles
  - Leafhoppers and planthoppers
  - Mealybugs
  - Mites
  - Scales
  - Scarab beetles, scarab grubs
  - Weevils
  - Wireworms, false wireworms
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic

- Algae and fungi (algae, dry patch, fairy rings, slime moulds)
- Animals
- Earthworms
- Environment
- Insects and allied pests (itch mites, springtails)
- Mechanical injury (clippings, compaction, equipment, playing damage)
- Mosses
- Nutrient deficiencies, toxicities
- Pesticide injury
- Pollutants
- Thatch

WEEDS

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Turfgrasses are remarkably free from virus diseases in Australia (there are many overseas). There is value in selecting turf cultivars resistant to virus diseases.

Barley yellow dwarf virus affects ***turfgrasses***, eg red fescue; ***field crops***, eg barley, oats, wheat, rye, pasture grasses; ***weeds***, eg winter grass. There are several strains. ***Symptoms*** include stunting, reduced tillering, sterility. Roots show no symptoms but are drastically reduced in weight. Losses are greater when infection occurs before tillering. ***Overwinters*** in annual or perennial grass hosts and in virus-infected aphids. ***Spread*** by aphids, eg corn aphid (*Rhopalosiphum maidis*), oat aphid (*R. padi*), by grafting, not by mechanical inoculation, not by contact between plants, not by seed, not by pollen. ***Favoured*** by cool, moist spring and early summer weather. Severity of symptoms is greatest at 16^{o}C, milder at 27^{o}C and masked at 32^{o}C. Unfertile land. Applications of ***nitrogen*** assists recovery. If virus is a problem, plant ***resistant or tolerant varieties***. Applications of insecticides to control aphid vectors are not economic.

Sugarcane mosaic virus affects ***turfgrasses***, eg carpet grass, buffalo grass, Qld blue couch; ***field crops***, eg sugarcane, maize, sorghum, pearl millet, Sudan grass, wonder forage grass, Tunis grass, wild grasses (wild sugar cane, bull grass, paspalum, crab grass, barnyard grass). ***Effects of virus are variable*** and include pale mottling especially on new unrolling leaves and yellow streaking of foliage. Some hosts show no symptoms. ***Spread*** by aphids, eg corn aphid (*R. maidis*), green peach aphid (*Myzus persicae*), rusty plum aphid (*Hysteroneura setariae*), by grafting, by mechanical inoculation, by seed (in a small percentage), not by pollen. In the US the 'bitter blue' cultivar of buffalo grass is considered to have some ***resistance***.

St. Augustine decline (panicum mosaic virus) affects buffalo grass (St Augustine grass) in the US causing chlorotic spots and death of large patches.

BACTERIAL DISEASES

Of the nearly 400 known diseases of turf overseas probably < 1% are due to bacterial infection. Bacterial diseases in Australia include ***bacterial leaf spot*** (*Pseudomonas syringae* pv. *syringae*) on kikuyu and pearl millet and ***bacterial leaf spot*** (*Xanthomonas albilians*) on paspalum and sourgrass, blady grass, hairy armgrass and sugarcane (Fahy and Persley 1983).

FUNGAL DISEASES

*Most serious turf diseases are caused by **soil fungi** which grow outwards from a centre of infection, killing grass as they grow. Patches may join together resulting in large areas of dead turf (Fig. 279). Damage is occurring all the time but symptoms are not obvious unless destruction is greater than the rate of regeneration. Disease must be identified by **laboratory tests**. Soil fungi **overwinter** in dead leaves, runners and stems, in perennial hosts. They are **spread** by renovation practices, eg mowers, irrigators, propagation material, and some also by wind. They are **favoured** by wet or humid weather and stressed turf. Correction of these factors is vital for disease **prevention and control**.*

Anthracnose (*Colletotrichium* spp.) attacks ***most turfgrasses*** (bent, couchgrass, fescue, ryegrass) but especially winter grass in bent turf. Different species attack different turfgrasses eg *C. graminicola* attacks bluegrass, *C. dematium* attacks ryegrass. ***Irregularly shaped patches of turf*** from several centimetres to many metres across, die. Anthracnose mainly attacks ***older deteriorating leaves and runners,*** hastening senescence but may also attack ***new growth.*** Infected leaves are red-brown, yellow, then brown. Water soaked and bleached lesions develop on ***stems***, which may be girdled. Plants yellow and die. Tiny black fungal fruiting bodies form in dead tissues and can be seen with a hand lens. ***Overwinters*** as mycelium or conidia in acervuli in dead leaves and stems. Spores are ***spread*** by water splash. ***Favoured*** by warm, dry soil and wet/humid canopy, poor drainage and soil fertility, compacted soil, stressed turf during spring and summer. ***Control*** may be necessary during hot, humid conditions, particularly when much winter grass is present. Provide a balanced ***fertiliser*** program, and avoid prolonged leaf wetness. ***Fungicides*** are registered for controlling anthracnose. See Fruit F 5.

Brown patch is a ***disease complex*** caused by *Rhizoctonia solani*. Other fungi, eg *Curvularia*, *Fusarium* and *Helminthosporium,* may also be associated with the disease. Brown patch may be a secondary disease following other diseases. It affects cool and warm season grasses but especially ***bents*** and ***fescues***. ***Strains*** of *R. solani* occur but the host range of each strain is not known. ***Symptoms*** vary according to grass species, soil conditions, height of turf, environment and fungal strain. The classical symptoms described below are for the disease as it occurs on bent during summer and early autumn. ***Patches of affected grass die***. Small discoloured irregular areas up to 500 mm across develop in spring. Sometimes in low cut turf there is a ***smoke ring*** around the margin, possibly due to infection through leaf wounds. Early in the morning when there is dew, fine fungal threads (hyphae) grow on these rings which, if touched, collapse immediately and disappear. Centres of patches may recover resulting in rings of diseased grass. ***Leaves*** are initially yellowish, but turn grey-black and die giving a greasy look to the patch. ***Crowns and stems*** may be rotted. ***Overwinters*** in soil, plant debris or in thatch, infected perennial grasses, propagation material and seed. ***Spread*** by the fungus growing through soil and across the turf surface, by anything that can spread contaminated soil, eg renovation practices, machinery, water drainage, irrigation water, boots, tools, by infected propagation material. ***Favoured*** by excessive thatch, irrigation and nitrogen (lush turf), poor drainage, light, ventilation and humid weather. Cloudy weather lengthens the time of leaf wetness, eg dew in early morning hours. Some strains prefer cool weather, others warm weather. Close mowing allows infection through wounds. ***Avoid or correct conditions*** which favour brown patch. Adequate phosphorus and potash are essential for high levels of turf ***resistance***. A ***fungus*** (*Trichoderma harzianum*) is being researched overseas as a biological control agent (Lo et al. 1996). ***Fungicides*** may be applied prior to anticipated season (in high risk areas) or as soon as disease has been positively identified. See Vegetables M 7.

Damping off, grease spot (*Pythium* spp.), also *Fusarium culmorum*, *Rhizoctonia solani*. *Helminthosporium sorokinianum*. Damping off (*Pythium* spp.) attacks ***cool season turf grasses,*** especially ***bents.*** ***Seeds may rot*** before emergence, causing bare patches in newly seeded turf. Infected ***seedlings*** wilt, wither and die, particularly in hot weather. ***Leaves*** wither, turn reddish, may lie flat, stick together, look greasy and feel slimy. ***Patches of turf die***, often small roughly circular spots up to 150 mm. ***In established lawns***, damping off may appear as pale coloured areas of turf which develop irregular streaks which may follow the grade of the lawn, outlining poorly drained areas. ***Overwinters*** in soil. ***Favoured*** by wet soil and low lying areas, poor soil aeration and drainage, overwatering, thickly sown seed, uncompacted seedbeds, warm (22-35^{o}C), humid or wet conditions, excessive nitrogen. ***Seed when temperatures*** are favourable for rapid germination (cool season grasses 15-25^{o}C, warm season 25-35^{o}C) at the correct rate and time of year. ***Pre-germinate seed*** and supply adequate phosphorus and potassium. In mature turf, reduce thatch. ***Avoid favouring conditions***. A ***fungus*** (*Trichoderma harzianum*) may be used overseas for biological control (Lo et al. 1996). ***Fungicides*** may be applied as seed treatments or as pre- or post-germination drenches. ***Plant growth regulators***, eg gibberellin inhibitors, may suppress dollar spot and enhance the efficacy of fungicides (Burpee et al. 1996. ***Re-sow*** affected areas after treatment. See Seedlings N 66.

Dollar spot (disease syndrome caused by *Sclerotinia homeocarpa*, *Lanzia*, *Moellerodiscus*) is a common disease of ***bent, Qld blue couch, winter grass.*** Possibly strains occur which vary in their response to temperature. ***On closely mown bowling and golf greens*** small circular sunken straw coloured spots 5-8 cm across ***(dollar spots)*** develop, later these join together to form large irregular dead areas. If dew is present in the early morning the fungus grows on dead leaves giving diseased patches a white, cobwebbed appearance. Initially ***leaves*** have yellow blotches, later they become straw coloured. ***Overwinters*** in infected plant debris in soil, and in the crowns and roots of infected plants. In spring, mycelium produced from sclerotia, or mycelium in the soil or in the crown and roots of infected plants, infects healthy leaves. ***Spread*** by the fungus growing through soil and from leaf to leaf, and by introduction of infected plant material, debris or contaminated soil during renovation practices. Fungal hyphae can only infect leaves. Windborne spores are produced but are not considered important. ***Favoured*** by surface temperatures (20-27^{o}C), high humidity, dew, nitrogen deficient soils, dry soils and stressed turf, excessive thatch. ***Avoid favouring conditions***. In mild attacks, damaged leaves may be mown off. Avoid planting ***very susceptible varieties*** if dollar spot is a problem. A ***fungus*** (*Trichoderma harzianum*) is being researched as a biological control agent (Lo et al. 1996). ***Fungicides*** may be applied as soon as disease is diagnosed or prior to the anticipated season. See Vegetables M 7.

Downy mildew (*Sclerophthora* sp.) may affect most grasses but seldom causes major losses. Bunches of shallow roots clumped together develop together with a proliferation of yellow-green shoots from the central crown. May cause serious damage on bents and fescues in NZ. See Annuals A 5.

Fungal leaf spots

***Curvularia* blight**, curvularia spot (*Curvularia* spp., Imperfect Fungi) affects most turfgrasses but especially **bentgrass** and may be a secondary invader following spring dead spot, *Helminthosporium* and other leaf spots diseases. Symptoms may be similar to those of dollar spot. **Irregular brown areas** develop on turf. Definite leaf spots may not develop, leaves may just brown and die. Crown and leaf sheath infections cause brown dry rots. Lesions are black due to **masses of dark spores**. **Favoured** by warm wet weather.

Grey leaf spot (*Pyricularia grisea*) affects turfgrasses, especially **buffalo.** Small brown **leaf and stem spots** develop. These enlarge into round or oblong spots (brown-grey with purple-brown borders), a halo may occur around or near spots. Leaf spots are usually concentrated along the mid-vein but may occur anywhere on the leaf surface. During warm, humid weather spots may be covered with grey mould. **Inflorescences and culms** may be affected. **Favoured** by warm weather, newly established turf, excessive nitrogen, and stressed turf.

***Helminthosporium* diseases** (*Helminthosporium* = *Bipolaris*, *Dreschlera*, *Exserohilum*) infect turfgrasses especially couch, kikuyu. Symptoms vary with turf species affected and part infected. **Infected turf** looks yellow. In warm moist weather, surface runners may dieback. **Leaf spots** are circular or elongate 1-10 mm across, pale to red-brown with a darker margin. **Runners** may also be attacked. Couch may be infected with *H. cynodontis* during warm moist summers. These diseases are **facultative parasites**, ie they can live on organic matter but have the ability to become parasitic.

***Leptosphaerulina* leaf blight** (*Leptosphaerulina* spp., *L. fuciformis*) is only evident on **bent** during extreme turf stress. **Leaves** dieback from the tip with lesions extending down to the leaf sheath. Old leaves wilt and tiny fruiting bodies develop on dead tissue. **Patches** of irregular bleached and later brown turf develop.

***Phoma* leaf spot** (*Phoma sorghina*, Imperfect Fungi) affects temperate climate grasses and is commonly found in decaying plant debris. Determine whether *Phoma* is actually the fungus causing the problem. **Large patches of turf** appear yellow and may die out. **Leaf spots** are roughly circular and pale grey to yellow. Tiny black fruiting bodies (pycnidia) are produced in the centres. **Favoured** by cool, wet conditions.

Others: Copper spot (*Gloeocercospora sorghi*), *Mastigosporum rubricosum*, *Cochliobolus*, *Mycosphaerella*, *Passalora,* *Phyllachora* and *Heterosporium*.

Spread by wind (spores), water splash from infected plants, by mowing and renovation practices, on tools; is possibly seedborne. **Favoured** by moist, humid conditions, excessive leaf wetness, turf stressed by poor soil aeration and drainage, drought, excessive nitrogen, soil compaction and herbicide induced stress. **Control of leaf spots is difficult.** **Avoid** favourable conditions, eg irrigate at in the morning and not in the evening. Improve drainage, aerate the soil, and raise the height of the mower. **Fungicides** can be applied prior to the anticipated occurrence or immediately disease has been observed, and confirmed by laboratory test. See Annuals A 5.

Fusarium diseases

***Fusarium* patch,** gerlachia patch, snow mould, winter Fusarium (*Gerlachia nivalis = Fusarium nivale,* Imperfect Fungi) affects cool season grasses and couch but especially **winter grass**, **creeping bent**. Irregular thinned-out patches of brown grass appear during wet weather. **On closely mown turf** the spots range from 50-300 mm across. Grass in the centre may recover resulting in a ring appearance. In wet weather a **pinkish mycelium** with masses of spores grows around leaf margins. **Leaves** die but roots and crown are not affected. **Favoured** by cool, moist weather in late autumn and winter when air temperatures are < 20^{o}C (especially 0-10^{o}C), excessive nitrogen and thatch, poor drainage and improper fertiliser programs. **No cultivars are resistant**.

***Fusarium* blight** (*Fusarium roseum* in association with *Fusarium* spp., *F. equiseti*, *F. poae,* Imperfect Fungi) is a disease of **cool season grasses** especially Kentucky bluegrass, also bent, fescue, winter grass. There may be different strains. *Fusarium* causes rotting of roots, crowns, stolons and rhizomes, and is first seen as patches of light green turf which later enlarge and die. A mass of **pink hyphae and spores** can be seen when infection is severe. **Dead patches** are usually < 300 mm across. **Favoured** by high humidity, temperatures and nitrogen levels, moist stress, compacted soil, nematode and fungal diseases. Baron Kentucky bluegrass is **resistant**.

***Fusarium* blight syndrome** (*Fusarium* spp., Imperfect Fungi) affects *Poa* spp. especially Kentucky bluegrass. It causes **large dead patches** and occurs in turfgrasses **> 3 years** old. **Favoured** by hot and very dry or wet conditions, thick thatch, faulty irrigation causing turf to go from extremes of wet to dry.

Overwinters and oversummers in infected turf debris in soil and various resistant spores. **Spread** by airborne spores, mowing, excessive wear and renovation practices, on equipment, animals and shoes. **Control procedures** include appropriate balanced fertiliser and irrigation programs and minimising thatch. Severely diseased areas may be replanted. Plant mixes of **less susceptible** turfgrass species. **Fungicides** are registered for *Fusarium* diseases. See Vegetables M 7.

Kikuyu yellows (*Verrucalvus flavofaciens*)

is ***a water mould and the most important disease of kikuyu*** lawns and pastures in Australia. **Conspicuous yellow patches** 100 mm to 1 m or more across occur randomly in lawns. Patches advance outwards slowly at < 1 m per year. The fungus invades and rots roots. Later it invades **stems and leaves** causing them to yellow (kikuyu yellows). Plants are easily pulled from soil. **Roots** when washed are sparse, partially decayed and yellowish brown in contrast to the creamy white abundant roots of healthy plants. **Plants** may be stunted and die, leaving bare patches, the centres of which are invaded by other grasses and weeds. **Overwinters** in infected plant material and soil. **Spread** by movement of infected planting material and soil adhering to animals' feet, vehicle wheels and by the movement of fungal spores in water. **Favoured** by high temperatures in spring and summer. **Nitrogenous fertilisers** green up yellow patches of diseased grass. Pasture variety kikuyu Noonan has ***high field tolerance*** but there are no resistant turf varieties. Only plant ***disease-free turf*** from disease-free areas. Fungicides are not really effective. Apply herbicide to diseased areas, ensure that all affected plants are killed.

Powdery mildew (*Erysiphe graminis*) is a minor disease on closely mown turf, eg fescues, Kentucky bluegrass. Grey-brown patches develop on ***leaves*** which may yellow and wither. ***Seedlings*** may die. ***Favoured*** by high humidity in spring. Collect and burn all infected clippings. Apply a suitable fungicide, and if necessary, repeat applications. See Annuals A 6.

Red thread (*Laetisaria fuciformis,* Basidiomycetes) affects ***cool season grasses*** especially fescue, also bent, ryegrass, winter grass. Usually a minor disease except for some areas, eg ACT, Victoria and Tasmania. Easy to identify. Water-soaked darkened irregular areas of turf from 50-500 mm across which become leached or tan. When air is saturated, ***light pink to red fungal hyphae***, 2 mm or more long, grow out from tips of leaves and from leaf sheaths. Symptoms are most obvious in ***longer growing turf***. ***Overwinters*** in infected plant debris as pinkish gelatinous crusts of fungal mycelium. Spores are ***spread*** by wind and water splash, movement of infected grass, clippings and mechanical renovation of turf. ***Favoured*** by cool wet weather in spring and autumn, low nutrient status, heavy dews, light rains and fogs, low temperatures (15-25^{o}C), dry soil conditions, incorrect pH for turf species being grown (normally 6.0-7.5), and other diseases. ***Keep turf growing vigorously*** and avoid favourable conditions. No fungicides are registered for red thread.

Rusts (*Puccinia* spp., *Uromyces* spp.) affect ***most turfgrasses*** especially ryegrass and bent, also kikuyu, bluegrass, couch, paspalum. Some turfgrasses may be infected with several different rust species. ***Clover rusts*** can occasionally be destructive in certain areas during late winter and early spring. Yellow-orange, red-brown or black pustules occur on ***leaves and leaf sheaths*** which yellow, wither and die. Turf may thin and be more susceptible to attack by other fungal diseases. ***Favoured*** by stress, nitrogen deficiency, shading, heavy dew in mornings, warm humid weather and soils in late summer/early autumn. Different rusts require different temperatures, eg cool season rusts prefer 10-20^{o}C, and warm season stem rust (*Puccinia graminis*) prefers temperatures of about 30^{o}C. ***Avoid favourable conditions***. Mow, collect and burn infected tops of blades. Plant ***resistant varieties***. ***Fungicides*** may be applied where necessary. See Annuals A 7.

Sclerotium stem rot, Rolf's disease, southern blight (*Sclerotium rolfsii*), is a minor disease of ***cool season turfgrasses***, eg bents, fescues, ryegrasses, *Poa* spp. and ***broadleaved turfs***, eg *Cotula* and *Dichondra* in warm temperate areas. ***Yellow, circular to crescent-shaped turf patches*** up to 200 mm across develop. Dead patches increase in size (up to 1-2 m across). Inspection of soil may reveal a ***white, cottony mycelium*** and small, pepper-sized white or brown ***sclerotia*** about 2 mm in diameter at the edge of the ring. Turf may become yellow and thin early in summer. A portion of the patch or ring at its edge dies, as the disease continues to develop and an ***area of green grass*** usually remains in the ***centre***. Grass looks reddish brown as it dies. Rings of dead grass may enlarge up to 200 mm/week during hot humid weather. Patches usually recolonise in autumn. ***Overwinters*** as resistant sclerotia in soil and thatch. ***Spread*** by water, renovation practices and movement of soil. ***Favoured*** by warm humid weather, dry soils, unhealthy turf, excessive thatch, temperatures of 25-35^{o}C, and, during September-April, periods of high moisture following drought. Cool temperatures and poorly aerated or neutral to alkaline soils restrict the growth of the fungus. ***Disease is less obvious*** on vigorously growing well fertilised turf. Reduce thatch and maintain adequate soil aeration and near neutral pH. For quick control, ***remove affected soil*** to a depth of 150 mm and burn (do not drop any on adjacent areas). ***Presently available fungicides*** only achieve limited control. See Vegetables M 8.

Spring dead spot

Scientific name: *Leptosphaeria narmari* and *L. korrae* (Ascomycetes) are present in thatch where they colonise stolons and roots.

Host range: A serious disease of intensively managed ***couch*** and its hybrids > 3 years old, occasionally buffalo.

Symptoms: ***Root and stolons*** rot below the ground. ***Well defined, circular patches*** of dead, bleached grass from 100-500 mm across (Fig. 279), occur in spring as dormant healthy couchgrass resumes growth quicker than infected areas. A few or several hundred spots may appear. Surrounding healthy grass grows in from the edges throughout summer so that symptoms have disappeared by midsummer. Patches tend to reappear and expand each season in the same spot for 3-4 years.

Overwintering: Infected plant roots and debris.

Spread: Growing from diseased to healthy roots. Mechanical renovation of the lawn.

Conditions favouring: Low to moderate soil temperatures (10-20^{o}C) with moist soil, and after a series of unusually cool days or wet, cold weather.

Control:

Cultural methods: Fertiliser management, adequate soil moisture and general renovation techniques encourage healthy and extensive root system. Replant large affected areas in spring. Minimise thatch.

Biological control: Maintaining adequate soil moisture through couch dormancy may favour soil bacteria antagonistic to spring dead spot.

Resistant varieties: Plant a ***hardy*** winter couch suited to the area. Greenlees Park couch is moderately resistant.

Disease-free planting material: Vegetative planting material should be obtained from a source with ***little or no dead spot present***.

Pesticides: Apply ***fungicides*** in autumn to prevent extensive root and stolon rot during winter. Use a wetting agent in conjunction with the chemical. While fungicides will not eradicate spring dead spot, they hasten recovery.

Take-all (*Gaeumannomyces graminis* var. *avenae*, Ascomycetes = ***Ophiobolus patch*** (*Ophiobolus graminis*, Imperfect Fungi)) affects ***turfgrasses*** especially bent golf greens, ***cereals***, eg oats. Other species affect other hosts, eg *G. graminis* var. *tritici* on wheat. Take-all is difficult to diagnose. ***Small circular or ring shaped dead spots*** (150-300 mm across) appear on turf. Patches may enlarge by 150 mm each year until they cover large areas (up to 3 m across). When actively growing, edges are bronzed, sunken and dead. Turf can be pulled up readily. Centres of the thinned patch may be colonised by fescues, winter grass and weeds. ***Stolons or rhizomes and roots*** rot, plants can be pulled up as a skin. If remaining roots are washed carefully brown hyphae are seen on the surface. Take-all resembles *Fusarium* patch but continues to spread throughout the year; *Fusarium* usually subsides in late spring. ***Overwinters*** as infected plant debris in turf or in areas outside, and in decomposing organic matter in thatch. ***Spread*** possibly by spores from adjacent areas, especially in longer turf as in home lawns, by wind and rain splash, by plant to plant contact, by renovation practices, by transport of infected plant debris, and by use of infected sod with no symptoms. ***Favoured*** by cool, wet, poorly drained soils with a light texture and low organic content in spring, excessive nitrogen, low or unbalanced fertility, and liming (alkaline or near neutral soils). Hot dry weather in late spring and summer stresses and kills infected turf. Soil sterilisation, eg fumigation. kills antagonistic microorganisms. ***Control is difficult.*** Avoid conditions which favour take-all. ***Monitor*** and maintain pH between 6.0-7.5. Provide good drainage, use recommended irrigation and fertiliser practices. After fumigation, incorporate rapidly decaying organic material to encourage antagonistic microorganisms. Small areas of ***diseased patches may be removed*** and reseeded. Several fungi, eg non-pathogenic *G. graminis* var. *graminis, G. graminis* var. *tritici*, also *Phialophora radicola* and an antibiotic bacteria (*Pseudomonas putida*-fluorescens) are possible ***biological control agents. Fungicides*** may be useful in controlling take-all.

Others

Ergots are parasitic fungi (*Claviceps* spp., Ascomycetes) which infect the flowers of grasses producing fungal structures called 'ergots' which are the resting bodies of the fungus. See Seeds N 79 (Fig. 440). ***Paspalum ergot*** (*C. paspali*) only infects *Paspalum* spp., eg paspalum, saltwater couch (*P. paspalodes*), Vasey grass (*P. urvillei*). Animals especially cattle, horses and sheep may be poisoned if they eat large numbers of paspalum ergots which contain poisonous alkaloids (McBarron 1983). Ergot-infected ***flower heads*** prior to forming the ergot produce a sticky honeydew which sticks to and stains clothing and may be a nuisance in unmown paspalum in lawns. ***Rye ergot*** (*C. purpurea*) affects ryegrass, cocksfoot (not paspalum) and cereals, eg wheat, ***phalaris ergot*** (*C. phalaridis*) affects phalaris.

Smuts (*Tilletia* spp., *Urocystis* spp., Ustilaginales, Basidiomyctes) affect many turfgrasses, eg bent, Kentucky bluegrass, ryegrass, couch, paspalum, fescue, buffalo, but are not a problem on mown turf. See Seeds N 79 (Fig, 441). Often host specific. Some turfgrasses may be infected with several different species of smut. ***Seed*** is replaced by black sooty smut spores (teliospores). Feet and trouser legs may become soiled by the spores. ***Favoured*** by unmown couchgrass in autumn, moist humid weather (20-27^{o}C). Keep grass mown to correct height in autumn.

PARASITIC PLANTS

Although parasitic plants have been recorded on grasses, they are of no importance on turfgrasses. See Trees K 9.

NEMATODE DISEASES

Parasitic and beneficial nematodes are common in turfgrass soil. Most parasitic nematodes are host specific and attack only a few plant species. Others, eg ***cyst nematodes*** (*Heterodera* spp.), may attack a wide range of grasses. Other nematodes parasitic on turfgrasses include ***dagger nematode*** (*Xiphinema* spp.), ***spiral nematode*** (*Helicotylenchus* spp.), *Hemicycliophora* spp., many other species (McLeod et al. 1994). Symptoms include ***yellow foliage***, slow growth, gradual premature wilting, and restricted root growth. Attacks may occur from spring to autumn. No turfgrass is known to be ***resistant.*** Frequent applications of ***fenamiphos*** over a long period may result in the increased ability of soil microflora to biodegrade fenamiphos reducing its effectiveness. Fenamiphos should only be applied after ***monitoring*** and if soil populations justify it (currently 50-100 nematodes/200 g soil). ***New products*** are being sought. See Vegetables M 10.

INSECTS AND ALLIED PESTS

African black beetle

Scientific name: Scarabaeidae, Coleoptera:
African black beetle (*Heteronychus arator*)

Host range: ***Most grasses***, eg bowling greens, golf courses, playing fields, pastures, especially those containing mat forming paspalum or kikuyu on light sandy soils; ***ornamentals***, eg dahlia, marigold, petunia, stock seedlings, rose cuttings; ***fruit***, eg grapevine cuttings, strawberry; ***vegetables***, eg brassicas, cucurbits, tomato, sweetcorn seedlings, potato and sweet potato tubers, rhubarb; ***field crops***, eg maize, ***weeds***.

Description and damage: ***Beetles*** are ***10-13 mm*** long, oval and shiny black with toothed legs and chewing mouthparts (Fig. 280). They hide in the ground by day and emerge at night to feed and mate. Swarming occurs at dusk. ***Larvae*** are typical scarab C-shaped 'curl grubs' up to ***25 mm*** long, whitish with a brown head (Fig. 280). Pupae are light brown and about 12 mm long. Young larvae feed on ***organic matter,*** later stages on ***grass roots. Dead patches of turf*** can be rolled back revealing severed roots and larvae. ***Birds*** feeding on larvae cause further damage. Beetles cause minor damage by ***eating crowns and horizontal stems***. Their emergence and burrowing results in an uneven surface. Some turf, eg ***kikuyu***, can support large numbers of larvae without damage. ***Other crops:*** Stems of seedlings at or just below ground level are chewed, tissues look ragged, seedlings die. Beetles bore into strawberries and potato tubers on the ground. Beetles are found in adjacent soil.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with usually 1 generation each year (overlapping stages). Beetles live for 9-11 months and feed during late summer and warm spells in autumn and again in late winter or spring. Females lay eggs in the soil from mid-October to January before dying. Eggs hatch in about 6 weeks. Older larvae feed on grass roots. When fully developed they burrow deeper into the soil and pupate. After 2-4 weeks beetles emerge from the soil and begin feeding. At the onset of cooler autumn weather they burrow down into the soil to overwinter.

Overwintering: As inactive adults in soil, but may emerge and feed during warm winters.

Spread: By adults flying, by flood water, and by beetles moving in from nearby pasture land.

Conditions favouring: Successive dry springs or summers cause beetle numbers to reach plague proportions. Swarming beetles may be attracted to lights, and greens in the vicinity are most likely to be heavily infested. Major damage occurs during December, January-February. Grassland is the preferred breeding site and strawberry, tomato and other crops planted in land recently under pasture (especially ***paspalum pasture***) where beetles have overwintered as adults will be damaged.

Control: Natural enemies include diseases, insects and birds, but these are unimportant. If conditions in spring and early summer are ***very dry*** many eggs and newly hatched larvae die from desiccation. ***Continual heavy rainfall*** in spring causes waterlogging which kills many eggs and young larva, in summer it causes older larvae and pupae to die from drowning and disease. ***Monitoring and soil plugs*** indicate any need for ***insecticide.*** Apply at first sign of adult activity and at prescribed time and intervals. See Turf L 11.

Ants

Scientific name: Formicidae, Hymenoptera:
Argentine ant (*Linepithema humile*)
Black house ants (*Ochetellus* spp.)
Brown house ant (*Doleromyrma darwiniana*)
Coastal brown ant (*Pheidole megacephala*)
Meat or gravel ants (*Iridomyrmex* spp.)
Funnel ant (*Aphaenogaster pythia*)
Seedharvesting ants (*Pheidole* spp.)

Description and damage: ***Seedharvesting ants*** may remove seed for food from newly sown turf. ***Ants nest and tunnel among roots*** of grasses causing wilting of turf (nests in soil are waterproofed) and stress. ***Nests disfigure*** turf. ***Funnel ants*** (*Aphaenogaster* spp.) and other species throw up mounds of earth around entrances to their nests. Other ants infesting lawns may ***bite and sting*** people and animals. Ants are attracted to ***honeydew*** produced by some sap sucking insects eg aphids, mealybugs, soft scales and indirectly transfer them to new hosts.

Overwintering: As all stages in nests.

Spread: By ants crawling and winged forms flying (kings and queens), and by transportation of ants, larvae and eggs on timber, and containers.

Conditions favouring: Usually active from early spring through to autumn; however, they can be troublesome at any time of the year.

Control: Only in relation to turf.
Sanitation: Do not leave plant debris and other litter attractive to ants lying around .
Pesticides: Lime coating or dusting seed being broadcast is known to minimise attack from ants as well as improve the speed of seed germination. If area is being treated, water soil first. Preferably find the nest and destroy it.

Argentine stem weevil *(ASW)*

Ryegrass stem borer

Scientific name: Curculionidae, Coleoptera:
Argentine stem weevil (*Listronotus bonariensis*)

Host range: ***Cool season grasses***, eg bent, winter grass, rough meadow grass, annual, Italian and perennial ryegrasses, cocksfoot, Kentucky bluegrass; ***field crops***, eg barley, oats and wheat. Also sweet vernal chewings fescue.

Description and damage: ***Weevils*** are grey-brown, up to ***3 mm*** long and have a ***snout*** (Fig. 281). They live in the top 10 mm of soil and may be covered with soil making them hard to see. They are nocturnal, hiding in thatch during the day and feeding at night, or during the day in overcast weather. Weevils eat the leaf surface which becomes silvery. ***Larvae*** are creamy, up to ***5 mm*** long. Larvae tunnel into grass tillers and stems causing them to wilt and brown. Larvae may also be found in crown of plant. ***Seedheads*** are damaged by larvae entering nodes from the 2nd-7th from the crown and tunnelling upwards. Seed heads die and are called 'whiteheads' and do not set seed. ***Patches of turfgrass*** yellow, and brown. Larvae can cause sudden death of large areas of turf in hot weather.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with 3 or more generations each year in warm climates. In spring females lay eggs in turfgrass leaves. After hatching, larvae tunnel in tillers etc, feed for several weeks, then drop into the soil to pupate at depth of about 6 mm. After 14 days, weevils emerge.

Overwintering: Adults occur all year round.

Spread: By adults flying and movement of infested turf, soil, fodder etc.

Conditions favouring: Hot weather, spring to mid-autumn. Turf damage can be severe during summer causing rapid desiccation of the foliage, particularly in closely mown turf.

Control:
Cultural methods: ***Manage turf*** appropriately to maintain uniform growth, resist infestation and enable quick recovery. Avoid mowing turf too closely.
Biological control: A fungus (*Beauveria bassiana*) may infect many insects, eg ***ASW***, black vine weevil (*Otiorhynchus sulcatus*), sitona weevil (*Sitona discoideus*), African black beetle (*Heteronychus arator*), also wasps

(*Vespula* spp.) and a hoverfly (*Syrphus novaezealandiae*). ***Strains*** of the fungus exist. *Beauveria* is being investigated in NZ for biological control of ***ASW***.

Resistant varieties: Plant less susceptible cultivars. eg tall fescue instead of perennial ryegrass. In the absence of *A. lolii* infection, ryegrass cultivars of Italian ryegrass (*L. multiflorum*) parentage are preferred to perennial ryegrass (*L. perenne*) cultivars. ***An endophyte fungus*** (*Acremonium lolii*), a true mutualistic fungus, confers ryegrass resistance to ***ASW*** (Hellman and Mathias 1990) The fungus produces symptomless systemic infection in the host plant with the hyphae concentrated in the basal tiller region of vegetative plants. Spores are not known, and it is spread by use of seed infected with vegetative hyphae. Three (3) metabolites are produced by endophyte-infected plants. ***Peramine*** is the most important and delays larval development. They cannot establish on the diet. Once established peramine has no effect on subsequent development. ***Ergotamine*** will reduce feeding by adult weevils. ***Lolitrem*** is a larval feeding deterrent and toxicant. In NZ ***perennial ryegrass staggers*** (a temporary neuro-muscular disease) occurs in livestock grazing on ryegrass pastures infected with the endophyte fungus.

Pesticides: Monitor adults by examining catchers during daytime, spraying area with pyrethrum or by leaving clippings in sun. ***Larvae*** can be detected by examining tillers. Spray to control adults when first noticed, eg in spring. If banks around golf greens are planted with cool season species, eg ryegrass or bent they should also be treated. Larvae are difficult to reach and eggs difficult to kill with insecticides.

Caterpillars, grassgrubs, lawn grubs, webworms (Lepidoptera) sporadically damage turf usually for short periods in summer and autumn.

Armyworms and cutworms (Noctuidae)
Black cutworm (*Agrotis ipsilon*)
Bogong moth, common cutworm (*A. infusa*)
Brown cutworm (*A. munda*)
Common armyworm (*Leucania convecta*)
Dayfeeding armyworm (*Spodoptera exempta*)
Lawn armyworm (*S. mauritia*)
Cutworms (*Agrostis* spp.) may damage turf especially couch and bent. ***Caterpillars*** are up to ***40 mm*** long, smooth bodied, dark-grey to almost black, dark-brown, olive green, pinkish. When disturbed they coil up like a watch spring and sham death. Older caterpillars feed on warm calm or cool clear nights or during the day in cloudy weather. They hide by day in the soil or in old core holes. Damage ***resembles that of dollar spot***, ie spots up to 50 mm across with a central and vertical chamber from which they feed. ***Back fill old core holes*** during green renovation. ***Natural controls*** include adverse weather (hot days, windy weather), birds, parasitic insects and diseases. Wet weather may force many older caterpillars to the surface. ***Monitor*** cutworms by laying a bag on the grass at night, caterpillars will shelter under it. Late afternoon or evening is the best time to gauge the need for spraying. Spray late in afternoon.

Grassgrubs, underground grassgrubs (*Oncopera* spp., Hepialidae), eg underground grass caterpillar (*O. fasiculata*), underground grassgrub or winter corbie (*O. rufobrunnea*), corbie (*O. intricata*), Ebor grassgrub (*O. alboguttata*), alpine grassgrub (*O. alpina*). ***Caterpillars*** occur in sporadic plagues, are up to ***75 mm*** long (Fig. 282), dark green-brown and feed on leaves in autumn and winter and throw up small heaps of soil together with fine threads of silk. Heavy watering may force caterpillars to the surface and birds eat them.

Webworms (Pyralidae) are caterpillars of some pyralid moths. They are usually green-brown with dark spots and up to about ***25 mm*** long, eg
Couchgrass webworm (*Sclerobia tritalis*)
Grass webworm (*Calamotropha leptogrammella*)
Pasture webworms (*Hednota*, *Ptochostola*)
Sod webworm, grass caterpillar (*Herpetogramma licarsisalis*) is a sporadic pest of turf in late summer/autumn. Caterpillars feed on ***leaf blades*** and may defoliate turf. Moths fly at night and are attracted to outside lights.

Others: Grass anthelid (*Pterolocera amplicornis*, Anthelidae), ***grass funnel moth*** (*Philobota chionoptera*, Oecophoridae), ***pasture day moth*** (*Apina callisto*, Agaristidae), ***brown pasture looper*** (*Ciampa arietaria*, Geometridae), ***buffel grass seed caterpillar*** (*Mampava rhodoneura,* Pyralidae). ***Alpine case moth*** (*Lomera caespitosae*, Psychidae) on native *Poa* sp. Also ***skippers*** (Hesperiidae), eg ***darts*** (*Ocybadistes* spp.), grassdarts (*Taractrocera* spp.), ***bright shield skipper*** (*Signeta flammeata*) and ***dispar skipper*** (*Dispar compacta*) on Kentucky bluegrass, ***cynone skipper*** (*Anisynta cynone*) on couchgrass; ***browns*** (Nymphalidae), eg ***Bank's brown butterfly*** (*Heteronympha banksii*) and ***browns*** (*Oreizenica* spp.) on Kentucky bluegrass, ***evening brown butterfly*** (*Malanitis leda*) on buffalo grass, ***Hobart brown*** (*Argynnina hobartia*), ***common brown ringlet*** (*Hypocysta metirus*) on couchgrass (Common and Waterhouse 1981, Common 1990).

See Annuals A 8.

Crickets (Orthoptera)

Black field cricket (*Teleogryllus commodus,* Gryllidae) affects turfgrasses and pasture, ornamentals, vegetables and fruit. They swarm to lights and into houses, where they have been known to damage clothing and other fabrics. ***Adults*** are strong fliers, black or dark brown, about ***25 mm*** long, with 2 pairs of wings, long antennae and strong back legs adapted for ***jumping*** (Fig. 283). Males produce a chirping sound in the evening by moving their wings. ***Nymphs*** resemble adults but have no wings. Nymphs and adults chew ***leaves and growing points***, plants may be chewed off at ground level. They also chew fruit, eg strawberries. They shelter under leaves and in soil cracks during the day and feed at night. ***Gradual metamorphosis*** (egg, nymph, adult) with 1 generation a year. Female adults lay about 300 eggs in cracks in soil after first autumn rains. Crickets die at the onset of cold weather. The eggs hatch the following spring/summer. Young nymphs live in cracks in the soil. ***Overwinters*** as eggs in soil. ***Spread*** by adults flying. Nymphs crawl and hop and may cover large distances. ***Favoured*** in late spring/summer/autumn. ***Manage soil to reduce cracking.*** In Victoria a wasp (*Procaccus dubius*) parasitises many eggs. A ***fungus*** (*Metarhizium anisopliae*) is being researched as a biological control agent (Milner et al. 1996). ***Baits*** may be broadcast in the late afternoon or crickets treated with insecticide when noticed in cracked soil during summer.

Mole crickets (*Gryllotalpa* spp., Gryllotalpidae) burrow in soil and sporadically feed on plant roots, runners and organic matter. ***Adults*** are dull brown, about ***40 mm*** long and as thick as a pencil. Their powerful front legs are broadly flattened with tooth-like projections for ***digging*** (Fig. 283). Crickets 'sing' using special structures on the wing covers. Adults shelter during the day in vertical tunnels (up to 1 m deep) and feed in the evening or at night on ***roots and lower stems of grasses*** and by ***tunnelling horizontally*** just beneath the soil, causing uneven playing surfaces, roots to dry out, and kill patches of grass. Newly seeded areas may be churned up, killing germinating seeds or uprooting seedlings. They throw up mounds of soil around their tunnel entrances. ***Gradual metamorphosis*** (egg, nymphs, adult) with 1-2 generations each year. Females lay eggs in clusters in cells 70-250 mm deep in the soil, during late spring/summer. All stages may be observed during summer. Adults predominate in the early summer, and nymphs in autumn-winter. ***Overwinters*** as adults or nymphs. ***Spread*** by crickets flying. ***Favoured*** by warm spells after heavy rain in spring/summer, moist sandy soils. Control by ***insecticides*** or by ***physical means***. ***Changa mole cricket*** (*Scapteriscus didactylus*) has been identified in Australia, it is a major horticultural and agricultural pest overseas (Kaapro 1996). The changa mole cricket has 2 digging claws on each of its front tibia whereas *Gryllotalpa* spp. has 4 digging claws.

See Strawberry F 141, Vegetables M 13.

Flies (Diptera)

Couchtip maggot (*Delia urbana,* Anthomyiidae, Diptera) affects newly established turf, especially couch. Decaying plant material attracts flies for egg laying. ***Flies*** are black, about ***2 mm*** long and are seen in summer and warm winter weather during egg laying in leaf sheaths. ***Maggots*** about ***1 mm*** long tunnel into stems and feed on ***growing points*** which wilt. Damaged turf generally browns off in irregular patches. ***Favoured*** by animal manures, organic fertilisers, during warm weather in spring and summer after cool wet winters. ***Avoid favouring conditions.*** Systemic insecticides may be applied if several adults or any maggots are observed. Maintain well watered and adequately fertilised turf.

Lawn fly (*Hydrellia tritici,* Ephydridae Diptera) ***maggots*** are mainly aquatic or live within stems or roots of land plants in wet areas and freshwater plants, especially in extra-tropical pastures. See Onion M 68.

Leaf beetles, flea beetles

(Chrysomelidae, Coleoptera)

Couch flea beetle (*Chaetocnema australica*) feeds on temperate climate turfgrasses, eg bent, couch. ***Flea beetles*** have small shiny bodies ***1.5-3 mm*** long, strong hind legs so they can hop like fleas. ***Turfgrasses*** stripped by beetles have silvery leaf markings and look ***bleached***. Turf may wilt and eventually die. There are 2-3 generations each season, the 1st hatching is in spring and the 2nd in autumn. Under favourable conditions there may be a 3rd hatching in late autumn. The life cycle is similar to that of the black beetle. Chemical treatments for control. Active in summer. Little is known about the larvae except that they live in the soil and may feed on the roots of grasses. See Hibiscus K 82.

Crabgrass leaf beetle (*Oulema rufotincta*) is small, dark brown, shiny, slightly larger than couch flea beetle. It can fly but not jump. When disturbed the beetles drop off the grass. They attack Qld blue couch and crabgrass. ***Larvae*** are small, slug-like, covered with a clear gelatinous substance. They are usually present with the adults. Larva are most damaging. Effect on infected lawns is similar to couch flea beetle with the surface turning grey, dry and unthrifty. No chemicals are presently registered to control this pest.

See Trees K 15.

Leafhoppers and planthoppers

(Hemiptera), eg ***Australian grass leafhopper*** (*Nesoclutha pallida*, Cicadellidae), ***turf planthopper*** (*Toya dryope*, Delphacidae) and ***leafhoppers or planthoppers*** (Jassidae) are sporadic pests capable of causing damage to turf if conditions are favourable. See Trees K 15.

Mealybugs (Pseudococcidae, Hemiptera),

eg ***grass-crown mealybug***, felted grass coccid (*Antonina graminis*) which damages couch, kikuyu, buffalo grass and Qld blue couch. Also ***ryegrass mealybug*** (*Phenacoccus graminicola*), ***grassroot mealybug*** (*Rhizoecus rumicis*) and ***Ripersia spp***. Mealybugs are ***subterranean pests*** that occur sporadically on ***roots*** of many turfgrasses especially ***bent and couch,*** and often escape detection. Colonies enveloped in white, cottony, waxy material develop which forms the egg covering. Damage mainly occurs after coring, the mealybugs breeding prolifically on the many roots in the ***core holes***. Brown or dry patches like dollar spot can form around core holes. Turf looks dry and wilted as adults suck sap from roots. ***Core holes should be back filled***. Top dressing soon after coring reduces access for the pest. Generous watering may also discourage them. Avoid heavy cutting as this weakens turf. Apply water and fertilisers to offset effects. Chemical control may be difficult because of the difficulty of getting insecticides to the target. See Greenhouses N 25.

Mites (Acarina)

Earth mites (Penthaleidae), eg ***blue oat mite*** (*Penthaleus major*), ***redlegged earth mite*** (*Halotydeus destructor*). ***Nymphs and adults*** suck sap from ***leaves*** which become mottled and whitish. Infested plants may become stunted, brown and die. ***Seedlings*** can be killed outright. Damage is often mistaken for frost injury. See Vegetables M 16.

Eriophyid mites (Eriophyidae): ***Couch mite*** (*Eriophyes tenuis*) and ***couchgrass mite*** (*E. cynodoniensis*) affect bent, couch, kikuyu. They are microscopic, creamy, worm-like with 2 pairs legs near the head. They produce no webbing. Mites feed on and in ***leaf axils*** and attack ***growing tips*** causing yellowing, stunting and bunchy growth. Heavily infested areas turn brown and die. ***Favoured*** by dry and stressed grass during summer. Avoid spreading mites by cutting affected parts of turf last and destroying clippings. Clean mowers after mowing. Miticides may be required. See Grapevine F 62.

False spider mites (Tenuipalpidae): ***Couch mite*** (*Dolichotetranychus australianus*) affects couch. It is red, flat, relatively slow moving, just visible to the naked eye, produces no webbing and damages turf in the same way as other grass mites.

Spider mites (Tetranychidae) can just be seen with the naked eye. ***Grasswebbing mites*** (*Oligonychus araneum*, *O. digitatus*) attack couch, Qld blue couch and buffalo. On dewy mornings mites can be seen running about on fine webbing. They damage turf in the same way as eriophyid mites. ***Pasture mite*** (*Bryobia repensi*) does not produce webs and affects ryegrass. ***Twospotted mite*** (*Tetranychus urticae*) may infest buffalo. See Beans (French) M 29.

Mite presence may be confirmed by ***laboratory examination***. Mites breed quickly during summer. Adequate watering and fertilising may stimulate turfgrass growth but recovery is usually slow. Miticides are registered for use.

Scales (Hemiptera)

Couchgrass scale (*Odonaspis ruthae,* Diaspididae) does not produce honeydew. Adult covers are hard, white, about ***1.5 mm*** long, elongated and taper towards the rear. Female covers are larger and broader. Scales normally hide ***beneath grass blades*** and are also found attached to ***runners*** of couch at the nodes above and below the ground surface. Washing out a plug will reveal them. Scales suck sap. ***Grass*** fails to make good root, stem or leaf growth and may be lighter in colour than unaffected grass. ***Stems*** may become red at the internodes. No pesticides are registered in WA. Many lawns and grassed areas can withstand infestations without being severely affected. See Citrus F 39.

Grass coccid (*Symonicoccus australis,* Coccidae) may infest turfgrasses. See Citrus F 41.

Ground pearls (Margarodidae), eg ***ground pearls*** (*Margarodes* spp.), may severely damage turfgrasses, eg couch, Qld blue couch, kikuyu, occasionally bent. They are subterranean pests which live deep in soil and feed on turf roots. ***Ground pearls*** are pale to purplish in colour, they have needle-like mouth parts and small pearl-like bodies and are up to 3 mm across. ***Nymphs*** crawl to suitable feeding sites on the ***roots*** of turfgrasses. As they mature, legs and antennae are lost and a characteristic pearl-like cover is secreted. When this hardens adult females become immobile and remain on roots feeding and producing eggs. One life cycle may take 1 year to complete. ***Affected turf*** may brown and die in irregular patches. ***Chemical control is difficult*** because of the difficulty of getting the insecticide to the target pest. Young nymphs and adult females are the only ***susceptible stages***. Insecticides are usually applied in late spring or summer, but the susceptible stages must be identified. White oil may be added as it is a wetting agent. ***Others: Pink ground pearl*** (*Eumargarodes laingi*), ***white ground pearl*** (*Promargarodes australis*). See Citrus F 41.

See Citrus F 39, F 41.

Scarab beetles, scarab grubs

Scientific name: Scarabaeidae, Coleoptera:
African black beetle (*Heteronychus arator*)
Argentinian scarab (*Cyclocephala signaticollis*)
Black beetle (*Metanastes vulgivagus*)
Blackheaded pasture cockchafer (*Aphodius tasmaniae, A. pseudotasmaniae*)
Brown cockchafer (*Ataenius imparalis*)
Christmas beetles (*Anoplognathus* spp.)
Dusky pasture scarab (*Sericesthis nigrolineata*)
Paspalum whitegrub *Lepidiota laevis*
Pasture whitegrubs (*Rhopaea* spp.)
Pruinose scarab (*Sericesthis geminata*)
Redheaded cockchafer (*Adoryphorus coulonii*)

Host range: ***Young larvae*** feed on organic matter in the soil and when older, feed mainly on roots of grasses and occasionally ***ornamentals***, eg herbaceous perennials, ***fruit***, eg peanut, pineapple, strawberry, ***vegetables***, eg potato, ***field crops***, eg sugarcane. ***Beetles*** may feed on stems/foliage of often ***quite different plants***, eg Christmas beetles and pruinose scarabs feed on eucalypt, tea-tree, introduced pepper tree (*Schinus molle*) and plum trees. ***Adults of some species***, eg African black beetle, feed on the same plants as the larvae. See Trees K 16, Turfgrasses L 7.

New Zealand grass grub (*Costelytra zealandica*) is a serious pest of pasture and crop plants in NZ. ***Quarantine risks and precautions:*** The probable means of entry to Australia would be as the adult beetle in the cargo holds of aircraft or associated with passenger baggage or goods freighted to Australia by air from New Zealand. Baggage of campers and hitchhikers may pose the greatest risk (Com. of Aust. 1987).

Description and damage: ***Beetles*** are usually broad, chunky and convex, and up to ***25 mm*** long (Fig. 280). ***Larvae*** are plump, soft, cylindrical, about 20-70 mm long, grey to white with a hard shiny dark head with prominent jaws and well developed legs on the thorax. They are nearly always curled in a C-shape (Fig. 280). Larvae live in the soil for up to 2 years feeding on the ***roots of turfgrasses***. Damage is usually first noticed in autumn when patches of turf die and become soft and uneven. More damage is caused by birds digging to feed on the larvae, particularly if the area is wet. Turf can be pulled back to reveal the grubs. ***Larvae can be identified*** by their anal shape and surrounding hairs. Identification is important as different species may require different management techniques. Infestation tends to move outwards from a central point where the eggs were laid. As many as 250 scarab grubs/m^2 have been recorded in the ACT. ***Fruit, ornamentals and vegetables***: Damage by larvae is often misdiagnosed and may occur if soil is excessively wet. Larvae may feed on roots of ***strawberry*** and ***pineapples*** and fruit or nut ***nursery stock***, planted in old pasture land, ***container-grown*** nursery plants, eg eucalypt (several larvae in a pot result in plants wilting and wobbling). ***Potato*** stems may be severed below ground or round deep holes gouged in tubers.

Pest cycle: Complete metamorphosis (egg, larva (curl grub, scarab grub), pupa, adult) with 1 generation each 1-3 years. In spring female beetles lay eggs in well watered fine open textured turf. Eggs hatch in January-February, larvae feed just below the soil surface on organic matter. Towards March larvae move deeper into the soil and feed on grass roots. When cold winter weather arrives, larvae burrow deeper into the soil. During late spring larvae pupate. In summer adult beetles emerge and fly off to host plants, mate and commence egg laying, after which they die.

Overwintering: As larvae in the soil in special overwintering chambers.

Spread: Adults can fly long distances. Adults of some species, eg African black beetle, may crawl in from nearby areas or be transported in flood water. Larvae may be spread in containers and bush litter used as mulch.

Conditions favouring: Well watered fine textured grass lawns and open textured soil are favoured for egg laying. If infestation is dense, severe damage usually occurs to turf during autumn. Fruit and vegetable crops may be damaged if planted out in recently-ploughed grassland containing paspalum on which larvae have been feeding. Beetles are attracted to street lights and may attempt to burrow under the lights even though the surface may be impossibly hard.

Control: In commercial turf ***identify*** the species of scarab grub so that the most effective method of control can be selected. Once an infestation is established, control measures are ineffective.

Cultural methods: Avoid situations which favour infestation and reduce the impact by maintaining turf in good condition. Healthy vigorous turf can support large populations of scarabs without apparent damage.

> ***Correct watering:*** As soil moisture levels are a major factor in attracting egg laying beetles to the lawn, avoid frequent light watering, as this encourages shallow-rooted turf which will not tolerate surface drying, and may also encourage invasion by scarab beetles. Soil compaction is the most common cause of water run-off which prevents water penetration, this should be remedied. ***Correct fertilisation*** should be carried out when turf is actively growing, eg spring and autumn. ***Aeration procedures (coring)*** result in better water penetration. ***Lawns containing clovers*** may be less severely damaged as larvae prefer to eat roots of grasses. Clovers maintain ground cover until grasses recover. ***Cut turf*** at the recommended height.

For other crops, a period of fallow between ploughing and planting is beneficial. Jetting gives some remission.

Biological control: Many viral, bacterial and fungal diseases, parasitic flies and wasps, and nematodes, may kill larvae. At present a ***nematode*** (*Steinernema glaseri*) is being researched for possible use against the ***redheaded pasture cockchafer*** (*Adoryphorus couloni*). In wet turf, starlings, currawongs, magpies and other ***birds*** feed on larvae when they are close to the surface. If larvae are present and near the surface, watering during the day or early evening may increase the activity of natural diseases which attack larvae. ***Extremes in weather***, especially prolonged drought or prolonged rain or extremely high soil temperatures at the time of egg laying will also limit larval populations.

Resistant varieties: The roots of some grasses, eg tall fescue, regenerate more quickly than some other grasses. Clover is less severely damaged.

Physical and mechanical methods: Light traps ***monitor*** beetle presence in high priority areas during the egg laying period. ***Nail studded rollers*** may be used behind mowers to injure the grubs when they are feeding close to the surface, allowing secondary infection and death.

Pesticides: Chemical control is only justified in ***commercial turf***, eg bowling greens, not in home gardens. ***Soil plugs*** to ***monitor*** scarab grub numbers in October indicate whether spraying is necessary for that season. If chemicals are to successfully control larvae they should be applied when larvae are close to the surface feeding on organic matter and body fat is minimal (***before*** damage is obvious). Treatment carried out when damage is obvious, usually in autumn, leads to poor results, because larvae are feeding deeper in the soil and contain larger quantities of fat which may absorb some of the chemical, preventing larvae from being killed. Birds feeding on larvae treated with some insecticides could be poisoned if eaten in sufficient numbers. Failure to control scarab grubs is usually due to poor timing of application and/or poor application methods. Check local dates for application. Water lightly and mow turf ***prior to treatment*** to ensure insecticide reaches larvae in soil. ***After treatment***, water heavily to carry chemicals into the root zone and reach larvae 25 mm deep and to avoid poisoning ducks. All poisoned larvae and adults should be removed from surface areas to avoid poisoning birds. Select insecticides non-toxic to birds.

Weevils (Curculionidae, Coleoptera)

In addition to ***Argentine stem weevil*** (*Listronotus bonariensis*) ***(ASW)*** larvae of several other species of weevils (mainly native) can damage cool and warm season turfgrasses if conditions favour plague numbers. See Turfgrasses L 8. ***Vegetable weevil*** (*Listroderes difficilis*) is a problem overseas. Weevil larvae are legless, up to ***10 mm long***, fat, white with brown or yellow heads. If in large numbers, chemical control may be required:

> ***Billbug***, La Plata weevil (*Sphenophorus brunnipennis*) is a sporadic pest of turfgrasses, especially ***kikuyu*** and ***some couch varieties. Billbugs*** are dark, hard weevils, ***9-10 mm*** long (Fig 281). Wing covers have lighter-coloured longitudinal striations, they have a long snout, club-shaped antennae and resemble ***ASW*** but are about 4 times their size. ***Larvae*** have a cream body, brown head, are legless and up to ***10 mm*** long. Young larvae ***tunnel in stems and crowns***. As they grow larger they leave the stolons and feed on ***rhizomes, stolons and crown,*** cutting leaves off from the roots. When fully fed, larvae pupate at, or just below, the soil surface. There are 2 generations each year. ***Overwinters*** as beetles. In summer ***irregular areas of dead turf*** can easily be pulled away from the soil. Birds may damage damp turf in their efforts to find larvae. Insecticides are applied as drenches, timing is critical to application.

Wireworms, false wireworms

(Coleoptera)

> ***False wireworms*** (Tenebrionidae) are the larvae of beetles, eg false wireworm (*Celibe* spp.), striate false wireworm (*Pterohelaeus alternatus*). ***False wireworm, small false wireworm*** (*Gonocephalum walkeri*) larvae are hard and shiny. ***Adult beetles*** are broad grey-black, flattened, about ***8 mm*** long. Often numerous in lawns and surrounding areas where they shelter under leaves and sticks during the day. They are often confused with black beetles, but they do not attack roots of grasses and cause little damage to healthy turf. Beetles and larvae may damage ***young seedlings*** in gardens but their control on lawns is seldom justified.

Wireworms (Elateridae) are click beetle larvae (Fig. 280) which feed on ***underground stems and roots*** causing them to die. They also feed on seed embryos, preventing germination. They are generally beneficial and prey on eggs and young larvae of other insects. They may damage grass by attacking ***seeds*** and ***growing tips of grasses***.

See Seedlings N 69.

Others: ***Aphids*** (Aphididae, Hemiptera), eg bluegreen aphid (*Acyrthosiphon kondoi*) and spotted alfalfa aphid (*Therioaphis trifolii*), are sporadic pests of turf. Also ***bugs*** (Hemiptera), eg kikuyu grass bug (*Halticus chrysolepsis*) and Rutherglen bug (*Nysius vinitor*), ***earwigs*** (Dermaptera), ***lucerne flea*** (*Sminthurus viridis*, Collembola), ***slaters*** (Porcellionidae, Isopoda), ***symphylids*** (Symphala) and ***cocksfoot thrips*** (*Chirothrips manicatus*).

SNAILS AND SLUGS

Slugs especially are often found on overgrown turf which is surrounded by weedy areas. See Seedlings N 70.

VERTEBRATE PESTS

Grazing animals may damage turf.

Non-parasitic

*In both commercial and home garden turf the most common and serious problems are **non-parasitic**, the worst being **weed infestations**, **compaction** and **dry patch**.*

Algae and fungi

Algae, black or green scum (*Nostoc* spp., other genera, Phylum Bryophyta) affects turf especially ***greens***, eg golf fairways and playing fields, where large quantities of water are applied and soils stay wet for long periods. Algae are microscopic green plants which occur naturally in soil and water. They are ***not parasitic*** on turfgrasses. A slippery, gelatinous, thin, dark green scum develops on the surface of thin turf. As it dries out it becomes a dark green-black thin crust which may crack, curl up and peel off. If severe, algae can smother young shoots and prevent growth. Algae is ***spread*** by active algal growth, by renovation practices and running water. ***Favoured*** by surface moisture, heavy rain or excessive irrigation, persistently wet soil, poor drainage and ventilation, shading, anything that prevents the rapid removal of excess water, low temperatures, bare and weak turf. ***Permanent control of algae*** is only obtained by avoiding conditions which favour it. Break existing scum up with a rake and remove, then top dress lightly with sandy soil. ***Fungicides and iron sulphate*** can assist with short term control until grass regrows.

Dry patch affects all types of turf, especially ***bent***. Some non-parasitic fungi growing in soil, coat sand grains with water-repellent chemicals, so that they wet only to a depth of 10-12 mm, even if large amounts of water are applied. Roots are unable to get water from the dry soil and turf suffers from moisture stress, leaves wilt and may die. Affected patches are usually circular but vary in size. A soil core taken from a dry patch after heavy watering will still be dry. Wet soil suppresses the soil organisms causing dry patch, other soil organisms take over the newly moistened soil. Microorganisms ***overwinter*** in soil organic matter. ***Spread*** by microorganisms growing through soil. ***Favoured*** by hot, dry, windy weather, October-March, sandy soils, slopes or greens, edges of bunkers, compacted turf areas, acid pH (keep pH at 6.0-7.5 on affected greens). ***Wet soil*** by spiking the green to a recommended depth to facilitate penetration of a wetting agent, slowly water area to allow the water to seep through affected zone. The green must be kept moist, as drying out will return it to its water repellent state quite quickly. If this occurs the re-wetting program must be carried out again. Repeat treatments may be necessary over 1-2 years.

Fairy rings (*Lepiota*, *Lycoperdon, Marasmius*, Basidiomycetes) grow in lawns, playing fields and pasture, they are ***not parasitic*** on living plants, but they grow on organic matter in the soil. The mycelium grows in all directions from a central point and forms a large circle in the soil. ***At the actively growing front of the ring,*** the fungus decays organic matter and releases soil nitrogen, which is used by itself and by grasses, resulting in a 100-200 mm wide ***circular or arc-shaped ring of darker green or faster growing grass.*** In late summer or autumn after mild wet weather, fruiting bodies ***(mushrooms or toadstools)*** may appear in this lush ring. Fairy rings tend to come up year after year in the same place. ***Various types of fairy rings*** may develop including those with rings of dead grass within the lush ring or no symptoms except fruiting bodies. ***Overwinters*** in the soil. Spores are ***spread*** by wind or by movement of infested soil on renovation machinery etc. ***Favoured*** by light textured poorly aerated soils which have low fertility, and are high in undecomposed organic matter and insufficient moisture, warm weather. Fairy rings are ***difficult to control.*** The organic matter in the soil on which the fungus grows is all eventually used up and fairy rings disappear. Maintain organic matter at < 3% to reduce food for fairy rings. Core and water, reduce thatch. ***Avoid conditions which favour fairy rings.*** Control methods include making the dark rings less conspicuous by applying ***nitrogen fertiliser*** so the colour difference is not so great. This is probably one of the best methods to use in the home garden. ***Watering encourages bacteria.*** Soil in affected areas may be removed as a minimum dig a trench 600-700 mm deep, extending 450 mm on either side of the stimulated zone and remove soil and destroy, do not spill it on to adjacent healthy parts of turf. Replace with disease-free soil and replant. Commercial turf may be drenched with ***wetting agents*** and/or ***fungicides*** after hollow-tyning, but is not always successful: Soil fumigation kills everything so that replanting is necessary.

Slime moulds (*Mucilago* spp., *Physarum cinereum*, Myxomycetes) are found on turfgrasses, low lying plants, eg bulbs, strawberries, lower portions of shrubs, dead leaves, logs, organic matter but are ***not parasitic*** on plants. The body (plasmodium) of a slime mould is a difficult-to-see jelly-like structure many centimetres across which creeps very slowly, like an amoeba, from place to place over the surface of decaying leaves, twigs and grass clippings, feeding on them and microorganisms, which it simply engulfs and digests. When it is fully grown, it moves up on to grass blades, leaves and low branches where it forms masses of ***grey, brown, white, pink, green or yellow fruiting bodies*** (spore-producing bodies) which attract attention (Fig. 285). Usually they do not injure plants, except to have a slight smothering (reducing photosynthesis) and cosmetic effect. Affected grass does not usually die or yellow. Fruiting bodies usually disappear within 1-2 weeks. Spores are ***spread*** by wind, water splash and possibly by machinery. ***Favoured*** by cool wet weather following heavy rain in late spring and early autumn. As soon as spores mature they can be washed away with a hose, leaving grass unaffected. In extreme cases, if it persists, it can be controlled with fungicide.

Animals: Injury from ***dog and cat urine*** damage is generally not persistent, as recovery followed by a lush growth normally occurs readily, especially where compounds in the urine have been dispersed by heavy watering. ***Birds*** may damage turf when seeking scarab larvae.

Earthworms (Class Annelida): Some of the 300 or more native worms are very large. There are more than 150 introduced species and it is these that are commonly encountered in turf and garden areas. ***Allolbophora caligninase*** are often washed on to paths and roadways after heavy rain. ***Tiger earthworms*** (*Eisenia* spp.) frequent compost heaps or places where leaf mould is plentiful. Worms occur in all soils except dry, sandy soils and where humus is deficient. ***Adult worms*** are segmented, have a long, thin, streamlined body permitting easy burrowing through soil, while a series of pairs of bristles help to grip the soil and push the worm along. Although there is a head, there are no eyes or specialised sense organs. Earthworms are hermaphroditic, but not self-fertilising. Eggs are deposited in moist earth. Earthworms increase soil fertility in moist soils containing abundant organic matter by ***breaking up soil particles*** during feeding and ***tunnelling*** resulting in better water penetration. They also ***eat***, along with earth particles, dead plant material and animal manure lying on the soil surface, digesting these. they pass out indigestible material (castings), which bacteria break down into materials useable by growing plants. ***This is probably their most important function***. These castings if numerous, ***ruin the appearance*** of lawns and turf where a smooth even turf is required. A ***heavy roller*** may alleviate mound damage to turf. A suitable pesticide may be applied when infestations are first noticed.

Environment: The need for ***irrigation*** of all turfgrasses, including those described as drought resistant, is generally accepted. In applying water to turf during summer, it is desirable to wet the entire root zone at each irrigation event, heavy watering at intervals of a few days is more effective and more economical than a daily light watering. Intervals between waterings will depend on weather, the depth of the root system and turf species. Deeper penetration of water can often be encouraged by forking or hollow-tyning during summer, particularly on slopes and areas which tend to become hard and impervious. Some turfgrass species tolerate more ***shade*** than others. Some species tolerate high or low ***temperatures*** better than others. ***Heat scald*** occurs where there is ponding of water, especially of turf with ***thick root mat*** which absorbs large quantities of water. Hot weather may then cause heating of the water which can literally 'cook' the turf in that area causing patches of dead turf. Manage turf to reduce root mat, provide good water management design and drainage.

Insects and allied pests

Itch mites, chigger mites (Trombiculidae, Acarina), eg ***blacksoil itch mite*** (*Eutrombicula sarcina*), ***scrub typhus mite*** (*Leptotrombidium deliense*), ***teatree itch mite*** (*E. samboni*), ***tropical scrub itch mite*** (*E. hirdti*). ***Grass itch mite*** (*Odontacarus australiensis*) is found in grass mostly on clay soils. It is minute and sucks blood attaching itself to the skin like a tick. Bites on humans cause swellings, which remain intensely itchy for days. Adults lay eggs in soil. One property may be severely infested while a neighbouring one may be free from infestation. Most common in September-April. It may be necessary to treat clothing, garden beds and lawns.

Springtails (Collembola, Arthropoda), eg ***garden springtail*** (*Bourletiella hortensis*), ***mushroom springtail*** (*Hypogastrura armeta*), ***white springtail*** (*Folsomia candida*) are mainly scavengers. Some are found in turf cores, on rotting bulbs, and damaged corms and seeds. Some live among moss, mushrooms or compost. Occasionally healthy seeds and seedlings are attacked. ***Adult springtails*** have 3 pairs of legs, antennae, are blue-black, green, grey, reddish, yellow or white, mostly ***< 6 mm*** long, with no wings, often with a forked structure (furcula) on the abdomen for jumping (Fig. 286). Female springtails lay eggs in soil or organic matter. There are several generations each year. ***Nymphs*** resemble adults (no metamorphosis) but are smaller. ***Spread*** by crawling, floating on water in drainage channels or streams, movement of decaying vegetable matter. ***Favoured*** by prolonged wet weather and decaying moist organic matter. Numbers decrease during warm summer months when soils are drier. ***Avoid conditions favouring springtails.*** Reduce moisture. If planting seedlings in heavily infested soil, pre-plant liming and frequent turning over of earth reduces numbers and risk of plant injury. Only if seeds or seedlings are being injured should soil or plants be treated with insecticide.

Mechanical injury:

Clippings may be allowed to fall on to turf if the turf is cut frequently and the cut is only a few mm. During summer, clippings wither rapidly and have a valuable mulching effect which tends to keep the soil moister and, as they decay, provide a certain amount of plant food. In winter and in damp weather, or if the clip is longer than a few mm, they do not disappear quickly and tend to collect in damp masses, which may cause local damage to grass as they decay. Increasing mowing height and frequency ***conserves water***.

Compaction occurs in areas subject to traffic forcing soil particles together at the expense of the air spaces, especially during wet conditions when soil particles under pressure move together more easily. Compacted soil reduces availability of ***air*** to roots, and space for roots to grow through. It is less able to absorb water and nutrients, resulting in bare areas and weak, shallow rooted turf, which does not tolerate wear or respond to fertilising. It may also be water repellent, not drain freely and be susceptible to diseases and invasion by mosses, algae and weeds. ***Reduce*** compaction by limiting traffic and ***renovation procedures***, eg hollowing-tyning, boring.

Equipment: Poorly maintained and adjusted equipment may damage the turf surface. Avoid skidding or scuffing especially when turning. Closeness and frequency of ***mowing*** affects not only the appearance of turf but also its botanical composition. True turf-forming grasses have either a crown which is set low in the ground or well developed surface or underground runners which can ***withstand constant close mowing*** without serious damage. Coarser, high-crowned grasses gradually die out under such regimes. Garden lawns usually are not mown as closely as golf and bowling greens. Mowing stimulates the production of new shoots and maintains, with proper cultural treatments, a dense and vigorous turf. Mow to a ***constant recommended height*** as frequently as possible, the aim being to remove no more than 1/3rd of the height of existing grass. ***Too close or irregular cutting*** reduces turf vigour by removing too great a proportion of the leaf blade, which is the major food-producing part of the plant. It also exposes the crown to excessive drying out and damage. It is one of the commonest causes of poor lawn vigour, development of bare patches and other problems in home gardens. ***Grass allowed to grow too long*** should only be reduced a little at each cutting until the correct height is reached. Infrequent but severe mowing is damaging to all turf. Grass may be left a little longer during the hottest times of the year, but any change in mowing should be made gradually.

Playing damage, eg divots may be reduced by management practices which include repair of damaged areas and distribution of playing demands, communication and education such as not playing in wet weather.

Others: ***Vandals*** may damage turf. Lawn mowers may damage tree collars (Fig. 287).

Mosses (Musci, Bryophyta) are not parasitic on plants but may form a dense growth in turf, lawns, on trees, logs and rocks. They are simple green plants, contain chlorophyll and produce much of their own food when exposed to light. They are soil makers, hold moisture and are mainly beneficial. ***Mosses may choke out turf-forming grasses***, but in summer they die resulting in large bare areas which may be invaded by weeds. Spores are ***spread*** by wind. ***Favoured*** by waterlogged, poorly drained, acid soils of low nutrient status, shady areas protected from drying winds. ***Permanent control*** can only be obtained by adequate drainage and soil aeration, diversion of surface water, adjusting soil pH to 6.0-7.5, supplying adequate fertiliser, reducing shade and increasing ventilation. Apply sulphate of iron. Affected areas should be hollow-tyned to a depth of 100-120 mm. Repeat treatments may be required. After moss is dead, rake and scarify area, lightly top dress and reseed.

Nutrient deficiencies, toxicities:

Nutritional disorders can lead to disease-like symptoms. Conduct regular leaf and soil analysis. ***Acid mat:*** The optimum pH for growing turf is between 6.0-7.5 so that while acid soils are preferred many are too strongly acid (those with a pH < 5.5). Grass appears unthrifty and some turf species may compact in growth habit forming a mat. ***Favoured*** by sandy soils, applications of sulphate of ammonia, urea or any mixture containing these nitrogenous fertilisers will increase soil acidity. Apply agricultural lime to raise the pH to the desired level. ***Deficiencies:*** A program of fertiliser treatment based on ***soil and leaf analyses*** from the time of sowing, will reduce weed problems and will improve vigour, density and appearance. Manure may introduce weeds. Phosphorous encourages clover growth. ***Many fertilisers may damage turf,*** especially if applied unevenly or at excessive rates to wet turf, or not watered in after application. Where excessive fertiliser application has occurred, immediate and regular watering normally corrects the problem. ***Top dress*** with soil occasionally to level up the surface. Apply as thinly as possible and work in with the back of a rake. The layer of soil must not be spread too thickly, grass leaves must not be buried. Raking turf and closely mowing it prior to top dressing will increase its benefits.

Pesticide injury may be caused by excessive or uneven applications or chemical drip. ***Herbicides*** may check growth or kill turf, especially selective grass herbicides. Chemicals must be applied according to label directions and, where recommended, watered in to complete treatment. ***Poorly maintained and calibrated equipment*** or unsuitable application techniques contribute to damage. Depending on the chemical, if over or uneven application has occurred, immediately dilute pesticide with copious amounts of water. Those that damage leaves have to be washed off. Some ***fungicides*** may cause discolouration of turf. Broadleaved hormone herbicide and fertiliser containers, which are attached to ***garden hoses***, tend to apply chemicals unevenly and drift on to, and damage, broadleaved plants surrounding the lawn.

Pollutants: ***Fuel, lubricants and cleaning agents*** kill turf and may remain active in soil for up to 6 months or longer. Poorly maintained equipment or bad practices, eg refuelling on turf, are causes. Avoid by regularly servicing machinery and not refuelling or servicing on the playing surface. Where spillage has occurred, immediately wash area with detergent then treat, with an absorbent, eg activated charcoal. Badly damaged areas may need re-planting.

Thatch mainly builds up in older turf and is an excessive accumulation of leaves, stems, roots and other organic materials which have not fully decayed and which over time has developed between the soil surface and grass (Fig. 288). ***Thatch provides*** shade for soil (temperatures are lower during the day and higher at night than they would be otherwise), has a mulching effect and reduces water loss. ***But turf with thatch*** is less vigorous. Water and fertilisers in thatch which should be available to grass roots, are retained in the thatch. Soil aeration is reduced (an abundance of roots in the thatch layer), the playing surface is spongy and diseases and pests increase. ***Favoured*** by high mowings especially on stoloniferous grasses, grass with a creeping habit, cool temperatures which reduce decay activity in the thatch layer, low pH in the thatch layer, high levels of nitrogen and the use of fungicides. ***Regularly de-thatch*** warm season grasses in summer, and cool season in autumn or spring. Aerify the soil. Yearly lime applications may increase decay by bacteria which are favoured by alkaline conditions. ***Root mat***

is composed of partially decayed thatch that has become part of the soil surface, plus turfgrass roots (an organic layer intermixed with soil from top dressing). ***Favoured*** by poorly drained or sandy soil, excess acidity which checks bacterial activity that decays organic matter. Shallow mat (< 40 mm thick) may be hollow-tyned as deep or deeper than the mat to be removed, water deeply but infrequently. If necessary raise soil pH to 6.0-7.5. Shallow mat in couch grass can be removed by shaving and burning.

WEEDS

Invasion by weeds and weed turfgrasses is the most common problem associated with turf (Fig. 289). They should not, however, be a problem in vigorous, well managed turf, as competition from the grass should not allow weeds to establish. ***Pre-plant weed control*** by cultivation and/or herbicides is essential to prevent weed problems in establishing turf. In cooler climates, it is often difficult to ***maintain*** vigorous turf. ***Common weeds in cool season turfgrasses*** include ***grass weeds***, eg couch, paspalum, winter grass, ***broadleaved weeds***, eg dandelion, plantain. ***In warm season turfgrasses*** weeds include ***grass weeds***, eg kikuyu, paspalum, ***broadleaved weeds***, eg bindii, creeping oxalis. ***Good management***, particularly adequate use of fertiliser, mowing at the correct height, irrigating and aerating generally keeps lawns free of weeds. ***Selective post and pre-emergent herbicides*** are available to control broadleaved and grass weeds in commercial turf and should be applied only when weeds are growing rapidly and during young stages. If weeds are not growing actively, fertiliser may be applied 14 days earlier to stimulate growth. Spray only at recommended rate, avoid spraying in wet weather, and mowing for 3-4 days after spraying. ***In home garden lawns*** weeds may be removed by hand and patches reseeded or replanted. Broadleaved weeds may also be selectively controlled using a weeding wand or by hormone herbicides.

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Black-headed Pasture Cockchafer (NSW Agfact, SA Fact Sheet
Diseases of Lawns (Vic Agnote)
Field Crickets (NSW Agriculture)
Fungus in Queensland Blue Lawns (WA Farmnote)
Insect and Related Pests of Lawns (WA Farmnote)
Kikuyu Yellows (NSW Agfact)
Lawn Care : Maintenance (SA Fact Sheet)
Lawns : Establishment and Maintenance (NT Agnote)
Maintenance of Lawns (Vic Agnote)
Mole Crickets (NSW Agfact)
Pest and Weed Control in Lawns (Vic Agnote)
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Turfplan Herbasys

Sports Turf Bulletin
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See Preface xii

Remember, always check for recent references

MANAGEMENT

Selection

Selection of the most suitable turf genotype is the basis for all turf management. Turf is then managed to minimise the effects of constant mowing. Various computerised planning systems are available, eg TurfMan.

Turf requirements: Choose species suitable for the purpose, eg bowling green or home garden lawn, and the climatic area. ***Cool season species*** (optimum temperature 15-25^{o}C), eg bluegrass, fescue, ryegrass, bent. ***Warm season species*** (optimum temperature 25-35^{o}C), eg couch, buffalo, kikuyu, Qld blue couch, salt water couch. ***Native grasses*** (which use less water), eg kangaroo grass, microlaena, wallaby grass. ***Alternatives to turf***, eg dichondra.

Resistant varieties: Species and cultivars of turfgrasses vary in ***disease and pest reaction*** (Table 5) and tolerance to heat, shade, wear and salt. ***Tolerance*** may vary depending on environmental conditions, management practices and strains of disease. Plant species with ***some resistance*** to, or at best with quick recuperative potential, against major fungal diseases and insect pests. In NZ, endophytic organisms make turf drought and heat stress tolerant and resistant to some insect pests. ***Endophytic perennial ryegrass*** is ***resistant*** to Argentine stem weevil. Tall fescue has some tolerance of drought and heat stress.

Disease-free planting material: Seed or turf should be purchased from quality suppliers and have some sort of certification that includes guaranteed seed viability, composition and disease, pest and weed freedom.

Establishment

Propagation: By seed (pre-germinate seed), runners or turf.

Pre-plant treatments include ***site preparation***, eg drains, weed control, final levels, grading contours and levelling; ***soil testing*** for pH, soluble salts, soil texture, gravel and availability of major nutrients (NPK) to determine fertiliser requirements.

Planting treatments include sowing or planting, starter fertiliser, lights, irrigation, rolling, mowing, pesticides including growth regulators for improving growth, striking cuttings and rooting induction.

Post-establishment care for 4-6 weeks includes irrigation, fertiliser, mowing heights and frequency. Insecticides, fungicides and herbicides may damage young turf.

Maintenance

Pest management programs must be prepared and implemented. Regular ***monitoring*** (Neylan 1996) and ***diagnostic testing*** must be carried out (Fig. 290). See Turfgrasses L 2.

Cultural methods: For consistent and uniformly growing turfgrass following the recommended cultural care is essential. ***Irrigation systems*** must consider water quality and evenness of application; ***fertiliser regimes*** should be based on soil and tissue analyses, turfgrass performance, leaf colour and clipping yield; ***pH*** must be maintained at the optimum by liming or fertiliser treatments; ***aeration treatments*** must be carried out as required by hollow-tyne-fork to allow water to penetrate and drain better; ***adequate ventilation*** provides air movement; ***light penetration*** is essential to reduce shading; ***turf must be mown*** at correct height and frequency and in the correct pattern; ***renovation*** treatments include de-thatching regularly (Fig. 290), top dressing with soil, treating and reseeding compacted worn areas; consideration of ***soil permeability***.

Sanitation: Weeds are commonly removed by hand in home gardens and occasionally in commercial turf.

Biological control: ***Fungi***, eg ***Metarhizium anisopliae*** is being researched for controlling black field cricket, and ***Trichoderma harzianum*** for controlling brown patch (*Rhizoctonia solani*), dollar spot (*Sclerotinia* homeocarpa) and damping off (*Pythium* sp.).

Pesticides: ***Insecticides and fungicides*** are used on ***commercial turf*** to control a range of diseases and pests. ***Plant growth regulators*** regulate growth in fine turf and low maintenance situations. A wide range of selective ***post-emergence and pre-emergence herbicides*** are available for control of broadleaved and grass weeds. Commercial turf generally has a high requirement for pesticides. For effective control of diseases, pests and weeds it is important to know when they are likely to occur (Table 6).

Postharvest

Clippings may be used for mulches or composting; turf may be sold but must be maintained in good condition until planted.

Table 5. Some pest, diseases and weeds of selected turfgrass species

		← COOL SEASON GRASSES			→	← WARM SEASON GRASSES				→
	Most turfgrass species	**Bentgrass** *Agrostis spp.*	**Kentucky blugrass** *Poa spp.*	**Red & tall fescues** *Festuca spp.*	**Perennial ryegrass** *Lolium perenne*	**Kikuyu** *Pennisetum clandestinum*	**Buffalo grass** *Stenotaphrum secundatum*	**Couch grass** *Cynodon dactylon*	**Queensland blue couch** *Digitaria didactyla*	**CLOSELY MOWN TURF** < 5-6 mm
VIRUS DISEASES										
BACTERIAL DISEASES										
FUNGAL DISEASES										
Anthracnose		—	—	—	—			—		—
Brown patch		—		—						—
Damping off		—								—
Dollar spot		—							—	—
Fungal leaf spots	—	—	—	—	—	—	—	—	—	—
Fusarium patch		—	—							—
Kikuyu yellows						—				—
Powdery mildew			—	—						—
Red thread		—			—					—
Rusts		—	—		—	—		—		—
Sclerotium		—		—	—			—		—
Spring dead spot								—		—
Take-all		—								—
NEMATODE DISEASES	—									—
INSECTS & ALLIED PESTS										
African black beetle	—								—	—
Ants	—									—
Argentine stem weevil		—	—		—					—
Caterpillars										
Armyworms, cutworms	—									—
Caterpillars, lawn grubs	—									—
Webworms	—									—
Couchtip maggot								—		—
Couchgrass mite								—		—
Couchgrass scale								—		—

Table 5. (contd)

	Most turfgrass species	Bentgrass *Agrostis* spp.	Kentucky blugrass *Poa* spp.	Red & tall fescues *Festuca* spp.	Perennial ryegrass *Lolium perenne*	Kikuyu *Pennisetum clandestinum*	Buffalo grass *Stenotaphrum secundatum*	Couch grass *Cynodon dactylon*	Queensland blue couch *Digitaria didactyla*	CLOSELY MOWN TURF < 5-6 mm
	← COOL SEASON GRASSES →					← WARM SEASON GRASSES →				
Crickets										
Mole crickets	—									—
Leafhoppers	—									—
Mealybugs		—			—	—	—	—	—	—
Scarab beetles	—									—
Weevils										
Argentine stem weevil		—	—		—					—
Billbug						—				—
NON-PARASITIC DISEASES										
Algae and fungi										
Algae	—									—
Dry patch	—									—
Fairy rings	—									—
Slime moulds	—									—
Animals	—									—
Earthworms	—									—
Environment	—									—
Mechanical injury										
Compaction	—									—
Equipment damage	—									—
Vandalism	—									—
Wear, playing damage	—									—
Moss	—									—
Nutrient deficienies	—									—
Pesticide injury										
Herbicide injury	—									—
Thatch	—									—
WEEDS										
Broadleaved weeds	—									—
Grass weeds	—									—

Table 6. Seasonal occurrence of pests, diseases and weeds in turf. *This information is given as a guide only for south-eastern Australia. It should be recognised that there are going to be differences in local soils, climates and seasonal growing conditions and that growers will have to adapt the information to suit their particular or local growing conditions.*

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
FUNGAL DISEASES												
Anthracnose			—	—	—	—	—	—				
Brown patch				—	—	—	—	—	—	—		
Dollar spot	—	—	—	—	—						—	—
Fusarium patch	—	—	—								—	—
Helminthosporium diseases						—	—	—	—			
Kikuyu yellows			—	—	—	—	—	—	—	—	—	
Powdery mildew					—	—	—	—	—	—		
Red thread			—	—	—	—						
Rusts			—	—	—	—	—	—				
Sclerotium disease						—	—	—	—	—		
Smuts								—	—	—		
Spring dead spot				—	—	—						
Take-all			—	—	—	—	—	—	—			
INSECTS & ALLIED PESTS												
Ants				—	—	—	—	—	—	—		
Caterpillars												
Cutworms	—	—					—	—				—
Lawn grubs			—	—	—	—	—	—				
Sod webworms						—	—					
Couchtip maggot			—	—	—	—	—	—				—
Couchgrass mite						—	—					
Couchgrass scale							—	—				
Crickets												
Black field cricket						—	—	—	—	—	—	
Mole cricket			—	—	—	—	—	—				
Ground pearls	—	—										—
Mealybugs	—	—	—	—	—	—	—	—	—	—	—	—
Felted grass coccid						—	—	—				
Flea beetles												
Flea beetles						—	—	—				
Couch flea beetle						—	—	—				
Scarab beetles												
African black beetle			—	—	—	—	—	—				
Black beetle						—	—	—				
Pasture cockchafers										—	—	—
Weevils												
Argentine stem weevil					—	—	—	—				
Billbug					—	—	—	—				
NON-PARASITIC DISEASES												
Algae and fungi												
Dry patch					—	—	—	—	—			
Fairy rings (fruiting bodies)								—	—	—		
Slime moulds					—	—			—	—		
Insects & allied pests												
Itch mites			—	—	—	—	—	—	—	—		
Springtails	—	—	—							—	—	—
Moss	—	—	—							—	—	—
WEEDS												
Annuals												
Broadleaved (capeweed)	—	—								—	—	—
Grasses (summer grass)					—	—	—	—	—	—		
(winter grass)	—	—									—	—
Perennials												
Broadleaved (oxalis)	—	—	—	—	—							—
Grasses (couchgrass)					—	—	—	—	—	—		

Vegetables

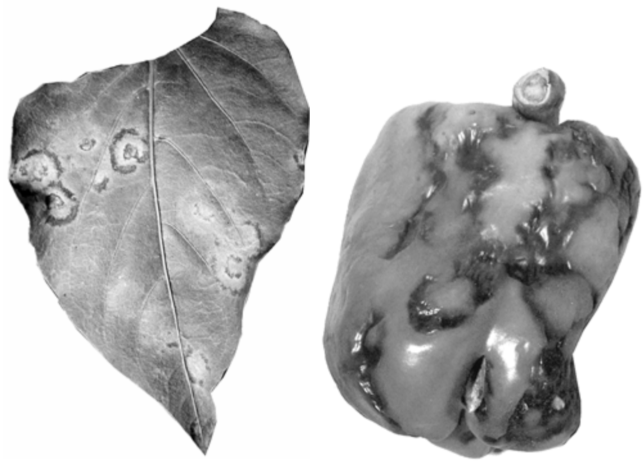


Fig. 291. Ringspotting on a capsicum leaf and fruit caused by tomato spotted wilt virus.

Fig. 292. Virus symptoms on sprouting potato tubers. ***Left :*** Healthy sprouts. ***Right :*** Spindly sprouts produced by virus-infected tuber.

Fig. 293. Halo blight of bean (*Pseudomonas phaseolicola*). Watersoaked spots with a pale border. Dept. of Agric., NSW.

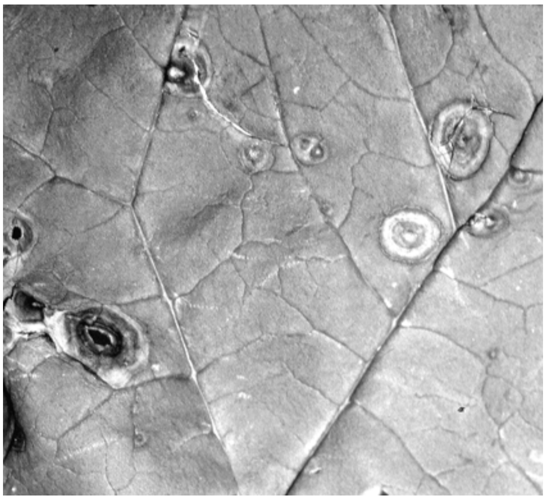


Fig. 294. Fungal leaf spot (*Ascochyta rhei*) on rhubarb.

VEGETABLES — M 1

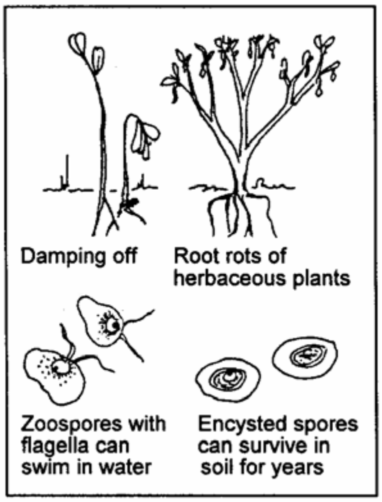
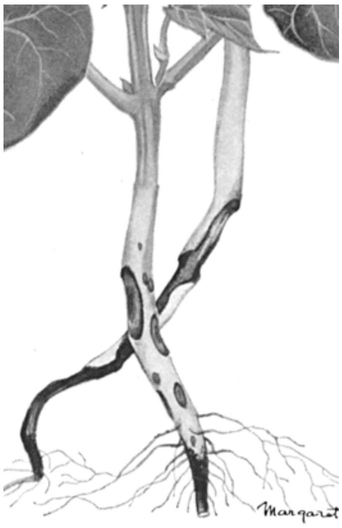


Fig. 295. Phytophthora root rot (*Phytophthora* spp.). Spores are microscopic.



Fig, 296. Rhizoctonia rot (*Rhizoctonia solani*) on French bean. Dept. of Agric., NSW.

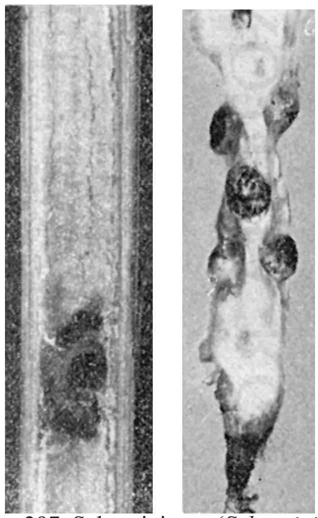


Fig. 297. Sclerotinia rot (*Sclerotinia sclerotiorum*). ***Left :*** Sclerotia on carrot. ***Right :*** Sclerotia inside dahlia stem. Dept. of Agric., NSW.

Fig. 298. Sclerotium stem rot (*Sclerotium rolfsii*). Sclerotia on stem. Dept. of Agric., NSW.

Fig. 299. Rust (*Uromyces appendiculatus*) on French bean. Dept. of Agric., NSW.

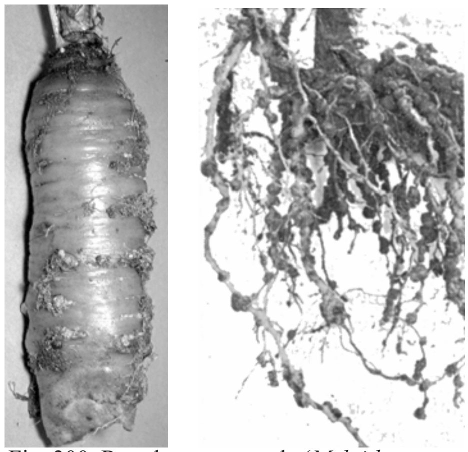


Fig. 300. Root knot nematode (*Meloidogyne* spp.) galls. ***Left :*** Carrot. ***Right :*** Tomato. Dept. of Agric., NSW.

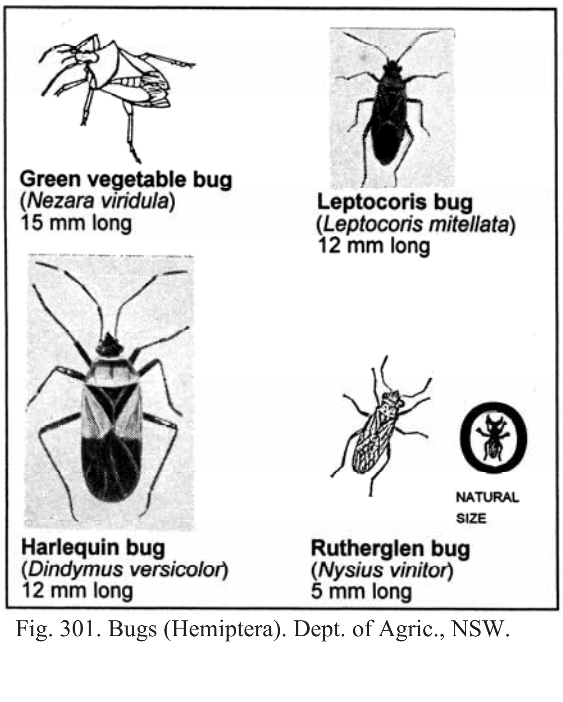


Fig. 301. Bugs (Hemiptera). Dept. of Agric., NSW.

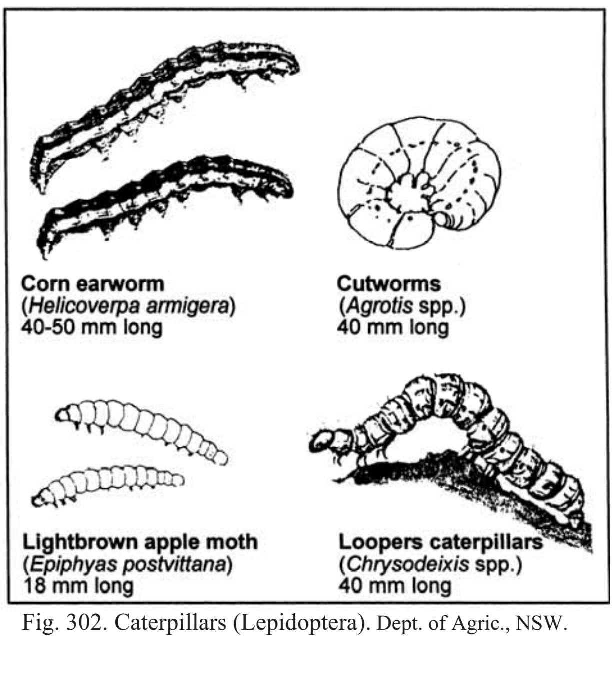


Fig. 302. Caterpillars (Lepidoptera). Dept. of Agric., NSW.

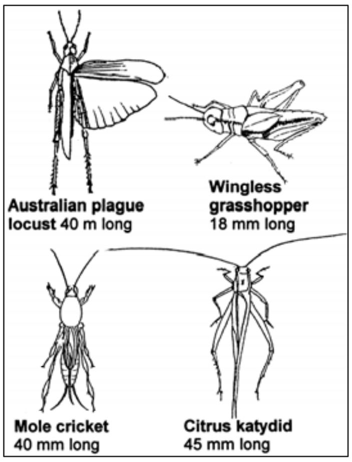


Fig. 303. Crickets, grasshoppers, locusts, katydids (Orthoptera).

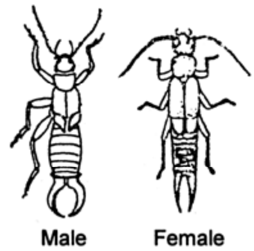


Fig. 304. European earwig (*Forficula auricularia*) up to 20 mm long.

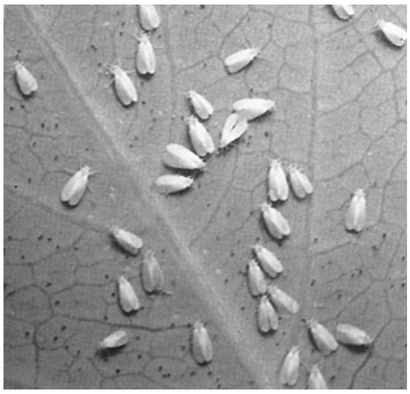


Fig. 305. Greenhouse whitefly (*Trialeurodes vaporariorum*).

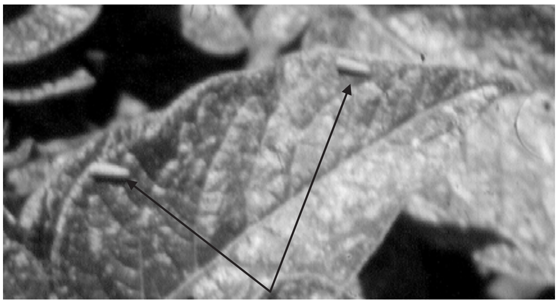


Fig. 306. Vegetable leafhoppers (*Austroasca viridigrisea*) on potato leaves.

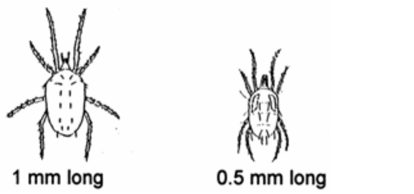


Fig. 307. ***Left :*** Redlegged earth mite (*Halotydeus destructor*). ***Right :*** Twospotted mite (*Tetranychus urticae*).

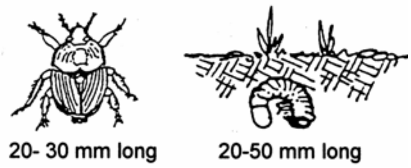


Fig. 308. Scarab beetle and larva (Scarabaeidae).

Fig. 310. Vegetable weevil (*Listroderes difficilis*).
1. Eggs. **2.** Larva. **3.** Pupa. **4.** weevil. All enlarged 5 times.
5. Earthen cell from which adult weevil has emerged.
6. Carrots damaged by larvae and adults. Actual size. Dept. of Agric., NSW.


Fig. 309. Onion thrips (*Thrips tabaci*) damage.


Fig. 311. Sunscald damage to capsicum.

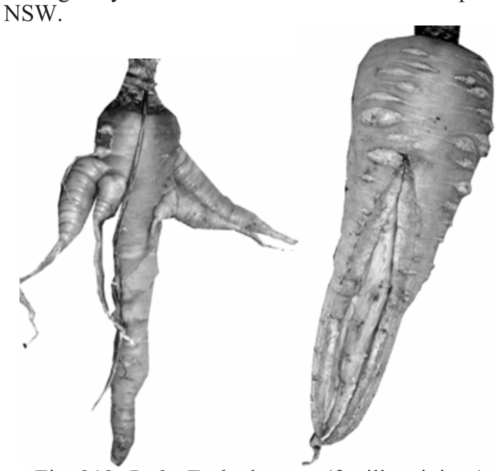


Fig. 312. ***Left :*** Forked carrot (fertiliser injury). ***Right :*** Split carrot (overmaturity).

Vegetables

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spots
  - Bacterial soft rots
  - Bacterial wilts
- **Fungal diseases**
  - Damping off
  - Downy mildews
  - Fruit rots
  - Fungal leaf spots
  - Grey mould, *Botrytis*
  - Powdery mildews
  - Root and crown rots
  - Rusts
  - Wilts
- **Nematode diseases**
  - Root knot nematodes
  - Root lesion nematodes
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Crickets, grasshoppers, katydids, locusts
  - European earwig
  - Flies
  - Greenhouse whitefly
  - Leafhoppers
  - Leafminer flies
  - Mites
  - Potato ladybirds
  - Scarab beetles
  - Thrips
  - Weevils
  - Wireworms, false wireworms
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities
- Overmaturity

WEEDS

*Vegetables are attacked by diseases and pests similar to those attacking **annuals**. There are minor variations.*

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Host range: Most vegetables are susceptible to at least one or several virus diseases. Some viruses attack only ***one species*** while others, eg cucumber mosaic virus and tomato spotted wilt virus, infect ***many species.*** Others, eg tobacco mosaic virus, may have ***different strains***, each of which has a different host range.

Symptoms vary with virus, cultivar, growth stage and temperature and usually appear one to several weeks after infection and may be more obvious during spring and autumn. ***Leaves*** develop mosaic patterns, pale yellow, green or brown ring-like markings (Fig. 291), blotches, and may be cupped and distorted. ***Stems*** may develop black streaks. ***Flowers and fruit*** may be affected (Figs. 291, 292). Virus diseases ***impair growth*** and ***quality*** but do not usually kill plants.

Overwintering: ***Infected hosts***, eg crops, older crops and weeds. Some may be ***seedborne***, or only seedborne on certain hosts. ***Others***, eg tobacco mosaic virus, overwinter in infected crop debris in soil, on the surface of seeds, and in natural leaf of manufactured tobacco, including cigarettes.

Spread: All viruses are spread by ***vegetative propagation*** and grafting from infected plants. Some by ***sap sucking insects,*** eg aphids, thrips, leafhoppers. More than 20% of virus diseases are ***seedborne*** but in a variable percentage. Some by ***mechanical transmission*** of plant sap by foliage contact, on hands, clothes and tools especially at picking time. By ***introduction*** of infected seedlings, plant material, and some by debris from infected plants.

Conditions favouring: Repeated vegetative propagation, weather favouring migration and buildup of insect vectors, proximity to weedy areas and older infected crops and other hosts. After hot dry weather, insect vectors migrate from drying weeds and other hosts where they breed and feed.

Control: ***Train staff*** in how viruses are spread. The aim is to prevent infection (there is no cure for plants once infected). ***Minimise losses*** by:

Cultural methods: A ***crop rotation*** of 2-3 years may be necessary for viruses which overwinter in plant debris, eg tobacco mosaic virus. Avoid growing vegetables close to infected crops or alternative hosts, eg weeds, perennial flowers.

Sanitation: Before planting seedbeds or crops, remove adjacent host weeds and volunteer crop plants which may harbour insect vectors. Deeply plough-in or destroy infected crops immediately after harvest, wait at least 3 months before replanting the same crop. For viruses spread during ***handling and on tools***, enforce ***strict hygiene***. Avoid unnecessary handling of plants, wash hands with hot soapy water before handling plants, handle healthy plants before handling infected plants. ***Disinfect tools*** with dilute household bleach (often diluted 1 part with 3 parts water but check label directions) and rinse between plants; have a number of implements soaking while one is being used. Regularly ***inspect crops***, remove and destroy suspect plants. See Nurseries N 51, N 53.

Resistant varieties: Grow ***resistant*** or ***tolerant*** cultivars if available, and where practical.

Plant quarantine: If possible, ***isolate seedbeds*** and crops from diseased or susceptible crops and other hosts that may harbour virus by a distance of at least 1 km.

Disease-free planting material: Plant ***virus-tested planting material*** (cuttings, certified seed, tubers) if available. Otherwise select and treat vegetative propagation material and seeds only from symptom-free plants. At ***transplanting*** discard all seedlings showing symptoms.

Physical and mechanical methods: Crops may be grown in ***fly-proofed*** greenhouses.

Pesticides: If virus diseases are a problem and are spread by insects, prevent re-infection of virus-tested stock and spread of virus within commercial seedbeds and plantings during spring/early summer. Spraying crops will not prevent disease from entering crops but will prevent spread within crops. In normal seasons when flights into crops are not large, insecticides may control disease. During dry, mild to warm conditions, when continuous aphid flights may occur, insecticides may be of limited value. ***Aphid and thrips management*** may be important for greenhouse crops.

BACTERIAL DISEASES

Bacterial leaf spots

Scientific name: *Pseudomonas*, *Xanthomonas.*

Host range: ***Vegetables***, eg bean, brassicas, cucurbits, tomato, ***ornamentals***, eg carnation, chrysanthemum, primrose, delphinium, viola, zinnia, ***fruit***, eg stone fruit, ***weeds***, eg nightshades. Many are host specific, eg *X. campestris* pv. *hederae* attacks ivy, others may attack a range of plants. There may be strains of bacteria.

Symptoms: Bacterial ***leaf*** spots may be water soaked, angular (Fig. 293) or circular and may enlarge rapidly on seedlings (fungal leaf spots tend to be obviously circular). ***Growing tips*** may die. Drops of bacteria may ooze from diseased tissue. Foliage of older plants is severely disfigured, plant vigour reduced. Microscopic examination or isolation is often required to ***confirm diagnosis***. ***Stems*** may be rotted and girdled.

Overwintering: Infected hosts including weeds, crop debris, soil (2-3 years or longer), seedborne.

Spread: By water splash from infected plants, wind-driven rain or irrigation, by movement of contaminated debris and soil. By vegetative propagation from infected plants, introduction of infected seed or plants. By movement of machinery, people and insects through crops wet from rain, irrigation or dew. By infected seed. Bacteria enter plants through natural openings.

Conditions favouring: Warm, humid or wet windy weather (exceptions), overcrowded conditions, wounding which facilitates entry of bacteria, prolonged wet weather.

Control: is difficult.

Cultural methods: Practise ***crop rotation*** to prevent buildup of inoculum. Prepare ground early to reduce undecomposed plant debris. ***Space plants*** well and avoid overhead irrigation to reduce humidity. Do not work in wet crops.

Sanitation: ***Remove and destroy*** infected leaves, stems (several centimetres below discoloured areas) or plants when observed. ***Plough-in*** or destroy crops immediately after harvest to reduce bacterial populations. ***Eliminate*** weed hosts where applicable. ***Sterilise*** secateurs.

Resistant varieties: Varieties differ in ***resistance***.

Disease-free planting material: Propagate only from ***disease-free plants*** and plant in leaf spot-free media. Seed may need to be treated. Produce disease-free seedlings in nurseries away from infected field crops.

Pesticides: ***Bactericides*** may provide some control only after diseased leaves and stems have been removed and cultural conditions improved. The only pesticides generally available for bacterial diseases are copper fungicides.

Bacterial soft rots

Scientific name: *Erwinia carotovora* pv. *carotovora,* also *E. carotovora* pv. *atroseptica* and *E. carotovora* pv. *chrysanthemi.*

Host range: Plants with soft succulent tissues and fleshy storage organs, ***vegetables***, eg cabbage, capsicum, carrot, celery, cucumber, lettuce, onion, potato, tomato, ***fruit***, eg banana, ***ornamentals***, eg iris, orchids. Soft rot bacteria are common and widespread in soil and may be part of the normal microflora of leaves.

Symptoms: Soft, watery, slimy and smelly brown rot of most fruits, tubers, fleshy roots, succulent buds and stems, no fungal growth. Flesh is rotted, so that skin may be left as a hollow shell containing an unpleasant-smelling liquid. Generally a ***postharvest*** disease, but plants in the ***field*** may also be affected, especially if wounds caused by other factors allow entry of bacteria as a secondary invader making diagnosis difficult.

Overwintering: Soil, soil water and infected crop debris in the field and storage. Volunteer host plants, eg potato tubers. Overseas also in insects.

Spread: By vegetative propagation, by introduction of infested soil, water and implements and by infected tubers. In the field spread by water splash, contaminated knives and insects. During transport and storage by contact, in bacterial ooze dripping from diseased leaves and in contaminated washing water.

Conditions favouring: As fruit near maturity in the field after prolonged warm, wet weather. Bacteria can enter through natural openings such as lenticels, but usually through cut surfaces and wounds caused during handling or after harvest, frost, or by other diseases or insects.

Control:

Cultural methods: Practise ***crop rotation***. Avoid overcrowding, shading, waterlogging. Ensure adequate drainage. ***Avoid planting*** in wet soil, over-irrigating and harvesting during wet and warm conditions. ***Avoid tuber injury*** during and after harvest. ***Store tubers*** in conditions favouring rapid healing of cut or injured tissue. Ensure that the surface of cut sets and other wounds has healed properly before planting. ***Harvest, cool, pack, transport*** and ***store*** at recommended temperatures and humidity in cool, well ventilated conditions. If produce is washed, change water frequently and properly disinfect to prevent contamination by bacteria. Dry, pack and consign to market promptly. Avoid soft growth caused by ***excessive fertiliser*** especially nitrogen or heavy watering.

Sanitation: ***Remove and destroy*** diseased parts of the plant. Treat cut surfaces with disinfectant. Discard affected vegetables and tubers before transport and storage.

Resistant varieties: Varieties vary in ***resistance***.

Disease-free planting material: Only plant ***certified bacteria-free*** planting material.

Pesticides: Dry material quickly after postharvest dips. Clean and ***disinfect*** harvesting implements, packing sheds and washing equipment. Disinfect tanks between washings.

Bacterial wilts

Scientific name: *Corynebacterium*, *Erwinia*, *Pseudomonas*, *Xanthomonas*. Strains may exist.

Host range: Mostly herbaceous plants, eg vegetables, field crops, tropical fruits and some ornamentals, eg ***bacterial canker and wilt of tomato*** (*C. michiganense* subsp. *michiganense*), ***moko disease*** of banana (*P. solanacearum*) and ***bacterial wilt of carnation*** (*P. caryophylli*). ***bacterial wilt of brassicas*** (*Xanthomonas campestris* pv. *campestris*).

Symptoms: Bacteria enter, multiply in and move through xylem vessels of the host interfering with the translocation of water and nutrients. Aboveground plant parts wilt and die. When stems are cut longitudinally in the initial stages of infection, ***vascular tissue*** is discoloured In this way bacterial wilts resemble ***fungal wilts***. Fungal wilts, however, remain almost exclusively in the vascular tissue while bacterial wilts spread to adjacent tissue, causing gumming and other symptoms. Bacteria may ***ooze*** from cut stems and other affected tissue.

Overwintering: Infected hosts, crop debris in soil for years, seed, tubers, vegetative propagation material, or very occasionally in an insect vector. Infected weeds and plants in older crops allow a buildup of populations, that can then infect young crops planted nearby.

Spread: Planting infected seed, seedlings, tubers or rootstock. Bacteria can spread rapidly through a crop by irrigation and rainwater, particularly down slopes, and by soil adhering to farm machinery, tools, shoes and animals. During handling, pruning, contact between plants, root contact, insect vectors, nematode-damaged roots, windblown dust from older infected crops, and from infected debris from diseased crops.

Conditions favouring: Warm moist weather and wounds that expose the vascular system, eg by nematodes. But once infected, plants wilt more readily under dry soil conditions. High soil moisture, poor drainage or after wet weather, but can also develop in relatively dry soil.

Control is difficult.

Cultural methods: Practise ***crop rotations*** of 3-4 years with non-susceptible crops. Prevent overcrowding of seedlings and keep seedling production areas free from susceptible weeds.

Sanitation: Avoid ***contaminating*** clean areas. Examine seedlings at transplanting, destroy diseased ones. ***Collect and destroy*** all diseased material as soon as observed to prevent disease spreading through crops and land becoming unduly contaminated. ***Plough-in*** deeply or destroy all crop residues immediately after harvest. ***Remove soil*** from machinery and other equipment before disinfecting. Cleaning down equipment with live steam may also be of value.

Resistant varieties: Varieties vary in ***resistance***.

Disease-free planting material: Plant ***bacteria-free*** seed or other propagation material in ***wilt-free soil***. Save seed only from healthy plants, treat seed of unknown origin in hot water. Dust after treatment to prevent damping off. Do not put seedbeds on land previously used to grow susceptible plants or sterilise soil before use.

Pesticides: Apply recommended ***bactericides*** to limit spread especially in seedbeds. Control ***insects*** which spread bacteria to healthy plants.

Others: ***Crown gall*** (*Agrobacterium*), various ***leaf spots*** and ***stem rots***.

FUNGAL DISEASES

Damping off (*Botrytis*, *Cylindrocladium*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia, Sclerotium*) is a common disease of ***seedlings***. Occasionally bacteria may be involved. Damage may be extensive and resowing necessary. ***Pre-emergence*** damping off occurs when seeds and seedlings rot before emerging. ***Post-emergence*** damping off (root, stem and top rot) occurs after plants have emerged from the soil. Seedlings emerge but yellow and die. When examined closely, rotted areas will be seen on young roots, stems or leaves. See Seedlings N 66.

Downy mildews (Peronosporaceae, Eumycetes) affects leaves, stems, petals and buds. Pale yellow lesions delineated by the veins develop on ***leaf uppersurfaces***. Lesions are more pronounced on ***leaf undersurfaces***, and during humid, cool conditions, a downy growth develops on these areas. As lesions dry out, leaves die, seedlings and plants may die if attacked early in the season. ***Stems, fruit*** and ***other aboveground parts*** may also be affected. See Annuals A 5.

Fruit rots

Alternaria rot (*Alternaria* sp.) affects rockmelon, tomato and other fruit and vegetables. Grey to black hyphae grow over affected surfaces. See Fruit F 6.

Anthracnose (various species) affects vegetables in the ***field*** and ***postharvest***. *Colletotrichum lindemuthianum* and *C. orbiculare*, affect cucurbits; *C. atramentarium* affects tomato; *Microdochium panattonianum* affects tomato, lettuce. Anthracnose causes sunken and watersoaked spots on ***leaves, stems*** and ***fruit***. Fruit spots may only appear ***postharvest*** during transport and storage on apparently healthy vegetables picked from a diseased crop. ***Pink spores*** develop on spots. See Fruit F 5.

Aspergillus black mould (*Aspergillus niger*) is a saprophyte and grows on organic matter and some vegetables, eg onion. Infection occurs in the ***field*** but is a major problem ***postharvest***. ***Black, powdery masses of spores*** develop on the surface of the outside scales and later between scales. Affected scales slowly shrivel and become brittle. See Fruit F 5.

Rhizopus soft rot (*Rhizopus stolonifer,* also *Rhizopus oryzae,* Eumycetes). A ***postharvest*** disease. A rapidly developing soft rot with coarse, ***open, black and white*** fungal growth. See Fruit F 6.

Sclerotinia rots (*Sclerotinia* spp.) may cause crop loss in the ***field*** and ***postharvest*** of beans, carrots and other vegetables (Fig. 297). See Vegetables M 7.

Others: ***Fusarium*** (*Fusarium* spp.), ***grey mould*** (*Botrytis* spp.), ***penicillium moulds*** (*Penicillium* spp.), ***rhizoctonia rot*** (*Rhizoctonia solani*), ***sour rot, yeasty rot*** (*Geotrichum candida*) (Beattie 1985, Beattie et al. 1989).

See Fruit F 5, Postharvest N 61.

Fungal leaf spots (various species)

Although the main symptoms are circular leaf spots (Fig. 294), spots may also develop on ***stems, flower stalks, seed bases, seed, curds*** and ***fruit***. Infected seedlings may ***die***. See Annuals A 5.

Grey mould (*Botrytis cinerea*), also

chocolate spot (*Botrytis fabae*) on beans. Grey mould can attack all plant parts. ***Seedlings*** may suffer from ***damping off***. ***Fruit*** and ***pods*** of cucumbers, capsicum, French bean and tomato, ***stems and leaves*** of lettuce and ***necks*** of onions in ***storage*** may rot. Under some conditions a ***grey-brown powdery growth*** with a crust of hard black resting bodies ***(sclerotia)*** may develop. Plants die if stems are rotted, or become stunted if stems are only damaged on the outside. See Fruit F 5, Greenhouses N 22.

Powdery mildews (Erysiphales,

Ascomycetes) may affect ***all above ground parts*** (leaves, stems, petals, buds, seed pods). The first sign of disease is usually the appearance of small white circular patches on stems and leaves. These increase in size, often running together to cover extensive areas of ***both upper and lower leaf surfaces***, which become powdery or mealy due to the production of masses of spores. In later stages of infection leaves may die. See Annuals A 6.

Root and crown rots

Scientific name: Various species of fungi from a range of fungal groups, occasionally by bacteria.

Host range: Many have a wide host range and can colonise plant debris and undecomposed plant material. Some, eg *Fusarium,* tend to be host specific while others, eg *Phytophthora*, *Sclerotinia* and *Sclerotium,* have wide host ranges. Many may also cause ***damping off***. See Seedlings N 66.

Symptoms: It is often ***difficult to identify*** the fungus causing the problem. For a positive diagnosis, the fungus should be isolated by a pathologist. Growers may purchase ***diagnostic kits***. ***Patches*** of diseased plants, which, if susceptible crops are repeatedly grown, increase in size each year. ***Young and old plants*** may be attacked; root or basal stem tissue rots, plants yellow, wilt and die. Symptoms of many soilborne fungal diseases are ***non-specific***, rather like nutrient deficiencies, waterlogging or water stress; they vary on different crops and even on the same host depending on the stage of growth at which the plant became infected. Plants may slowly die over a short or long period. If seedborne, disease may occur in seedling nurseries.

Aphanomyces root rot, black root rot (*Aphanomyces cochlioides*) causes a browning or blackening of the ***tap root*** of young plants, eg beet. *Aphanomyces* forms ***zoospores*** which can swim in water and soilborne ***resting oospores***. Infection and disease is ***favoured*** by warm weather and high soil moisture, poorly drained areas. Provide good seedbed tilth and drainage, plant into raised seedbeds.

Ashy stem blight, charcoal rot (*Macrophomina phaseolina,* Ascomycetes) affects bean, rape, pea and other plants. A pale, ***ash-coloured***, dry rot of the ***stem*** and small black dots develop in the dead areas. Plants soon ***die***.

Fusarium root and stem rots (*Fusarium solani* f.spp.) may attack a wide range of vegetables, eg *Fusarium solani* f.sp. *phaseoli* attacks beans. ***Stems*** of young plants rot, later plants turn yellow, wilt and die. ***Pink spore masses*** form on rotted tissue. Some species are weak pathogens and only invade ***roots*** of weakened or damaged plants. Some species or strains only infect particular vegetables causing severe root rots or wilt diseases. ***Favoured*** by warm, dry conditions, but may vary with the form species, compacted soil. See Vegetables M 9.

Phytophthora root rot (*Phytophthora* spp.) causes plants (often young plants) to yellow, wilt and eventually die. A wet rot of ***roots*** and ***stems*** develops causing a browning of the water-conducting tissues, roots are dead and decayed (Fig. 295). Rotting may progress up into the stem (this may also be caused by waterlogging and other fungal diseases). Fibrous roots rot first, the rot then spreads to the larger roots and stem bases. ***Secondary bacteria*** may invade some plants, eg rhubarb, causing affected stalks to decay rapidly. ***Others:*** *P. nicotianae* pv. *parasiticae* affects rhubarb, *P. megasperma* affects brassicas. See Trees K 6.

Pythium stem rot (*Pythium* spp.) is a common soil inhabitant and causes a black, wet rot of tissues that spreads up ***stems*** to leaf petioles and blades. ***Roots*** may rot. Spores swim in ***free water*** in wet soils. Pod infection causes a rapidly developing transit rot.

Rhizoctonia root or stem rot, black scurf, bottom rot, brown patch, crater rot, damping off, rhizoctonia seed rots, web blight on azalea, wirestem (*Rhizoctonia solani*, Imperfect Fungi) is a normal component of the soil microflora which colonises organic matter in soil. It affects most ***annual and perennial herbaceous plants, turfgrasses and weeds***. Strains of *R. solani* occur, the exact host range for each strain is not known. Some may attack a wide range of vegetables, others may have a restricted host range. Plants can be attacked at any stage of growth and symptoms vary with the growth stage and with the host. ***Damping off*** may occur causing seed, seedling and cutting rots and wirestem, seedlings die. ***Stem rots, stem cankers*** and ***collar rots*** develop on older more mature plants (Fig. 296). Infection occurs directly from fungal strands in the soil which gain entry through injury. Soil particles adhere to damaged tissues and are held together by fungal threads (white, cream initially, brown with age). Dry, light brown rot constricts the stem at ground level, plants wilt and die. Sunken cankers develop at the stem base, stems brown upwards from the decayed section. Root systems only decay after the plant is dead. ***Storage organs***, eg tubers, tap roots, may become misshapen, sunken cankers may develop on swede, turnip and radish roots and develop into root rots on which black irregularly resting bodies ***(sclerotia)*** of the fungus often form on the surface. ***Fruit***, eg pods, in contact with soil, may be attacked. A ***postharvest*** (transport and storage) rot with off-white fungal growth can develop. Secondary rots often follow.

Sclerotinia rots, cottony rot, drop, pink rot, white moulds (*Sclerotinia sclerotiorum, S. minor*, Ascomycetes) affect ***herbaceous plants*** (not cereals, grasses, onions) including weeds, and grows on plant debris. Occurs in the ***field*** and ***postharvest***. Greatest losses usually occur when plants are nearing maturity. A soft brown watery rot develops on ***stems, leaves*** and ***fruit*** near ground level in the field. Foliage may wilt and yellow, plants may die. Under humid conditions rotted areas are covered with white cottony mycelium in which irregularly shaped hard black resting bodies ***(sclerotia)*** up to about ***12 mm*** long develop (Fig. 297). They may also develop in pith cavities. Sclerotia of *S. minor* are smaller. Mycelium may grow from vegetable to vegetable during ***storage (nesting)***. See Postharvest N 63 (Fig. 429). Drying and rewetting of the soil surface stimulates sclerotia to produce mycelium which can infect plants at ground level up to 0.5 m away. During moist weather sclerotia in the top 50 mm 'germinate' to form small, light brown, cup-like fruiting bodies ***(apothecia)*** which discharge spores spread by wind and air currents to infect ageing plant parts, eg old flowers and leaves on nearby plants.

Sclerotium stem rot, southern blight (*Sclerotium rolfsii,* Imperfect Fungi) affects herbaceous and woody plants, turf, weeds and usually rots lower stems, roots and crowns of ***more mature plants*** at ground level. A white mat of fungal mycelium develops on ***stems*** at ground level and adjacent soil. White resting bodies ***(sclerotia)***, 1-2 mm across, are produced on the surface of the mycelium, these later turn brown and are hard to see (Fig. 298). A brown dry rot develops, the plant yellows, wilts and dies. The fungus may spread down into the ***roots*** and further up the ***stem***. Branches, leaves and fruit which touch the ***soil*** may also be attacked. ***No spores are produced.*** Sclerotia near the soil surface are stimulated by drying and rewetting of soil and the presence of susceptible plants nearby to produce hyphae which infect host plants through injury. Due to irregularity of soil conditions even in a small area, only some plants in an affected area are attacked. Nearly all plants attacked are ***killed***.

Thielaviopsis black root rot (*Thielaviopsis basicola*) causes a ***root rot*** and ***damping off*** of many herbaceous plants, eg vegetables and weeds. Plants may be affected both in the ***nursery*** and in the ***field***. Generally first appears on ***roots*** as watersoaked areas that later turn black. Eventually the whole root is affected. Plants grow poorly or die. In extreme cases root systems are reduced to stubs. The fungus lives, grows and multiplies in the soil, usually in association with dead organic matter, high soil moisture and high relative humidity in the air.

Others: Some other root rots mainly attack woody plants rather than herbaceous plants, eg ***armillaria root rot*** (*Armillaria* sp.). See Trees K 4. ***Rosellinia root rot*** (*Rosellinia necatrix*) attacks pome fruits and other trees. See Pome fruits F 110.

Overwintering: In crop debris, in soil, in perennial hosts and infected propagation material, eg bulbs, tubers, seed. *Rhizoctonia, Sclerotinia* and *Sclerotium* produce ***sclerotia*** which accumulate in soil where infected crops have been grown. Sclerotia may become mixed with seed on some hosts. *Fusarium* and *Phytophthora* form ***resistant spores***, eg chlamydospores. Some survive in the soil for years.

Spread: By flood, surface drainage or irrigation water, in soil adhering to tools, machinery, implements, footwear, tubers, in containers and soil deliveries. By the introduction of infected plants, propagation material, eg bulbs, tubers, seed, plants, transplant seedlings, infected vegetables and fruits. In some hosts as ***sclerotia*** (*Rhizoctonia*, *Sclerotinia*, *Sclerotium*) mixed with seed or compost. By ***spores*** (*Phytophthora, Pythium*) which swim or are washed or windblown to new sites. By ***spores*** (*Fusarium*, *Sclerotinia)* spread by wind or water splash. By ***mycelium*** (*Rhizoctonia, Sclerotinia, Sclerotium*) growing through the soil to new hosts or from vegetable to vegetable ***postharvest*** (nesting).

Conditions favouring: Continual cropping with the same susceptible crop, unfavourable growing conditions for the host. ***Fusarium*** is favoured by warm, dry conditions, stress and compacted soil. ***Phytophthora*** and ***Pythium*** by low soil temperatures (some strains prefer high temperatures), wet heavy soil, poor drainage, prolonged wet weather, balled roots. ***Rhizoctonia*** by cool moderately wet soils, tissue injury, planting of transplants too deeply, soil with high organic levels, eg recently cultivated pasture. ***Sclerotinia*** is most active in cool wet weather during late autumn, winter and spring. The optimum temperature is about 25^{o}C (warm soil conditions of 24-28^{o}C). Favoured by high soil moisture, sandy soils, poor ventilation in dense plantings. ***Sclerotium*** by high soil temperatures during late spring, summer and early autumn, fluctuating soil moisture, abundant undecayed organic matter on which it can grow and produce more sclerotia, relatively dry conditions following rain or irrigation, soil low in nitrogen, well aerated sandy soils, acid soils, organic matter in contact with bark tissue, planting too deeply or injury at soil level, subtropical and tropical areas (26-32^{o}C).

Control is ***difficult*** because of their wide host range, and the ability of sclerotia and resistant spores to survive for many years in soil and of the fungal mycelium to grow on decaying plant debris. It is difficult to treat affected plants so the aim is to prevent infection and spread. ***To minimise losses*** from soilborne diseases:

Cultural methods: Practise ***crop rotation*** (3-4 years) with unrelated crops, avoid planting areas with a history of infestation with one susceptible crop after another. Avoid planting winter crops in areas where ***Sclerotinia*** has been a problem and planting summer crops where ***Sclerotium*** has been a problem. Avoid planting crops susceptible to ***Rhizoctonia*** in old pasture. Maintain ***optimum plant growth***. Ensure plant residues in soil are completely broken down. Avoid planting too deeply, injury, poor aeration and drainage, excessive applications of nitrogen. ***Fusarium:*** Avoid compacted soil, and stress caused by low soil temperature, intermittent drought, excessive soil water, etc. ***Phytophthora*** and ***Pythium:*** Avoid over watering and provide good drainage, aeration and optimum conditions for plant growth. Avoid planting too deeply (plant crown just above soil level), plant/mulch contact, unnecessary root injury during transplanting and cultivation and excessive applications of nitrogen fertilisers. ***Rhizoctonia:*** Grow seedlings in soil-less mixes or in sterilised or pasteurised soil. Treat seed with recommended fungicide before planting, maintain optimum plant growth and avoid injuring plants as wounds provide a means of entry for the fungus. Where possible avoid soil contact with fruit by using black plastic or by staking plants. Ensure crop residues are thoroughly decomposed before planting an area. ***Sclerotinia:*** Space plants well to prevent excessive shading and poor ventilation. Regular cultivation eliminates host weeds, lowers humidity around plants and destroys fruiting bodies (apothecia) under the crop. Avoid wet shady areas and irrigation close to harvest. ***Sclerotium:*** Prepare ground early to ensure plant residues have decomposed before planting, deep plough to bury host debris and sclerotia. Include non-susceptible crops, eg maize and small grains, in rotations, drench transplants with recommended fungicides. Avoid planting too deeply, injury, or overcrowding of beds and shaded or poorly drained sites.

Sanitation: Deeply ***plough-in*** or destroy, diseased crops and debris immediately after harvest to prevent prolific production of sclerotia and resistant spores and to facilitate their breakdown by microorganisms. If ***sclerotia*** present in a crop are buried deeper than ***12-150 mm*** in moist soil they will not germinate and will ***die*** in about 7 weeks. In dry soil they can remain in a dormant state for many years and will germinate when brought to the soil surface. ***Remove and destroy*** obviously diseased plants (including the roots) when observed. ***Clean*** cultivation equipment, eg rotary hoes, before working new areas. Practice ***nursery hygiene*** in nurseries; disinfect benches, containers and tools to prevent contamination. ***Sclerotinia***: Do not add infected plants or vegetable matter to compost heaps. This can lead to prolific production of sclerotia that may later be distributed throughout an area. Do not feed infected plants to stock as some of the sclerotia will pass through the animal unharmed and spread the disease. Discard diseased, rotting or damaged roots/pods when packing for market. Destroy infected seedlings.

Biological control: Biological control is not yet a practical reality for controlling root rotting fungi, eg *Phytophthora* or *Rhizoctonia* in field crops. It is likely though that ***damping off diseases*** caused by these fungi may be biologically controlled within a several years (Table 7, Greenhouses N 31). ***Rhizoctonia stem rot*** (*Rhizoctonia solani*) can be controlled biologically overseas (Cartwright and Benson 1995)

Resistant varieties: Resistance varies depending on the host and the fungus. All commercially grown cultivars of potato in NSW are ***susceptible*** to *Rhizoctonia solani*. All tomato cultivars are ***susceptible*** to *Sclerotinia*. Some lettuce varieties are ***resistant*** to *Thielaviopsis basicola*.

Plant quarantine: Avoid ***introducing*** infected seed, plants or contaminated soil into disease-free nurseries, greenhouses or crop sites. Isolate new plants.

Disease-free planting material: ***Plant certified disease-tested*** seed, seedlings, cuttings, tubers or other planting stock into ***disease-free seedbeds or soil***. Alternatively select seed, tubers, etc, from only disease-free crops. Treat seed or tubers from infected crops with hot water or systemic chemicals. Examine seedlings at transplanting, destroy diseased ones. If a crop is grown repeatedly in the same area, ***Rhizoctonia*** may become adapted to the host and cause increased losses. Buy from reputable suppliers.

Physical and mechanical methods/Pesticides: ***Seed treatments:*** Seed may need to be treated with hot water or with fungicide, eg thiram. ***Soil treatments:*** Soil-less mixes and some purchased mixes are guaranteed free from disease. ***Pre-plant treatments*** include soil pasteurisation (for small areas like seedbeds), soil solarisation (in warm climates and for some soil diseases only), fumigants and fungicides (for pots and cutting beds). ***Post-plant treatments*** for *Phytophthora*, *Sclerotinia*, include fungicides, at transplanting around seedlings, as soil drenches or granules, as regular preventative treatments, or at first signs of infection. ***Resistance*** may develop and most fungicides are ***suppressive*** only, so disease may be suppressed in the nursery but flare up later. Some Nursery Accreditation Schemes prohibit their use. ***Foliage treatments:*** Foliage, crown or collars of *Sclerotinia*-susceptible plants during the latter stages of crop growth may need to be sprayed. If weather is wet or disease is known to be well established in the area. it may be necessary to spray young crops. Field spraying is often uneconomic. ***Post-harvest treatments:*** Where there is a risk of nesting, pack only healthy fruit, pods and roots after dipping them in fungicide and draining before packing for market to reduce spread during transit.

Rusts (Uredinales) attacks leaves, stems and stalks. ***Leaf uppersurfaces*** become speckled with small yellow patches which often run together. On the ***undersurface*** there are corresponding dusty orange or rusty-brown pustules or blisters containing spores (Fig. 299). When infection is heavy there may be premature and repeated ***leaf fall*** which weakens the plant. Severely infected plants look unsightly. If ***stems*** or ***stalks*** are girdled by the rust lesions, the above plant parts will die. See Annuals A 7.

Wilts

Scientific name: Imperfect Fungi:
Fusarium wilt (*Fusarium oxysporum* f. spp.)
Verticillium wilt (*Verticillium dahliae*)

Host range: ***Fusarium wilt:*** Mainly ***annual*** and ***herbaceous perennial plants***. There are usually races or forms, eg *Fusarium oxysporum* f. sp. *lycopersici* attacks tomato (Solanaceae) while *F. oxysporum* f.sp. *dianthi* attacks carnation. ***Verticillium wilt:*** Wide host range. ***Fruit***, eg apricot, strawberry, ***ornamentals***, eg carnation, ***vegetables***, eg potato, tomato, ***vegetables rarely infected*** include asparagus, beans, most brassicas, celery, garlic, onion, peas, corn, cereals and grasses; ***weeds***, eg mintweed, Noogoora burr. ***Both wilt fungi*** grow on organic matter and both may infect some plants, eg carnation, chrysanthemum.

Symptoms: Wilt fungi enter roots and invade the water-conducting tissue (sapwood) preventing translocation of nutrients and water within the plant, causing wilting, yellowing and browning of leaves, starting at the bottom of the plant but gradually working upwards. Whole plants may wilt and ***die***. There are no external markings on the stem. If stems are split longitudinally, ***water-conducting tissues*** are brown. When stem is cut across, sapwood appears as a black or brown ring. Symptoms caused by both wilt fungi are similar and on those hosts affected by both the two diseases can only be identified by ***laboratory tests.*** Young plants may show a one-sided yellowing and wilt on one side during warm days when plants are under water stress. Branches of older plants wilt and die one at a time, finally plants die. ***Verticillium*** is uncommon on trees and is only economic in young trees 3-6 years old.

Overwintering: Once introduced to soil both wilts become established forever, even in the absence of host plants. Infected perennial host plants, propagation material, tubers and bulbs in the ground and in storage, weeds, infected crop debris, compost, sometimes seed. ***Verticillium*** also as microsclerotia. ***Fusarium*** also as chlamydospores.

Spread: Soil becomes contaminated by the ***introduction*** of infected cuttings, corms, tubers or seedlings, or contaminated soil on tools, machinery, footwear, and in containers, or contaminated compost and soil water. By ***vegetative propagation*** or ***seeds*** from symptomless infected plants. Root contact within a crop (minor). Healthy plants become infected by ***planting in infected soil*** or close to infected plants. ***Spores*** are spread by wind, soil or drainage water.

Conditions favouring: ***Fusarium*** by high soil temperatures (optimum 28^{o}C). ***Verticillium*** by low soil temperatures (optimum 20^{o}C), winter, good growing conditions, excessive nitrogen applications and waterlogged conditions. ***Both*** are favoured by injury to roots by nematodes and cultivation, and by continual cropping with susceptible crops.

Control: There is no cure for infected plants. The aim is to ***prevent infection***.

Cultural methods: Avoid planting susceptible crops in ***contaminated sites*** unless soil has been pre-plant treated. Practise ***crop rotations*** of 3-5 years where disease has occurred to reduce inoculum levels. Prepare ground early to reduce undecomposed plant debris. ***Control weed hosts***. Avoid poorly drained sites where surface run-off from diseased crops can contaminate soil. ***Fusarium:*** Avoid using hormone preparations or excess nitrogenous fertilisers.

Sanitation: ***Destroy*** diseased crops immediately after harvest to reduce inoculum. Do not compost debris or roots. Do not ***spread*** fungus around when moving infected plants, vehicles and other machinery. Ensure ***strict hygiene*** in propagation areas.

Biological control: Overseas, *Streptomyces griseoviridis* (Mycostop®), which secretes an antibiotic and inhibits seed and soilborne diseases, eg *Fusarium* wilt of carnation (*F. oxysporum* f.sp. *dianthi*), is available. Saprophytic ***Fusarium soil isolates*** are antagonistic to *Fusarium* wilt of carnation. Neither are available in Australia.

Resistant varieties: This is often the only ***practical means of control***. Where wilts are a problem, plant resistant or tolerant cultivars or rootstocks, eg passionfruit and tomato grafted on to *Fusarium*-resistant ***seedling rootstocks***.

Plant quarantine: Avoid spread of wilt fungi in water or soil. Isolate new purchases. If wilt disease appears, plants can be destroyed and the area taken out of cultivation.

Disease-free planting material: Plant ***certified wilt-free plants***, eg tissue cultured plants, nursery stock, otherwise propagate only from healthy plants, from beds that are wilt-free and not adjacent to diseased plants. Plant in ***wilt-free*** soil or soils not previously cropped with susceptible crops (and weeds), or intercropping with susceptible crops, eg tomato. Control weeds between plants. Susceptible species should not be planted in contaminated soil unless soil has been treated. Soil, media, sawdust, peanut shells, sand, stone chips in contact with ***soil*** are likely to be ***contaminated*** with *Fusarium*. Suspect seed should be treated with hot water.

Physical and mechanical methods: ***Pasteurise soil*** for seed or cutting beds. Plants may be grown in containers, if disease occurs, whole containers can be destroyed and spread prevented.

Pesticides: Pre-plant soil fumigation has only been practical and profitable for high value susceptible crops in small areas, eg seedbeds and greenhouses with a history of wilt diseases. Infected plants are carefully removed before treatment. However, ***methyl bromide*** is to be deregistered, but less hazardous products may become available.

NEMATODE DISEASES

Root knot nematodes

Scientific name: *Meloidogyne* spp. (Nematoda).

Host range: Especially broadleaved plants, ***ornamentals***, eg dahlia, ***vegetables***, eg potato, ***fruit***, eg strawberry, ***field crops*** and ***weeds***. Grasses are less susceptible. There are many races.

Symptoms: Seedlings are often infected. Plant symptoms are ***non-specific*** but include stunting, yellowing, wilting in hot weather and death due to disruption of water and nutrient uptake and transport. Yields are reduced. Galls up to 25 mm across develop on main and lateral ***roots*** or ***tubers*** (Fig. 300). The whole root system may be stunted. If ***galls*** are cut open, glistening female microscopic worm-like nematodes about 0.5 mm long are found. The feeding of the nematode stimulates root tissue to produce galls. Infected plants are ***more susceptible*** to water stress, bacterial and fungal root rots and vascular wilts. Once plants have a strong root system they can usually withstand infestation. Prevent nematode damage early in the life of a crop. High numbers of nematodes need to be present in soil before significant damage occurs. Soil may be ***analysed*** for nematode numbers.

Pest cycle: There are many generations each year. Mature females in galls lay hundreds of eggs on the root surface which hatch in warm soil. Juveniles hatch from eggs, move through the soil and invade roots near the tip where they develop into females (less commonly into males).

Overwintering: Infected perennial hosts, root debris, soil. Infected volunteer plants, eg potato tubers and other plants, and infected seedlings of other species. Nematode populations may decline rapidly under fallow or non-host cover, ***eradication*** is not achieved because a few nematodes usually survive on old roots remaining in the soil.

Spread: Introduction of infected seedlings, nursery stock, tubers, contaminated soil on machinery, tools, footwear, containers, drainage and running water, animals. Natural spread by nematodes moving through soil is only a few centimetres each year. By propagation from infected plants. Run off from infected crops.

Conditions favouring: Light, well drained, sandy soils, warm weather. and repeated cropping with susceptible crops. Inactive during cooler months when soil temperatures are low.

Control is ***difficult***. The race of nematode present should be ***identified*** by laboratory tests.

Cultural methods: Avoid contaminated soil. ***Rotate crops***. Only a few crops, eg cabbages, cauliflowers, maize, sweetcorn, onion, cereals and garlic are ***resistant***. Fallowing for 1 growing season will reduce populations providing the area is kept free of weeds and cultivated after rain (repeated cultivation kills nematodes in the upper soil layers by exposing them to the mechanical abrasion and the heating and drying action of the sun). In warm moist soils a ***4-6 month*** fallow may reduce a nematode population by ***> 95%***,. Longer fallows are not normally economically feasible and soil is exposed to increased risks of erosion. ***To reduce*** the effects of infestation irrigate and fertilise appropriately.

Sanitation: ***Destroy*** diseased crops and debris (including roots) as soon as possible after harvest to reduce inoculum. Do not compost them. Ensure that irrigation or run off water from contaminated blocks does not ***contaminate*** nematode-free areas. Ensure ***strict hygiene*** in propagation areas. ***Remove*** and destroy/burn diseased plants, ***clean*** implements used in contaminated soils and manage water appropriately. Plants should be ***ploughed-in*** as soon as crops are harvested. Destroy weed hosts as soon as they germinate.

Biological control*:** ***Tagetes patula will reduce populations if grown for one season. Weeds must be controlled (Kerruish 1990, Kerruish and Unger 1991). ***Bacteria*** are parasitic on root knot nematodes but their natural spread is slow.

Resistant varieties: Use ***resistant varieties*** or varieties grafted on to ***resistant rootstock*** for effective control and to reduce populations. Varieties of tomato and sweet potato with some resistance to root knot nematodes have been used, they may not be resistant to all strains. Protect against common populations.

Plant quarantine: Do not ***introduce*** infected plant material, soil and manures to nematode-free crops. Do not ***transfer*** contaminated soil and seedlings to other areas.

Disease-free planting material: Propagate only from ***nematode-free plants*** and plant in ***root knot-free soil***. Do not introduce infected planting material, eg tubers. Use green-shoot cuttings. If ***seedlings*** are planted, it is essential that seedlings and potting mixes are nematode-free. Peat, and other components free of root knot, must not be contaminated before use.

Pesticides: ***Nematicides*** (non-fumigant) can be used as pre- or post-plant drenches. If management practices described above are used, nematicides should only be needed in the field when nematode damage is likely to be severe, eg tomatoes planted in sandy soil. Even where root knot is severe, ***good management*** can reduce population pressure so that nematicides have a better chance of effecting control.

Root lesion nematodes

Root lesion nematodes (*Pratylenchus* spp.) have a wide host range affecting ***ornamentals***, eg rose, ***fruit***, eg apple (causing a replant disease complex of young replanted trees), ***vegetables***, eg French bean, ***field crops***, eg wheat, ***weeds***. ***Root systems*** of affected trees are small and discoloured, and often grow in ***tufts*** and ***lack well developed feeder roots***. ***Lesions*** on mainly the feeder roots (often near root hairs) are tiny, elongate, watersoaked or yellow spots that soon turn brown/black. Lesions enlarge and may be invaded by ***secondary organisms***. All stages can move in and out of roots. They often spend their entire life migrating through the root system. Roots of nursery trees may be infected with nematodes from the rootstock stool beds or the nursery soils. They spread in the same way as root knot nematodes. ***Replant problems*** associated with these nematodes can be serious if hosts have been grown recently. See Pome fruits F 111.

Others:

Others: ***Beet nematode*** (*Heterodera schachtii*), ***stem and bulb nematode*** (*Ditylenchus dipsaci*).

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Cabbage aphid (*Brevicoryne brassicae*)
Cotton aphid, melon aphid (*Aphis gossypii*)
Carrot aphid (*Cavariella aegopodii*)
Cowpea aphid (*Aphis craccivora*)
Fennel aphid (*Dysaphis foeniculus*)
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum euphorbiae*
Sowthistle aphid (*Hyperomyzus lactucae*)

Host range: Most species have a wide host, some have a narrow host range, eg ***cabbage aphid*** (*B. brassicae*) mainly infests brassicas.

Description and damage: ***Aphids*** are soft-bodied insects about ***1-2 mm*** long which may be found on the undersides of leaves, around flower buds and on young shoots. They are of ***various colours*** (usually green), depending on the species and sometimes on the food plant. They may be ***winged or wingless*** and usually have a pair of ***cornicles*** on the upper surface of the posterior of the body. Aphids ***suck plant sap*** and, when numerous, ***leaves*** may dry up and curl, buds and flowers are distorted and the entire plant weakened. Most species secrete ***honeydew***, to which ants are attracted and on which sooty mould may grow. ***Nymphs*** are wingless and resemble adults in shape and colour. Many species ***transmit virus diseases.*** Interplanting with plants such as garlic which are ***reputed to repel aphids*** by their aroma may be useful in home gardens. Carrot crops ***sown*** after the middle of October have a good chance of escaping infestation. Provision of ***good irrigation*** and other growing conditions can offset, to some extent, injurious effects of aphids. The importance of the aphid pest problem in vegetables may depend on the ***frequency of arrival*** of migrant swarms. ***Monitor*** aphids and their ***parasites and predators***. Because aphids are sap sucking, ***systemic insecticides*** are used for control. Many contact insecticides are also effective but require more careful application. ***Contact insecticides*** will not stop viruses from entering a crop but may stop aphids breeding and transmitting viruses within a crop. ***Resistance*** to insecticides is present in the green peach aphid which can transmit > 100 virus diseases. See Roses J 4.

Bugs (Hemiptera)

Both introduced and native bugs may be pests, some introduced bugs are naturalised. Some only attack ***one species***, eg acacia spotting bug, eucalyptus tip bug, but many infest a ***wide range of plants***. Bugs suck sap from ***young tissues*** which eventually wilt and die. Some blemish ***fruit*** and other plant parts with excrement.

Green mirid bug (*Creontiades dilutus,* Miridae) is slender, active, pale yellow-green, about ***6 mm*** long and difficult to see. It feeds on ***vegetables***, eg carrot, French bean, potato, ***fruit***, eg passion vine, peach, nectarine, prune during late spring and summer. Wings are translucent and delicate, legs and antennae are long and slender. ***Nymphs*** suck the sap from ***terminal shoots*** which arrests plant growth. Growing points may wither and eventually fall out. Very small populations of these bugs may ***reduce yields*** in October-November after abnormally low night temperatures in September. Checks in plant growth caused by cold weather may make crops unusually susceptible to subsequent mirid damage. Eggs are laid in leaf stalks. A ***predatory bug*** (*Nabis capsiformis*) kills green mirids and is thought to be important in limiting their numbers.

Green stink bug (*Plautia affinis,* Pentatomidae) is a shield-shaped bug about ***8 mm*** long, green with brown wing covers. They look like green vegetable bugs but are smaller and give off an offensive odour when handled. They suck sap from French bean ***pods*** and other vegetables, eg silver beet, tomato, and grapevines. See Beans (French) M 28.

Green vegetable bug (*Nezara viridula,* Miridae) attacks a wide range of herbaceous plants and weeds. ***Adult bugs*** are shield-shaped, about ***15 mm*** long and usually green (Fig. 301). Overwintering adults become brownish purple during hibernation. ***Nymphs*** change in colour patterns as they develop with different combinations of green, black, yellow, orange, brown and red. All stages suck plant sap, preferably from ***fruit*** (tomato, bean pods) and ***seeds*** but also from ***young foliage*** (potatoes and cabbages). Bug damage usually occurs or threatens within a few weeks of harvest. There are ***several generations each year*** but often only one cycle within a crop. Yellow eggs are laid in rafts on leaf undersurfaces. ***Overwinters*** as adults which move into young crops. ***Favoured*** by late autumn weather when bugs migrate to crops from plants and weeds where they bred. ***Control:*** Eliminate weed hosts, from which bug populations can migrate to susceptible crops. Plough-in old crops. A ***black wasp*** (*Trissolcus basalis*) about 1 mm long lays an egg within the egg of the green vegetable bug, which turns black and within a week, a wasp emerges. This wasp generally controls the pest in coastal areas but is not so successful in drier inland areas.

Harlequin bug (*Dindymus versicolor,* Pyrrhocoridae) is a native, strikingly marked bug which may suck sap from ***young tissues*** of ornamentals, fruit trees, vegetables, weeds. They may also ***swarm*** on tree trunks, fence posts and the sides of sheds. ***Adults*** are about ***12 mm*** long; head, inner margins of forewings and wing tips are black; thorax and bases of the forewings are ***reddish orange***; body undersurface is yellowish green with red and black markings (Fig. 301). They hibernate in winter in these places or under the bark of trees. ***Nymphs*** are wingless and brighter than the adults.

Leptocoris bug (*Leptocoris mitellata,* Rhopalidae) infests exotic and native garden plants, fruit trees and vegetables, eg tomato. It is narrow, winged and about ***12 mm*** long and a general reddish brown (Fig. 301).

Metallic shield bug (*Scutiphora pedicellata,* Scutelleridae) may reach nuisance levels. ***Adults*** are up to ***10 mm*** long, shield-shaped and a ***deep metallic blue mottled*** with black and 2 bright red blotches on the thorax. They feed on the new tissue of many exotic and native garden plants, eg almond, fig, *Hibiscus tiliaceus*), melaleuca, tea-tree. Their feeding on fig may be followed by sap exudation.

Rutherglen bug (*Nysius vinitor,* Lygaeidae) is a small native bug which develops on many ***weeds***, eg capeweed, pigface, summer grass, capeweed, ***during winter***. When weeds dry off in ***spring*** bugs swarm on to ***succulent crops***, ***fruit***, eg citrus, grape, peach, ***vegetables***, eg bean, onion, potato, tomato, ***ornamentals***, eg brachycome, *Helichrysum*, *Helipterum*. ***Adult females*** are grey-brown, about ***5 mm*** long with 2 pairs of silvery wings (Fig. 301). ***Nymphs*** are similar to adults but are yellow initially, turning dark. They cannot fly so they suck sap from ***seeds*** of capeweed and other Asteraceae. Adults can fly up to 100 m and cluster on young ***shoots*** and ***fruit*** and suck sap, causing wilting and sometimes death of plants. Plants may look scorched. Seed production may be limited, and plants may be fouled with excreta. Females can lay up to 400 eggs, in groups of 5, in flower heads of weeds and debris. There are ***many generations each year***. The length of the life cycle, from egg to adult can be as short as 4 weeks. Adults ***overwinter*** in debris. All stages give off an ***acrid smell*** when disturbed or crushed, and may irritate pickers. ***Control*** by deep ploughing weeds if practicable during winter to get rid of overwintering adults. Plant alternative crops to prevent breeding. ***Grey cluster bug*** (*Nysius clevelandensis*) causes similar damage. See Stone fruits F 130.

Pest cycle: Gradual metamorphosis (egg. nymph, adult) with many generations each season.

Overwintering: Harlequin bug, green vegetable bug and Rutherglen bug, as adults.

Spread: By adults flying (they can fly considerable distances), nymphs do not usually crawl far from their food plants.

Conditions favouring: Good plant growth in winter and spring. If hot dry conditions occur in spring and early summer natural hosts (grasses and weeds) dry off or if they are ploughed in, these bugs swarm into crops.

Control varies depending on the species and the host. General recommendations include:

Sanitation: Bugs breed on ***weeds***, eliminate weed hosts. Turn in cover crops or crop debris early.

Biological control: Some bugs have been under a degree of ***biological control*** for years (see Green vegetable bug above).

Pesticides: ***Monitor*** bug populations (Brough et al. 1994). It is essential to know ***when they are likely to attack the crop***, eg green vegetable bug damages crops just before harvest. If direct control is necessary, a material of short residual life should be used because bug damage usually occurs or threatens to occur within a few weeks of harvest. Infested plants and surrounding weeds must be thoroughly sprayed. Weed and ground treatments may provide adequate control.

Caterpillars (Lepidoptera)

Host range: Some species, eg ***cabbage moth*** (*Plutella xylostella*), only attack brassicas, while others, eg ***cluster caterpillar*** (*Spodoptera litura*), ***leafroller moths*** (Tortricidae), attack a wide range of vegetables and other plants.

Description and damage: Caterpillars and their chewing damage, ie holes in leaves, are easily seen. Droppings may be found on plants or on the ground under the plants.

Noctuids (Noctuidae): ***Cluster caterpillar*** (*Spodoptera litura,* Noctuidae) mostly feeds on broadleaved plants, vegetables, fruit, field crops, weeds. ***Moths*** are thick-set greyish-brown and lay eggs on leaf undersurfaces in clusters usually of outer lower leaves. ***Caterpillars*** are up to ***40-50 mm*** long green to brownish purple with a row of dark triangular spots on each side of the body. Caterpillars ***feed during the day*** and only leave the plant when fully grown to pupate in soil. Young caterpillars ***skeletonise leaf undersurfaces***, older caterpillars are more solitary and feed on l***eaves, flowers*** and ***fruit***. It is not easy to distinguish damage from that of other caterpillars, except from the feeding pattern of young caterpillars. ***Corn earworm***, tomato grub (*Helicoverpa armigera*) and native budworm (*H. punctigera*) caterpillars are up to ***40-50 mm*** long, various coloured dark stripes running along their bodies (Fig. 302). Caterpillars feed on ***flowers, in fruit, pods*** and ***cobs*** and by boring into the heads of crops, eg cabbage and lettuce. Young tomatoes may be destroyed as soon as the caterpillar enters, or they may continue to grow with the developing caterpillar inside. Sweetcorn is usually damaged at the ends of the cobs. Older caterpillars enter bean pods and eat seeds. Young caterpillars may also damage buds, flowers and young leaves. See Sweetcorn M 89. ***Cutworms and armyworms*** (various species) shelter in soil (Fig. 302) under clods by day and cut through stems of vegetable ***seedlings*** at night so that they fall over and die. Older plants may be infested and be partially or completely defoliated. ***Favoured*** by planting crops in previously weedy land. See Seedlings N 68. ***Looper caterpillars*** (*Chrysodeixis* spp.) infest ornamentals, indoor plants, vegetables (especially bean and tomato), field crops, broadleaved weeds. ***Moths*** are dark brown with silver markings, stoutly built with a wingspan of 30-40 mm. They fly at dusk and are attracted to lights at night. Females lay their eggs on leaf undersurfaces. ***Caterpillars*** are green with white longitudinal stripes, move with a ***looping motion***, are up to ***30-40 mm*** long (Fig. 302), have a tapering shape and chew large holes in leaf undersurfaces, pods and fruit. Pellets of dark green excreta fall on lower leaves. Caterpillars ***pupate*** in white silken cocoons in folded leaves, or between webbed leaves attached to undersurfaces. Many generations each year. Overwinters in a loose silken cocoon attached to leaf undersurface. ***Favoured*** by mild, moist, cloudy weather, shady situations, especially in autumn.

Leafroller moths (Tortricidae), eg ***lightbrown apple moth*** (*Epiphyas postvittana*) and ***lucerne leafroller*** (*Merophyas divulsana*), have similar life histories and habits. ***Caterpillars*** are slender, green, about ***10-18 mm*** long with brown head capsule, and wriggle backwards when disturbed (Fig. 302). They live within webbed and rolled leaves and feed on foliage. Damage may occur in spring and autumn. See Pome fruits F 112.

Others: ***Cabbage-centre grub*** (*Hellula* spp.), ***cabbage cluster caterpillar*** (*Crocidolomia pavonana*), ***cabbage moth*** (*Plutella xylostella*), ***cabbage white butterfly*** (*Pieris rapae*), loopers (Geometridae), ***loopers*** (Geometridae), ***painted apple moth*** (*Teia anartoides*), ***woollybear caterpillar*** (*Spilosoma glatignyi*).

Caterpillars must be ***monitored***. See Annuals A 8, Brassicas M 39.

Crickets, grasshoppers, katydids, locusts (Orthoptera) may feed on seedlings and older plants, chewing ***leaves, flowers*** and ***growing points***, usually during summer. Plants may be chewed off at ground level. When they mature they can reach plague proportions. eating anything in their path. They seldom thrive in the usually moist environment of gardens.

Crickets: ***Black field cricket*** (*Teleogryllus commodus,* Gryllidae) are about ***25 mm*** long and black or brown. Nymphs and adults attack ***young plants*** of all sorts but particularly foliage and stalks of young plants of potato, tomato, turnip, swedes. Leaves and growing points may be eaten. Plants may be chewed off at ground level. They also chew ***fruit*** such as strawberries. They shelter under leaves and in soil cracks during the day and feed at night. See Turfgrasses L 9, Strawberry F 141. ***Mole crickets*** (*Gryllotalpa* spp., Gryllotalpidae) are about ***40 mm*** long (Fig. 303) and sometimes attack potatoes by surface-furrowing or boring holes in the ***tubers*** when the crop is nearly ready to dig. Occasionally damage occurs in small gardens but not in commercial crops. Control measures on potatoes are rarely needed. See Turfgrasses L 10.

Grasshoppers and locusts (Acrididae): ***Grass hoppers*** are generally solitary insects while ***locusts*** are gregarious and may gather in swarms. All species feed by chewing large lumps out of ***leaves*** usually leaving only the midrib. Locusts chew all plants in their way and may even chew ***green stems***. Solitary grasshoppers are not usually a problem but some grasshoppers may be, eg wingless grasshoppers. ***Australian plague locust*** (*Chortiocetes terminifera*) swarms are common in south eastern Australia. In some seasons, swarms may ***defoliate any plants*** in their path. They prefer trees lacking in vigour, such as those suffering from the effects of root rot or saline soil. ***Locusts*** are ***40 mm*** long from the front of the head to the tips of the folded wings and are dark brown, grey or green (Fig. 303). Forewings are mottled with dark spots or blotched and the transparent hindwings have a large black spot at the tip, shanks of the hind legs are scarlet. ***Overwinters*** as eggs in soil and as adults. ***Spread*** by flying and by wind. ***Favoured*** by moist springs (Kerruish and Unger 1991). ***Giant grasshopper*** (*Valanga irregularis)*, one of the world's largest grasshoppers, occurs in tropics and subtropics. In north-western areas of NSW it may damage ***foliage and fruit*** of citrus during autumn and winter. These insects are up to ***90 mm*** long in the adult stage, but may be difficult to see because of their green-brown colour as adults and pale green colour as nymphs. ***Spur-throated locust*** (*Austracris guttulosa*) may sometimes damage citrus foliage in the north-western areas in autumn and winter. The adult is up to 75 mm long, purple-brown and has a spur on the underside of the neck. ***Wingless grasshopper*** (*Phaulacridium vittatum*) is brown-grey, about ***18 mm*** long (Fig. 303). They generally move into crops (potato, pea, bean, strawberry) from adjoining pasture land when it dries out. They may soon penetrate deeply into the field, leaving a trail of devastation. They can strip the ***foliage*** and leave bare skeletons of plants. They breed up on good pasture which then dries off, leaving the hoppers without green feed. Often the insects have gone before the damage is recognised. Hoppers in the crop can be controlled by spraying. Treat borders around crop to reduce migration. ***Yellow-winged locust*** (*Gastrimargus musicus*) are up to ***50 mm*** long, and sometimes attack brassica crops on the tablelands and slopes in summer, reducing the plants to leafless stalks. The hindwings are bright yellow, and they make a clicking sound in flight. They create a great deal of damage in a short time. Control is difficult as the winged insects may continue to invade in moderate numbers. ***Others:*** ***Migratory locust*** (*Locusta migratoria*), ***small plague grasshopper*** (*Austoicetes cruciata*) (Woods et al. 1990).

Katydids, longhorned grasshoppers (Tettigoniidae) mainly damage ***fruit***. Some are not really pests, eg ***katydid*** (*Caedicia olivacea*) and ***green gum treehopper*** (*Torbia perficta*), which are common green species with flattened wing covers resembling a gum leave. Both species have slender antennae and are well camouflaged in the foliage. ***Mountain katydid*** (*Acripeza reticulata*), ***citrus katydid*** (*Caedicia strenua*) and ***inland katydid*** (*C. simplex*), damage ***leaves*** and ***young fruit*** of blackberry, citrus, stone fruits. ***Katydids*** are angular, flat-sided with long antennae and strong hind legs for jumping. ***Adults*** are green and about ***45 mm*** long (Fig. 303). Forewings are narrow and opaque, with a black band on the posterior edge. Hindwings are fan-like, transparent and pale green. Nymphs skeletonise young leaves and adults chew holes in older leaves, but damage is unimportant. Nymphs gnaw rind of ***young fruit*** causing disfigurement and fruit drop. Damaged older fruits remain on trees; as they grow, scars grey and flatten out. There is only 1 generation per year. Adults appear in early summer, females lay eggs on soil beneath trees in late summer, and in moss in tree forks of thickly-foliaged trees. ***Monitor*** damage to fruit prior to applying an insecticide (Brough et al. 1994).

Pest cycle: Gradual metamorphosis (egg, nymph, adult) with usually 1-2 generations per year depending on the species. Eggs are usually laid in the surface soil, but some may be laid in moss in tree forks and in other places.

Overwintering: As eggs.

Spread: By adults flying.

Conditions favouring: Different species are favoured by different conditions, eg Australian plague locust is favoured by widespread rainfall, it only swarms under certain conditions.

Control:

Sanitation: Hand picking katydids is often practical as soon as damage is observed.

Biological control: There are many ***natural controls***. ***Predators*** include birds (thought to be the most important natural predators), lizards, frogs, ants and bugs. ***Parasites*** include flies, nematodes and wasps (Kerruish and Unger 1991). Also possibly by a ***protozoa*** (*Nosema locystae*). Scientists have successfully developed a ***fungus*** (*Metarhizium flavoviride*) to kill the ***Australian plague locust*** and the ***wingless grasshopper*** in small-scale field trials. The fungus takes several days to work, so it needs to be applied when the insects are still in the juvenile stage. It shows good potential as an alternative to chemical control of locust and grasshopper pests (Jenkins 1994).

Pesticides: Plagues of the ***Australian plague locust*** in eastern Australia are monitored by the Australian Plague Locust Commission. State Departments of Agriculture coordinate and supervise control within their borders. Control by aerial and broadacre sprayng is difficult.

European earwig

Scientific name: Dermaptera:
European earwig (*Forficula auricularia*)

Host range: ***Vegetables***, eg lettuce, ***flowers***, eg dahlia, chrysanthemum, fuchsia, zinnia, ***fruit*** on trees, also ***foodstuffs***, eg sugar, flour, starch fat, meat, live and dead insects, mosses, lichens, algae also organic matter. They may invade houses.

Description and damage: Adults and nymphs are nocturnal, hiding during the day in vegetable rubbish, under bark and pots, in fruit clusters and flowers. ***Adults*** are about ***12 mm*** long, brown with a flattened body with pincers (cerci) at the end of the abdomen which are used for capturing prey and defence (Fig. 304). Pores on the back may eject an offensive fluid. Membranous hindwings are folded and almost concealed beneath wing covers. They seldom fly. ***Nymphs*** resemble adults in shape and colour but are wingless. ***Leaves, petals*** and ***fruit*** may be damaged by earwigs chewing and become ragged. They also feed on ***fallen fruit*** and ***seedling roots***. Plant appearance is spoiled by their presence and excrement, eg lettuce. Do not confuse plant damage caused by earwigs with that caused by caterpillars, beetles, locusts, or snails and slugs, or other pests.

Pest cycle: Their eggs are laid in small nests in soil. Females guard developing eggs and nymphs.

Overwintering: As adults in litter etc.

Spread: By nymphs and adults crawling (adults have wings but seldom fly), by movement of nursery stock, pot plants, bulbs or anything that might carry soil.

Conditions favouring: Cool, moist weather during spring and autumn. They are rarely troublesome during cold or hot weather. Heavy weed growth. They hide under plastic weed mats.

Control:

Sanitation: ***Remove*** rubbish, decaying plant material and other debris which provide shelter.

Biological control: Birds ***prey*** on earwigs. Flies and nematodes may ***parasitise*** them.

Physical and mechanical methods: Rolled newspapers or upturned flower pots filled with crumpled paper or corrugated cardboard left out at night, attract and provide ***shelter*** for earwigs. Inspect traps every few days and destroy earwigs. Indoors earwigs can be swept up and destroyed.

Pesticides: If earwigs are plentiful, apply 300 mm ***wide bands of insecticide*** to paths, fences and around the edges of garden beds. One thorough treatment should give control for one season. ***Baits*** can be prepared and scattered over the infested area particularly along paths, fences and around the edges of garden beds. Infested flowers may be sprayed with ***insecticide***, spray late in the day when bees are not working. The use of ***herbicides*** to control weeds should limit populations of earwigs.

Flies (Diptera)

Ferment flies (Drosophilidae) may infest ripe and over-ripe vegetables. See Fruit F 8.

Fruit flies (Tephritidae) may infest fruits of vegetables, eg tomato, before it is ripe. See Fruit F 9.

Onion maggot (*Delia platura*) is the larva of a small grey fly. ***Maggots*** are tapered, white, legless and about 7 mm long. They tunnel in the stems of ***seedlings*** of asparagus, beans, cucurbits, onions and sweetcorn below ground level, causing wilting and destruction. See Onion M 68.

Greenhouse whitefly

Greenhouse whitefly (*Trialeuroides vaporariorum*) is a small, delicate, white insect about 1.5 mm long (Fig. 305). Immature scale-like ***nymphs*** and ***adults*** are found on ***leaf undersurfaces***, where they suck plant sap causing a mottled speckled pattern on ***leaves***. Whiteflies secrete ***honeydew*** on which sooty mould may grow. Severe infestation can cause plants to lose vigour and wilt; however, there may be infestation but no damage. They are seldom a pest in field crops but can be in mild moist conditions such as in ***greenhouses*** and in protected situations with a humid atmosphere in summer and autumn. Leaf damage may be ***confused*** with that caused by leafhoppers, thrips and twospotted mites. See Greenhouses N 24, Trees K 24 (Table 3).

Leafhoppers

Scientific name: Cicadellidae, Hemiptera
Apple leafhopper (*Edwardsiana australis*)
Common brown leafhopper (*Orosius argentatus*)
Vegetable leafhopper (*Austroasca viridigrisea*)
Yellow jassid (*Erythoneura ix*)
Passionvine leafhopper (*Scolypopa australis,* Ricaniidae) is a planthopper which may damage vegetables.

Host range: Especially broadleaved plants but also grasses. ***Ornamentals***, eg dahlia, marigold, ***vegetables***, eg beans, carrots, celery, parsnip, potato, tomato, ***weeds*** and ***grasses***.

Description and damage: Leafhoppers range from very small to medium sized insects and are often very abundant. ***Adults*** are ***3-4 mm*** long, wedge-shaped, mobile insects (Fig. 306). ***Nymphs*** are a similar shape except they are smaller and wingless. Nymphs and adults suck sap mostly from ***leaf undersurfaces,*** causing a whitish speckled feeding pattern, each speckle is a feeding puncture (Fig. 306). Damage is usually only noticed after they have left the plant. Leaves may curl up at the edges and may die. If numerous, leafhoppers cause stunting of the crop. Both adults and nymphs have the characteristic habit of hopping sideways (crab-like) to avoid danger and will move to other leaves or plants if disturbed. Make sure that you can ***distinguish*** leafhopper injury from greenhouse thrips, greenhouse whitefly and twospotted mite injury. See Trees K 24 (Table 3).

Common brown leafhopper (*Orosius argentatus*) is a small brownish insect, about ***3 mm*** long, and the ***vector*** of serious virus diseases, eg tobacco yellow dwarf virus in bean, tomato big bud mycoplasma of tomato. See Beans (French) M 29.

Vegetable leafhopper, tomato leafhopper (*Austroasca viridigrisea*) is a small, yellow-green, torpedo-shaped, weak flying insect, about ***4 mm*** long with 2 pairs of wings. ***Fruit*** show faint whitish spots and small specks of jassid excreta scattered over surface. Females lay eggs within the tissues of the youngest parts of plants, eg in stems and leaf petioles. ***Favoured*** by warm, dry weather.

Pest cycle: Gradual metamorphosis (egg, nymph, adult) with many generations each season. They pass their whole life cycle on stems, leaves or grasses.

Overwintering: As eggs (apple leafhopper).

Spread: By adults flying. By the movement of infested seedlings and other plant parts carrying eggs.

Conditions favouring: In spring, summer and autumn when the leafhoppers migrate from drying herbage. They appear to be more prevalent in the drier inland districts and more common in crops when general conditions are warm and dry. Unirrigated crops are more susceptible to damage.

Control: Infestations are ***difficult to control***.

Cultural methods: ***Rain*** or irrigation will quickly remove established infestations of vegetable leafhopper and usually reduce the need for chemical control. Well watered crops seldom suffer direct damage.

Sanitation: Wherever possible likely sources of vegetable leafhopper infestation in old crops or ***susceptible weeds*** should be treated or avoided.

Pesticides: ***Insecticides*** are registered for use in spring and early autumn, but these will at the most reduce the amount of injury.

Leafminer flies (Agromyzidae, Diptera):

Maggots of several species may mine in leaves of vegetables disfiguring them.

Beet leafminer (*Liriomyza chenopodii*) maggots mine in the leaves of ***ornamentals***, eg wallflower, ***vegetables***, eg beetroot, silver beet, spinach, ***weeds***, eg chickweed. See Beet M 34.

Cabbage leafminer (*Liriomyza brassicae*) is a minor pest of ***brassicas***. If plants are growing in good conditions there is not much damage. See Brassicas M 39.

Cineraria leafminer (*Phytomyza syngenesiae*) maggots mine in the leaves of ***ornamentals***, eg chrysanthemum, cineraria, gazania, helichrysum, nasturtium, ***vegetables***, eg lettuce, ***weeds***, eg sow or milk thistle, cape weed, prickly lettuce. See Cineraria A 28.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) feeds on new growth of bean, silver beet and rhubarb, especially young inner ***leaves***, causing distortion during late summer and autumn in coastal areas and considerable reduction in vigour. ***Leaves*** and ***stalks*** become rusty or silvery-looking and distorted; the injury is sometimes similar to the effect of hormone herbicides, eg 2,4-D. See Greenhouses N 26.

Earth mites (Penthaleidae): ***Redlegged earth mite*** (*Halotydeus destructor*) is somewhat flattened, active, about ***1 mm*** long with velvety black, globular body and 8 red legs (Fig. 307). See Pea M 76 (Fig. 344). It mainly sucks sap from broadleaved plants, eg ornamentals, weeds, clover, pea and legumes. ***Blue oat mite, pea mite*** (*Penthaleus major*) is similar in appearance to the redlegged earth mite but has a red spot on the back towards the rear end and is less active. It attacks cereals, eg oats, grasses, clovers, ornamentals, vegetables, eg pea, brassicas, weeds. ***Both species:*** ***Nymphs and adults*** feed gregariously at night or in cloudy weather by day. ***Leaves*** become mottled, silvery, curled at edges and may wither and die. Seedlings may wither and die. Damage is often mistaken for frost injury. If disturbed while feeding mites will rapidly disperse. ***Pest cycle:*** Gradual metamorphosis (egg, nymph, adult) with many generations in the cooler months. Orange eggs are laid on leaves, stems or on the soil. ***Oversummers*** as unlaid eggs in dead bodies which protect the eggs. ***Spread*** by nymphs and adults crawling, eggs on the hooves of stock, in sheep manure, possibly on windblown leaves, machinery, clothes and movement of infested plants in containers. ***Favoured*** by cool weather during autumn, winter and spring especially if good autumn rains are followed by dry winter weather. Eggs hatch after the first autumn rains and may build up large populations. The combined effects of poor growing conditions, bordering weedy areas and mites feeding, can severely check crop growth. ***Control:*** Ensure crops are growing satisfactorily. Population numbers are strongly influenced by weather. ***Sanitation:*** Weeds with a rosette habit are important redlegged earth mite breeding sites. Destroy adjacent broadleaved weed hosts. A long weed-free fallow reduces mite numbers. Infested crops should be destroyed after harvest. ***Biological controls:*** Mites are attacked by predatory mites but natural controls are not reliable. ***Pesticides*** may be applied to crops and surrounding edges when infestation is observed. Mow or graze pasture before treatment.

Spider mites (Tetranychidae): ***Twospotted mite*** (*Tetranychus urticae*) and ***bean spider mite*** (*T. ludeni*) may attack vegetables, especially unirrigated crops in hot weather if they have been planted close to old spider mite-infested crops, eg French bean. ***Adult twospotted mites*** are up to ***0.5 mm*** long, globular, almost translucent, greenish with 2 large brownish spots on the abdomen, with 4 pairs of legs (Fig. 307). They produce webbing on which they crawl around and to which they attach their eggs. Mites suck plant sap causing speckling and mottling of ***leaves***. Mites and their eggs under fine webbing may be seen on leaf undersurfaces. Growth and cropping of plants may be retarded. Severely infested plants may ***die***. In severe cases, fruit may be attacked. Also ***vegetable spider mite*** (*T. neocaledonicus*). See Beans (French) M 29.

Potato ladybirds (*Epilachna* spp.) are oval, strongly convex and about ***6 mm*** long. ***Larvae*** are yellowish-green, up to ***6 mm*** long and covered with long, black branching spines on the upper surface of the body. Adults feed on ***leaf uppersurfaces***, often starting at the margin, while ***larvae*** generally feed on the ***undersurface***. Leaves are initially skeletonised but sometimes adults chew holes right through leaving only the veins. Severely skeletonised leaves wither. ***Fruit*** may also be damaged. ***Do not confuse*** leafeating ladybirds with predatory species. See Potato M 81.

Scarab beetles (Scarabaeidae, Coleoptera): ***Larvae*** are white, plump, soft-bodied grubs with hard, brown heads and strong jaws. They assume the shape of the letter ***'C'*** and are up to ***50 mm*** long (Fig. 308). They feed on ***vegetable matter*** in the soil and, in their later stages, mainly on the ***roots*** of grasses and other plants. Damaged plants wilt and are easily pulled from the soil.

African black beetle (*Heteronychus arator*) is about ***12 mm*** long, oval and shining black (Fig. 308). It chews ***stems*** and ***root crowns*** of ***young plants*** at ground level, causing sudden wilting and death. Injured stems of seedlings usually have a ragged teased out look. They also gouge holes in tubers and may be found in adjacent soil. ***Mature larvae*** attack ***grass roots***. In spring, beetles bore into ripening ***fruits and vegetables*** lying on the ground and hollow them out from underneath. ***Susceptible crops*** should not be planted where overwintering beetles may be expected in the soil, or near pastures of mat-forming grasses such as paspalum, carpet grass, kikuyu and buffalo in which the beetles have overwintered as adults. If such land is to be used, it should be cultivated a year earlier and kept free from mat-forming grasses and weeds. Preferably plant where land has been used for growing legume crops, eg bean, pea, cowpea, velvet bean, bean, soybean, which are ***not susceptible*** to black beetle. Alternatively use a long clean ***fallow*** which may be undesirable economically and environmentally. With vegetables, ***insecticides*** may be incorporated into the soil at planting. Young plants may be protected by jetting soil around them. If the plants are already being damaged, jetting around the stems with an insecticide, or scattering bait lightly through the crop has proved effective. Once brassica transplants are ***well established*** they are no longer in danger. Where infestation of land is suspected, treat with baits or sprays prior to planting. If beetles are moving in from nearby pasture land, a deep steep-sided furrow can be ploughed around the outside of the crop area and maize bait scatter in this (Hely et al. 1982). See Turfgrasses L 7.

White curl grubs (Scarabaeidae) may cause losses. Most common larvae are Christmas beetle (*Anoplognathus porosus*), pruinose scarab (*Sericesthis geminata*), dusky pasture scarab (*S. nigrolineata*), *Rhopaea magnicornis*, *Repsimus aeneus*. On strawberries, larvae eat off ***roots*** right up to the crown. Plants stop growing and if weather is dry, soon wilt and ***die***. Affected plants can easily be pulled from the ground. See Strawberry F 142.

See Eucalypts K 61, Trees K 16, Turfgrasses L 11.

Thrips

Thrips (Thripidae, Thysanoptera) are small, elongated, dark insects about ***1-1.5 mm*** long and can be ***easily seen*** with the naked eye. They feed by rasping and sucking plant surfaces. ***Nymphs*** are yellowish and wingless.

Onion thrips (*Thrips tabaci*) and ***tomato thrips*** (*Frankliniella schultzei*) mainly feed on ***leaves*** which become silvery (Fig. 309). Onion thrips may also damage ***flowers*** causing them to drop. Plants may ***die***. Onion thrips is a ***vector*** of tomato spotted wilt virus. See Onion M 68.

Plague thrips (*Thrips imaginis*) may infest ***flowers*** of vegetables. See Roses J 6.

Tomato thrips (*Frankliniella schultzei*) cause whitish blemishes on ***leaves*** and ***transmits*** tomato spotted wilt virus. See Tomato M 103.

Western flower thrips (*F. occidentalis*) is also a ***vector*** for tomato spotted wilt virus. See Annuals A 9.

Favoured by previous autumns and winters of above average rainfall and mild temperatures, followed by dry, sunny, spring weather, during which thrips invade crops in considerable numbers from drying weeds and other hosts in surrounding areas. Sheltered plant parts, eg throats of onions are favoured parts. ***Clean cultivation*** and the ***destruction*** of nearby weed growth should help to avoid onion thrips infestation early in the life of crops. ***Insecticides*** are registered because adults carry tomato spotted wilt virus into the crop from outside sources. Control of disease can be difficult. See Roses J 6.

Weevils

Weevils (Curculionidae, Coleoptera)
Some attack only one species, eg sweetpotato weevil, but most species infest a range of plants.

Fuller's rose weevil (*Asynonychus cervinus*) attack beans in late summer and autumn. ***Adults*** chew pieces from ***leaf edges***, producing a ***saw-toothed appearance***. ***Larvae*** are small white and legless. They cause serious damage in spring to tomato, cucurbits and beans. They destroy the fibrous root system and gouge out the main ***root*** and underground stems, and this may ***kill*** plants or reduce quantity and quality of the crop. Infestation usually results from a spill-over from nearby weeds. See Roses J 6.

Spotted vegetable weevil (*Desiantha diversipes*) is brown-grey and about ***6 mm*** long. It damages turnips severely in tableland areas in autumn, feeding on the ***leaves*** and ***stalks***. It also feeds on stems, leaves and ***runners*** of strawberry in spring and autumn. Eggs are laid in late summer-autumn. ***Larvae*** hatch from eggs and enter the soil where they feed on ***roots***. Adult weevils have been controlled with insecticides.

Vegetable weevil (*Listroderes difficilis*) ***(VW)*** affects ***ornamentals***, eg cineraria, Iceland poppy, pansy, stock, ***vegetables***, eg cabbage, turnip, carrot, parsnip, celery, lettuce, onion, beetroot, silver beet, spinach, potato, tomato, ***weeds***, eg capeweed, marshmallow. ***Weevils*** are box-shaped grey brown, about ***8-12 mm*** long with V-shaped markings on the wing covers, often stained with soil (Fig. 310). The head is extended into a typical snout. When disturbed, they feign death and are difficult to see. ***Larvae*** are stout-bodied, curved, legless, initially cream, later ***light greenish-yellow*** and up to ***12 mm*** long. Larvae usually feed during winter on fleshy ***roots*** of carrots and turnips which may be gouged out or furrowed. Adults and larvae feed at night or during the day in cloudy weather and shelter by day in the soil at the base of plants. Both larvae and adults chew holes in ***leaves, stems*** and ***fleshy roots***. Larvae on occasions feed on the growing points of young plants and gouge tap roots of carrots. ***Pest cycle:*** 1 generation each year. Weevils emerge from pupae in early spring and feed on plants. They become inactive in the soil during the summer until late autumn when they lay eggs in the soil at the base of plants or on plant stems. Adults feed again at this time to a limited extent. There are no males and all weevils lay fertile eggs. They pupate in spring in earthen cells 20-80 mm below soil surface. ***Overwinters*** as inactive adults. A ***tachinid fly*** and ***several wasp parasites*** (*Tersilochus* spp.) were introduced but have not established themselves successfully. Some carrot varieties are more ***susceptible*** than others.

Whitefringed weevil (*Graphognathus leucoloma*) ***(WV)*** infests ***ornamentals***, eg chrysanthemum, ***fruit***, eg citrus, passionfruit, ***vegetables***, eg bean, brassicas, carrot, cucurbits, lettuce, parsnip, potato, sweet potato, ***field crops***, eg lucerne (a favoured host), ***weeds***, eg capeweed. ***Weevils*** are grey with a short broad snout and are about ***12 mm*** long. There is a white band around the edge of the wing covers. No males are known. All adults lay fertile eggs. ***Larvae*** are thickset, legless, white or grey with brown heads, wrinkled, slightly curved, tapering and up to ***13 mm*** long. They are found on roots at depths of 50-150 mm below the soil surface but some may go deeper. Larvae do most damage and furrow into ***tap roots***, ***stem bases***, ***underground stems*** and ***tubers*** ringbarking or extensively furrowing them. Plants wilt suddenly. Young plants may be severely damaged. Infestation is usually patchy. Damage is most severe in the spring when larvae are nearly fully grown. Adults may feed on foliage, plants become stunted and some may die. ***Pest cycle:*** Probably only 1 generation each year Adults emerge from pupae in soil from November-April (peak in February) and may live for several months. Each may lay > 1,000 eggs on or just under the soil surface or stuck to soil debris. Young larvae hatch and burrow into soil to feed for many months before becoming fully-fed in the late spring when they form cells in soil and pupate. ***Overwinters*** as larvae.

Others: Garden weevil (*Phlyctinus callosus*), ***sweetpotato weevil*** (*Cylas formicarius*), ***whitestriped weevil*** (*Perperus lateralis*)

Pest cycle: Complete metamorphosis (egg, larvae, pupa, adult) with usually 1 cycle per year.

Overwintering: Depends on the species, some as pupae in the soil, others as feeding or non-feeding adults or as larvae.

Spread: By adults, eg ***WV*** adults crawl into crops from surrounding areas where they have bred on weed hosts, and from plant to plant, by hitch-hiking on hay bales, packages and many sorts of farm produce. Eggs, larvae, adults of ***VW*** may be transported on seedlings, boxes or other items.

Conditions favouring: When susceptible crops are planted in ground recently planted with susceptible or weed hosts. Adjoining weedy areas.

Control: Control measures are not effective once plants are attacked.

Cultural methods: FRW: Prevent damage by thorough ***early preparation*** of the land by ploughing in the weeds in late summer, and growing a crop of oats to be grazed and ***ploughed-in*** as recommended. ***VW:*** Plant susceptible crops in well-fallowed and cultivated land before sowing the crop (keep free from weeds for some time) or ***crop rotate*** with beans, peas or a cereal. ***Clean cultivate*** for some months prior to planting. Control ***susceptible weeds***, eg capeweed and marshmallow, during late autumn and early winter. Prevent migration of adult weevils to spring crops from nearby weedy land by cultivating the weedy areas in winter to destroy weeds and weevils. ***WW:*** Growing winter cereals, eg oats, which are ***not susceptible*** or establishing a clean fallow commencing in autumn will reduce numbers sufficiently for susceptible crops to be grown. Abnormal high rainfall may kill many larvae.

Sanitation: ***Destroy*** crop debris, weeds.

Resistant varieties: Some types and varieties of vegetables, are ***more susceptible*** than others.

Pesticides: Populations must be ***monitored***. ***VW: Insecticide*** sprays or baits may be applied before planting, if land and adjoining areas are known to be infested, or when infestations are found. Often it is necessary to treat only a relatively ***small portion*** of the crop but the vegetation from which the weevils are moving should be treated. Sprays should be applied late in the afternoon. ***FRW:*** Also by spraying if damage is serious. ***Insecticides*** incorporated into the crop at sowing, or jetted into the soil of infested seedlings, may give some control. ***Good control*** of larvae of other weevil species without harm to established plants has been achieved overseas by fumigation.

Wireworms (Elateridae), ***false wireworms*** (Tenebrionidae): ***Larvae*** chew into germinating ***seed*** and ***seedlings***, causing them wilt or ***die***. They chew patches of flesh and bore narrow holes deep into carrot ***roots***, potato and sweet potato ***tubers***, and onion ***bulbs***. ***Vegetable beetle*** (*Gonocephalum elderi*, Tenebrionidae) adults and larvae are often found in large numbers but do not necessarily damage crops. See Seedlings N 69.

Others: ***Symphylids*** (Symphyla) are small centipede-like animals which may damage ***fruit***, eg pineapple, ***vegetables***, eg asparagus, bean and occur in ***greenhouses***. They are delicate, white, up to ***10 mm*** long and about 1 mm thick with antennae and ***12 pairs*** of legs. They avoid light and when exposed move rapidly back into the soil. They live in soil and usually feed on ***organic matter*** and ***roots***, and may tunnel in seed leaves, ***crowns*** and ***underground stems*** causing short, branching roots. Primary roots may be destroyed during germination. They can penetrate ***2 m*** into the soil. so the use of insecticides is impractical. ***Favoured*** by poor drainage, moist well-drained soils with plenty of organic matter. Under favourable growing conditions severe root damage is ***tolerated***, but not by drought-affected plants. Where they are a problem their populations should be ***monitored***. Pre-plant application of insecticides, thorough cultivation and removal of organic debris, and avoid planting in moist areas with high organic matter content, and a history of infestation. Centipedes and other soil dwelling ***predators*** exert some control in untreated soils.

SNAILS AND SLUGS

Snails and slugs may cause extensive damage to ***seedlings*** and chew holes in ***leaves*** and ***fruit*** of mature vegetables. They may hide in leaves and contaminate hearts with excrement and slime. Damage is easily identified if they are present on plants or if their shiny slime trails are visible. Do not ***confuse*** damage with that caused by leafeating caterpillars and beetles. See Seedlings N 70.

VERTEBRATE PESTS

Small birds, eg sparrows, starlings and silver eyes damage young ***seedlings*** after planting out, especially lettuce, spinach, beet. Bird netting may be necessary. Some control is obtained by a lacework of strings and bottle tops over the crop. ***Rats and mice*** may damage vegetables in ***storage***. See Fruit F 13.

Non-parasitic

Environment: Many vegetables are sensitive to ***frost***. Fruit may be ***sunburnt*** (Fig. 311). Ripening of fruit may be affected by ***temperature***, eg tomatoes may not ripen during cool summer months in Tableland areas of NSW. The premature running to seed is called ***bolting***. It may be caused by being grown out of season (autumn lettuce may bolt in spring), unsuitable fertilisers and unfavourable seasonal conditions. Grow only varieties suited to the season and the locality. Because of the lush nature of vegetable crops, ***hot windy weather*** without adequate water or shelter is usually detrimental to flowering and fruiting. Many ***postharvest diseases*** are due to injury caused by excessive chilling, high temperatures, physical damage or prolonged overstorage (Beattie 1985).

Nutrient deficiencies, excesses: Vegetables are susceptible to deficiencies and toxicities. Fertiliser programs should be based on ***soil analysis*** before planting and ***tissue analysis*** after planting (Weir and Cresswell 1993). The application of fertiliser ***in excess or at the wrong time*** is a common problem resulting in large leafy vegetables, failure of plants to heart (lettuce), browning of vascular tissue (lettuce). Use all fertilisers at lowest effective rate. Avoid direct contact of roots with concentrated fertiliser (Fig. 312). Use poultry manure only in small amounts and apply in spring or early autumn, not just before winter. ***Soils can accumulate fertiliser***. Land being fertilised for the first time may need large amounts of fertiliser, but some will remain in the ground for the next crop. Heavy soils accumulate more nutrients than sandy soils.

Overmaturity: ***Root crops*** are often allowed to become overmature resulting in cracking (Fig. 312). Cabbages may also ***split*** when overmature. Vegetables must be harvested at the correct time

Others: ***Pesticide injury*** and ***residues***, ***pollination***, ***springtails*** (Collembola).

WEEDS

Most vegetables compete poorly with weeds during ***establishment*** (first few weeks after emergence), until there is sufficient vine and leaf growth to cover the soil, eg sweet potato, pea, so that early and efficient weed control is essential to prevent any check in crop growth. Some vegetables compete poorly with weeds ***throughout the life of the crop*** (poor ground cover offered by the crop), eg carrots and onions. An efficient weed control program is required throughout the entire growing period of the crop. Some weeds may be ***difficult to control*** adequately in some crops, eg slender celery and wild carrot, in carrot crops. ***Weed control is based on good land preparation.*** This involves a combination of mechanical weeding of various types, interrow cultivation, mulches and pre- and post-emergence herbicide applications. ***Pre-emergence herbicides*** are registered for most vegetables, which may be applied pre- or post-plant to control a range of broadleaved and grass weed seeds. ***Selective post-emergence herbicides*** are used to control a wide range of emerged broadleaved and grass weeds. Herbicides must be applied at the right time to achieve effective weed control (Salvestrin 1991).

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Boron Deficiency
Handling Fruit and Vegetables in Retail Stores
Identifying Deficiencies in Vegetable Crops
Monitoring Pesticide Residues in Fresh Fruit & Vegetables 1992-94
Postharvest Diseases, Injuries & Disorders of Vegetables
Seasonal Availability of Fresh Vegetables
Soil Acidity and Vegetable Growth.
Storage Conditions for Fruit and Vegetables
Testing Fruit and Vegetables for Pesticide
Transporting Fresh Produce in Refrigerated Trucks

Vic Agnotes

Commercial Vegetable Growing in Victoria
Commercial Vegetables Kit
Control Seedborne Diseases with a Hot-water Bath
Seedling Production : Damping Off
Storage Life of Vegetables
Trace Element Deficiencies in Vegetable Crops
Sustainable Vegetable Growing Projects (The Vegetable Research Station, Frankston)
Use of Low Quality Water for Vegetables
Vegetable Advisory Services
Vegetable Growing in East Gippsland
Vegetable Growing in the Lodden-Campaspe Region
Vegetable Growing in North & West of Melbourne
Vegetable Seeds Buying Guide
Vegetable Seedling Production
Vegetable Seeds & Seedlings, How to Work Out Quantities
Windbreaks for Vegetable Crops
Yields of Vegetable Crops

WA Farmnotes

Nitrogen and Phosphorus Disorder of Vegetable Crops (Bull. 4175. WA Dept of Agric)
Root-knot Nematode in Vegetable Crops (SA Fact Sheet)
Storage Conditions for Fruit and Vegetables (NSW Agfact, WA Farmnote)

Associations, Journals etc.

Australian Vegetable & Potato Growers Federation (AUSVEG)
Fruit and Vegetable Prices and Receivals 1994-95 (avail. from Johima Book, Parramatta)
Good Fruit and Vegetables
NSW Chinese Vegetable Growers Assoc

See Preface xii, Annuals and herbaceous plants A 10

MANAGEMENT

Remember, always check for recent references

Selection

Horticultural requirements: Choose varieties to ***suit*** the market, season and site.

Resistant varieties: Choose species or varieties which are ***relatively problem-free***. Where particular problems recur, eg root knot nematode, check to see if ***resistant varieties*** are available. Do not plant susceptible species in areas where soilborne problems are known to occur.

Diseases-free planting material: Purchase ***certified virus-or pathogen-tested*** seed or plants. Otherwise only propagate vegetatively and save seed from disease-free plants, and treat with hot water or fungicides.

Establishment and maintenance

Effective control can only be achieved by identifying the problem accurately; if unable to do so seek advice. Many ***postharvest diseases*** originate from field infections, eg *Sclerotinia* rot, so field disease control is important. ***Monitor*** disease, pest and weed infestations in crops.

Propagation: By seed, division and tubers, by grafting and by tissue culture.

Cultural methods: ***Rotate crops*** (3-4 year rotation with non-host plants) to avoid buildup of leaf spot fungi and soilborne root and crown rots, in plant debris. ***Site plants*** according to their cultural requirements. ***Space plants*** well to prevent seedbed diseases and provide good aeration so that leaves dry rapidly. Control snails and other ***problems that affect seedlings***. See Seedlings N 66. Sow as far ***as possible from other infected plants*** or from land containing infected crop debris. Irrigate and fertilise as recommended, ie irrigate early in the morning and avoid overhead irrigation. Do not damage roots during cultivation. ***Pick crop regularly*** and keep it growing vigorously to avoid diseases establishing.

Sanitation: Many soilborne fungi ***grow on crop debris*** after harvest. Debris from vegetable crops should either be deep buried, so that it can be broken down by soil microorganisms, or collected and destroyed.

Biological control: Biological control agents may have been ***released***, eg for green vegetable bug, or may be available for ***purchase***, eg predatory mites.

Plant quarantine: ***Comply with*** local, regional and export/import regulations.

Physical and mechanical methods: Use if relevant and practical, eg bird netting, plastic mulch.

Pesticides: ***Monitor diseases or pests*** before applying a pesticide (Brough et al. 1994). ***Systemic fungicides*** can effectively control disease by both killing germinating spores before they infect the plant and by eradicating recent infections. ***Protectant fungicides*** should be applied in advance of when the disease is expected to occur. Observe ***withholding periods*** on vegetable crops so that crops do not contain more than prescribed ***maximum residue limits***. For home gardeners there is a range of ready-to-dispense combination pesticides which are ideal for small areas. Commercial growers should select insecticides, fungicides and herbicides in such a way as to reduce the possibility of ***resistance development.***

Pest management: Prepare a ***monthly chart*** for vegetables from the time of planting which should include all activities, eg planting, pruning, fertilising, pesticide applications, postharvest treatments.

Postharvest

Postharvest diseases and pests: Harvest leaves, fruit or roots ***at the correct stage*** for the market. ***Discard*** diseased or injured produce. Only package, store and market ***healthy and uninjured produce***. ***Fresh vegetables*** are susceptible to many postharvest ***bacterial diseases***, eg soft rot, ***fungal diseases***, eg rhizopus soft rot, and ***disorders***. See Postharvest N 61. ***Dried stored vegetables*** are also susceptible to many insect pests, eg bean weevil and cockroaches, dried fruit beetles, flat grain beetles. See Seeds N 75.

Harvest/Storage/Shelf life: ***Each vegetable*** must be harvested, maintained at recommended temperatures and humidities and packaged, stored, transported and displayed according to ***prescribed standards*** (Salvestrin 1991). International Standards for Fruit and Vegetables defines the quality requirements to be supplied fresh to the consumer (OECD cur. edn.). ***Quality standards*** are available for most vegetables.

Asparagus

Asparagus officinalis
Family Liliaceae

PESTS AND DISEASES
Parasitic
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf spots
  - Root, crown and spear rots
  - Rust
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Cutworms
  - Garden symphylid
  - Thrips
- **Snails and slugs**

Non-parasitic
  - Autotoxicity
  - Nutrient deficiencies, toxicities

Asparagus suffers from few pests and diseases in Australia.

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*). See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots: ***Grey leaf spot,*** fern spot (*Stemphylium* sp.) causes small purple spots on asparagus ***ferns*** and sometimes on ***spears***. Spots on ferns enlarge to become light brown with purple margins, and may completely girdle fern ***stems*** causing affected ferns to die. Remove and destroy old ferns to prevent *Stemphylium* surviving on them. See Annuals A 5.

Root, crown and spear rots

Fusarium crown rot, asparagus decline, fusarium decline (*Fusarium moniliforme* and to a lesser extent *F. oxysporum*) may be a ***serious disease***; it is usually associated with wilting, yellowing and browning of ferns (Elmer et al. 1996). Longitudinal reddish-brown flecks develop on ***stem bases*** below ground level, stems may crack and the vascular system stained brown. Roots and crowns rot, plants ***die***. *F. moniliforme* is widespread in soils and also affects many other crops, eg sorghum, maize, rice and peanut. Spores are ***spread*** by wind and water (Persley and Cooke 1994). Some *Fusarium* spp. are ***seedborne***. ***Favoured*** by stress, eg compaction over the crown, competition, defoliation, excessive harvesting, waterlogging. Where *Fusarium* occurs, only plant ***Fusarium-free crowns*** and seedlings of ***Fusarium-tolerant varieties*** in new sites not previously planted with asparagus or other susceptible crops, and avoid stress. Treat seed, crowns, soil and emerged crowns as recommended with fungicides. See Vegetables M 6, M 9.

Phytophthora spear rot (*Phytophthora megasperma*) is ***widespread*** but not as serious as *Fusarium*. It causes a soft wet advancing rot of ***green spears***. Lesions usually develop a white centre with a thin brown margin. Avoid replanting areas where crops have been badly affected and during cool spring conditions. See Trees K 6, Vegetables M 7.

Phoma rot, spear discoloration (*Phoma betae*, Imperfect Fungi) causes a black rot of ***seedlings***, brown streaks on ***seed stalks***, brown spots on old ***leaves***, and a rot of ***fleshy roots***. Seedborne, ***overwinters*** in roots carried over for seed production and in debris.

Rhizoctonia root rot, base rot and spear distortion, violet root rot (*Rhizoctonia* sp.) is a ***common soil inhabitant*** and may invade plants when spears are harvested. A dark brown rot occurs at the ***base of the plant*** extending out along ***roots***. Affected spears show small red lesions and kinked growth. Rot may then grow down to the base of the plant where it may cause general decay. Spears are infected as they grow through roots or stems affected by the fungus. ***Favoured*** by sandy soils, warm weather and wet conditions. See Vegetables M 7.

Others: Blue mould, red-brown spear (*Penicillium* sp.), ***pythium root rot*** (*Pythium* sp.), ***stem rot*** (*Diplodia asparagi*).

See Vegetables M 7.

Rust (*Puccinia asparagi*) spores remain on old stems until spring, germinating then to infect ***new shoots*** as they emerge from the ground. If tops are attacked several years in succession, the root system is so weakened that shoots fail to appear in spring or are culls. Overseas, a ***parasitic fungus*** (*Darluca filum*) helps keep rust in check. Varieties vary in ***resistance***. Remove volunteer or wild asparagus around beds. ***Sanitation*** procedures must be carried out for chemical control to be effective. Asparagus tops can be sprayed or dusted after the cutting period. See Annuals A 7.

NEMATODE DISEASES

Although asparagus root exudates are strongly ***suppressive*** of many soil nematode pests, ***root knot nematode*** (*Meloidogyne* sp.) and ***Paratrichodorus spp***. have been reported on or around asparagus. See Vegetables M 10, M 11.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may contaminate asparagus ***postharvest***. See Roses J 4, Vegetables M 11.

Cutworms (*Agrostis* spp.) can occasionally damage asparagus plantations and can seriously damage ***young plants***. See Seedlings N 68.

Garden symphylid (*Scutigerella immaculata*) may damage ***crowns and spears*** in dry seasons. Symphylids are centipede-like insects < 9 mm long. See Greenhouses N 27, Vegetables M 18.

Thrips (Thripidae, Thysanoptera) may be a problem in ***young nurseries***. They are concealed beneath bracts and are difficult to remove by washing. May be a ***postharvest*** pest. See Roses J 6, Vegetables M 17.

Others: ***Black field cricket*** (*Teleogryllus commodus*), mole crickets (*Gryllotalpa* spp.), wingless grasshopper (*Phaulacridium vittatum*). ***Flea beetles*** (Galerucinae) and ***Rutherglen bug*** (*Nysius vinitor*) may attack fern growth. ***Vegetable weevil*** (*Listroderes difficilis*) and larvae may feed on stems. ***Mirid bugs*** (Miridae) and ***redlegged earth mite*** (*Halotydeus destructor*) may contaminate harvested asparagus. ***Others***: Overseas, ***asparagus beetles*** (*Criceris* spp., Chrysomelidae, Coleoptera) and their larvae gnaw buds and tips when shoots emerge in spring. Maggots of the ***asparagus leafminer*** (*Ophiomyia simplex*, Agromyzidae, Diptera) mine in asparagus stems near the base of plants, foliage yellows and dies prematurely.

SNAILS AND SLUGS

Snails and slugs may nibble on emerging spears. See Seedlings N 70.

Non-parasitic

Autotoxicity: Failure to re-establish asparagus in old asparagus fields is usually diagnosed as an accumulation of ***pathogenic organisms*** causing *Fusarium* wilt, crown and root rots (Elmer et al. 1996). Chemical treatments to effectively control these diseases does improve establishment but asparagus seedlings may be ***stunted***. This stunting is considered to be due to an accumulation of toxic substances produced by asparagus. ***Asparagusic acid*** and related compounds are present in asparagus shoot tissues and inhibit lettuce, rice and radish, and seedlings of ***asparagus itself***. Do not replant for 7-10 years after removal of crowns (McGeary et al. 1985). ***Asparagus roots*** strongly suppress many soil ***nematode pests***.

Nutrient deficiencies, toxicities: Leaf analysis standards are available for asparagus (Weir and Cresswell 1993).

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State/Territory Departments of Agriculture/Primary Industry eg

Asparagus Culture (NSW Agfact)

Asparagus Production (Vic Agnote)

Asparagus : Weed Control (Vic Agnote)

Home Vegetable Garden Books (Most states)

Associations, Journals etc.

Good Fruit and Vegetables

Growing Asparagus Conferences

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Asparagus is one of the few perennial vegetables and is grown for the fresh market or for canning. An overview of the industry has been presented by Coombs (1995). It requires cold weather to induce ***winter dormancy***. Without this, crowns continue to produce new fern at the expense of the spring flush of spears. Select varieties with some ***resistance*** to *Fusarium*, *Phytophthora* and other diseases, Washington varieties have some resistance to rust. Only plant out ***Fusarium-free*** crowns and seedlings. ***Propagated*** from crowns, seed, seedling transplants. Asparagus plantations may last for 30-35 years, but economic life is usually 10-15 years and depends on soil type, tendency to overcut and other factors. Excessive cutting of newly established asparagus saps the vigour of crowns and reduces yield and life of the stand. ***Choose new sites*** not previously used for asparagus. It is usually almost impossible to re-establish asparagus successfully in land previously used for asparagus, due to the buildup of ***Fusarium spp***. (Elmer et al. 1996) in the soil, or due to ***autotoxicity***. Soils should be deep, fertile, friable, with lots of organic matter. Avoid environmental stress. Although asparagus has a high resistance to root pests, minor soil insects pests in the soil from previous crops, especially pasture, can transfer on to asparagus roots or stem bases. Protect emerging spears from snails, slugs and cutworms. ***Blanched asparagus*** is produced by special cultural methods, forming a mound of soil 200-300 mm high over the rows to blanch the spears before they emerge and are cut. ***For green asparagus***, no mounding is carried out and spears are not cut until they are 200-240 mm above the ground. ***Perennial weeds*** can be a ***major problem***. They should be controlled prior to planting, during the dormant season, and before and after emergence of the fern. Post-emergence and pre-emergence herbicides are registered for use. ***Harvest*** spears every day or they become stringy and unpalatable. Preferably eat them the day they are harvested. Cool spears quickly, eg up to 4 hours, $2^{o}C$, > 95% relative humidity. Spears are ethylene sensitive, but appropriately treated may store for 2-4 weeks. Aphids, mirid bugs, mites and thrips may contaminate spears ***postharvest***. ***For the fresh market***, asparagus is graded according to size, and should be washed, graded, bundled and packaged in a cool room on the day they are harvested. ***For canning,*** asparagus is graded according to amount of fibre, spear size, compactness of spear head and correct colour (white or green), it should be processed as soon as possible. ***Quality standards and grades*** should be followed.

Bean (broad)

Vicia faba var. *major*
Family Fabaceae

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Broad bean wilt
- **Bacterial diseases**
- **Fungal diseases**
  - Fungal leaf, pod and stem spots
  - Root, collar and stem rots
  - Rust
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Seed weevils
- **Snails and slugs**

Non-parasitic
- Environment
- Mechanical and chemical injury
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Broad bean wilt

Scientific name: Broad bean wilt virus. It is not as important as it used to be.

Host range: ***Legumes***, eg pea (*Pisum sativum*), sweet pea (*Lathyrus odoratus*), narrowleaved lupin (*Lupinus angustifolius*), spotted medic (*Medicago arabica*), purple vetch (*Vicia benghalensis*), ***ornamentals***, eg nasturtium (*Tropaeolum majus*), ***weeds***, eg ribwort (*Plantago lanceolata*), *Salvia* spp., cape gooseberry (*Physalis peruviana*).

Symptoms: Systemic veinclearing and mottling of apical leaves, ***growing points turn black and die***, wilting of whole plant, new stunted growth with leaf shape distortion, mosaic in 'recovered' side shoots. Symptoms are most pronounced in ***cool conditions*** and disappear soon after infection.

Overwintering: In other infected plants.

Spread: By aphids, eg cowpea aphid (*Aphis craccivora*), green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), not by seed.

Control:
Cultural methods: Plant so that as much of the life of the crop as possible, 18-20 weeks, occurs at > 20°C especially towards the end of growth. Autumn sowing on the coast and summer sowings on tablelands are most prone to infection.
Sanitation: In small plantings remove and burn affected plants as soon as they are noticed.
Disease-free planting material: Do not use seed from infected plants.
Pesticides: Commercial growers may apply a registered insecticide for vector control.

Others: Leaf symptoms include mosaic, mottling, rolling, staining, streaking, stunted plants, growing tips may die. Symptoms may vary over weeks. More than 50% of the viruses affecting broad bean are ***seedborne***, many are also spread by ***insects***.

Subterranean clover stunt virus. New growth is yellow, ***leaves roll inwardly*** and are narrow. Older leaves become harsh and thick. Plants are stunted with a reduction in leaf size, shortening of petioles and internodes.
Tomato spotted wilt virus: Blackening and ***death of growing points, dark streaking of stems***, black sunken spots on pods. See Tomato M 96.
Others: Alfalfa mosaic virus, bean yellow mosaic virus, broad bean true mosaic virus, broad bean stain virus, clover yellow vein virus, cucumber mosaic virus, subterranean clover red leaf virus.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial blight (*Pseudomonas syringae* pv. *syringae*) on broad bean. See Stone fruits F 124, Vegetables M 5.

FUNGAL DISEASES

Fungal leaf, pod and stem spots

Ascochyta leaf spot (*Ascochyta fabae*) causes brown leaf spots in which ***small dot-like black fruiting bodies*** (pycnidia) develop.
Grey mould, chocolate spot (*Botrytis fabae*, *B. cinerea*) causes grey or brown ***leaf spots***, which can merge causing blighting. ***Petals*** may also be affected. ***Favoured*** by cool moist weather, plant injury, aphid secretions, dense crop growth and poorly drained soil. See Greenhouses N 22.
Others: Leaf, pod and stem spot (*Cercospora fabae*), ***leaf spots*** (*Alternaria* spp., *Mycosphaerella* sp.).

See Annuals A 5.

Root, collar and stem rots (*Fusarium*, *Pythium*, *Rhizoctonia, Sclerotinia*) may cause ***damping off*** diseases of broad bean, and root and collar rots of ***older plants***. See Vegetables M 7.

Rust (*Uromyces vicae-fabae*) affects broad bean and vetch. Small pustules, containing red-brown spore masses, develop on ***leaves and stems***, leaves shrivel, flowers and young pods may fall. Often occurs towards the end of the crop. Some varieties, eg Coles Dwarf, are more ***resistant***. See Annuals A 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.), ***root lesion nematode*** (*Pratylenchus* spp.), ***stem and bulb nematode*** (*Ditylechus dipsaci*), *Merlinius brevidens, Scutellonema brachyurum*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Cowpea aphid (*Aphis craccivora*)
Bean root aphid (*Smynthurodes betae*)
Foxglove aphid (*Aulacorthum solani*)
Green peach aphid (*Myzus persicae*)
Leafcurl plum aphid (*Brachycaudus helichrysi*)
Potato aphid (*Macrosiphum euphorbiae*)
Aphids may breed rapidly on broad beans and may attack ***flowers*** causing poor pod set. Honeydew on ***leaves*** causes leaf cells to produce a brown pigment. Aphids on ***foliage*** may be controlled with insecticides. Bean root aphids are not usually controlled chemically. Some aphids are ***vectors*** for virus diseases of broad beans. See Roses J 4, Vegetables M 11.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.) may eat into seeds and are difficult to control as they are concealed within ***pods***. ***Inspect regularly*** to detect and control budworms at the beginning of infestations. A trap ***monitoring system*** is useful in detecting the presence of moths. See Sweetcorn M 89.
Others: ***Cutworms*** (Noctuidae), ***looper caterpillars*** (*Chrysodeixis* spp.), ***painted apple moth*** (*Teia anartoides*), ***pea blue butterfly*** (*Lampides boeticus*) and ***grass blue butterfly*** (*Zizina labradus labradus*).

See Annuals A 8, Vegetables M 13.

Seed weevils (Chrysomelidae, Coleoptera)

Bean weevil (*Acanthoscelides obtectus*) may infest beans and cowpeas in the field. ***Beetles*** are about ***3 mm*** long, stout, brown, with white, grey, brown or black patches on the upper surface. ***Larvae*** about ***3 mm*** long feed ***inside bean seeds***. These insects can breed continuously in the seeds. See Beans (French) M 31, M 32 (Fig. 318), Seeds N 74.
Others: ***Broadbean weevil*** (*Bruchus rufimanus*) attacks broad bean, pea and vetch. Several can occur in a single seed (Metcalfe and Metcalfe 1993).

See Seeds N 74, N 75.

Others: ***Mites*** (Acarina), eg earth mites (Penthalidae), spider mites (*Tetranychus* spp.); ***green vegetable bug*** (*Nezara viridula*), ***thrips*** (Thysanoptera), eg bean blossom thrips (*Megalurothrips usitatus*), plague thrips (*Thrips imaginis*); ***bean fly*** (*Ophiomyia phaseoli*), ***bean podborer*** (*Maruca testulalis*); ***crickets and grasshoppers*** (Orthoptera).

SNAILS AND SLUGS

Slugs also create problems in some seasons. See Seedlings N 70.

Non-parasitic

Environment: Broad beans are tolerant of even severe frosts but flowers may wither and drop due to ***variable temperatures***, or too much or too little ***water***. Regular setting of pods occurs when spring temperatures stabilise. ***Bees*** improve pollination.

Mechanical and chemical injury may cause leaf and stem spotting as broad beans are soft and tender.

Nutrient deficiencies, toxicities: Excess ***nitrogenous fertiliser*** may cause excess leafy growth and fewer pods.

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State/Territory Departments of Agriculture/Primary Industry eg
Broad Beans for Processing : Cultural Notes (Tas Farmnote)
Broad Beans in the Home Garden (Vic Agnote)
Diseases of Broad Bean (NSW Agfact)
Foliar Diseases of Broad Beans (Tas Farmnote)
Insect Pests of Stored Foodstuffs (NSW Agfact)
Pests and Diseases of Broad Beans (SA Fact Sheet)
See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Broad beans are grown for the fresh market and canning. Some varieties have ***resistance*** to rust. Plant ***certified disease-tested seed*** (more than half of the diseases affecting broad bean in Australia are seedborne). Dust seed before sowing to protect against damping off fungi present in soil. ***Propagated*** by seed. ***Practise crop rotations*** of 3-4 years. Broad beans tolerate lower temperatures than other beans and may be sown in late autumn or winter. Avoid autumn sowings on the coast and summer sowings on the tablelands to reduce losses from broad bean wilt. Plant seed in heavy, well drained neutral to slightly alkaline soil. The need for irrigation is most critical at pod set. In small plantings ***remove and burn plants*** with broad bean wilt. ***Plough in diseased crops*** as soon as possible after harvest. ***Perennial weeds*** should be controlled prior to planting either by cultivation or by ***post-emergence herbicides. Pre-emergence herbicides*** may be applied to moist soil immediately after planting to control broadleaved weeds and some grasses. Commercial growers may control ***insect vectors*** of virus diseases where these are a problem. A tenderometer is used to determine ***maturity*** of beans for canning. Broad beans should be harvested before pods become over-mature (coarse and leathery). Home gardeners may preferably use pods as soon as picked and shell and freeze any surplus.

Beans (French)

Phaseolus vulgaris
Family Fabaceae (pea family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Stunted, yellow plants or leaf mosaics, indicate virus infection.

Bean common mosaic virus affects beans (*Phaseolus* spp., *Vigna* spp.), burr medic (*Medicago polymorpha*). Symptoms vary with the cultivar but include leaf mottling, stunting, distortion of ***leaves*** and ***pods***. Dark green tissue is often bubbled and/or in bands next to veins. Affected plants are smaller, with curled pods with a greasy appearance and reduced yields. ***Spread*** by aphids (Aphididae), by seed, by pollen to seed. Plant ***certified disease-free seed*** of ***resistant*** cultivars.

Bean yellow mosaic virus affects ***vegetables***, eg bean, broad bean, pea, ***ornamentals***, eg freesia, gladiolus, ***field crops***, eg lupin, medics, soybean, subterranean clover. ***Leaves*** have a bright, coarse, dark and yellow-green mosaic, often with yellow spots and stunting. Severe strains may cause rough, wrinkled malformed leaves. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), pea aphid (*Acyrthosiphon pisum*), potato aphid (*Macrosiphum euphorbiae*), by sap, by seed.

Tobacco yellow dwarf virus (bean summer death virus) affects bean (*P. vulgaris*), common thornapple (*Datura stramonium*), tobacco (*Nicotiana tabacum*). Different strains attack different bean cultivars. May be symptomless. Plants yellow and die rapidly in hot weather. Death is slower during cool weather and plants are often stunted and wilted with young leaves curling downwards. ***Spread*** by common brown leafhopper (*Orosius argentatus*) which spreads from drying beans and other crops after hot weather; by grafting between solanaceous hosts, not by seed. Plant ***resistant*** cultivars.

Others: Passionfruit woodiness virus, peanut mottle virus, subterranean clover red leaf virus, subterranean clover stunt virus, tomato big bud mycoplasma.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial blights

Bacterial brown spot, brown spot (*Pseudomonas syringae* pv. *syringae*) causes red-brown spots on ***leaves, stems*** and ***pods***. Pod spots are water-soaked, sunken with red-brown margins. Only serious on crops damaged by hail, rust, windy rain, machinery. Avoid susceptible cultivars.

Common blight (*Xanthomonas campestris* pv. *phaseoli*) causes spotting of ***leaves*** and ***pods***, wilting and death of plants. Spots are similar to those caused by halo blight but are larger with a narrow yellow halo. Laboratory tests are necessary for positive identification. A golden ***ooze*** may form on leaf and pod spots in moist conditions.

Halo blight (*Pseudomonas syringae* pv. *phaseolicola*) affects beans, tropical legumes, eg glycine. Leaves of severely affected ***seedlings*** are often mottled with bright-green veins on a paler background. ***Leaf spots*** are small, angular, watersoaked or dead, usually with a wide pale yellowish-green border. See Vegetables M 1 (Fig. 293). In cool weather halos are obvious, but they may not develop in hot weather. Some strains of halo blight do not produce a definite halo. ***Pods spots*** are circular, dark-green, water soaked and often run together. Under moist conditions, a silvery bacterial ooze forms on both leaf and pod spots. If the bacteria invade the vascular system plants may be stunted, wilted and eventually ***die***.

Pod twist (*Pseudomonas syringae* pv. *flectens*) causes small watersoaked areas on young pods, which wither and fall, remaining ***pods*** are twisted. Bacterial ooze may dry to a shiny encrustation. Bacteria are spread from plant to plant by ***bean blossom thrips*** (*Taeniothrips nigricornis*) which itself causes twisting and scarring of pods.

Overwintering: Infected seed, ie direct pod infection or contact of seed coat with bacteria during harvesting and cleaning, handling, contaminated machinery, infected plants, crop debris and dust for more than a year.

Spread: Wind-driven rain, machinery, irrigation equipment, people, insects, domestic and wild animals, machines or people moving through a crop when it is wet with rain or dew.

Conditions favouring: ***Common blight*** by warm, humid or wet conditions. A very low level of seedborne disease, or one small area of infection, can start a serious outbreak. ***Halo blight and brown spot*** by cool, damp, windy weather, overhead irrigation, injury from hail and heavy driving rain. ***Pod twist*** by warm weather.

Control: ***Monitor*** crops for disease, most outbreaks start from a few small initial patches.

Cultural methods: Practice a ***crop rotation*** of 2-3 years. Do not grow beans near infected hosts.

Sanitation: ***Destroy*** alternative hosts, legumes, weeds and volunteer beans from nearby bean crops. ***Plough-in*** diseased crops immediately after harvest. Store and handle bean seed to avoid risk of contamination. Do not contaminate healthy plants with diseased ones during harvesting. Handle infected plants first and disinfect hands, clothing and machinery before handling seed or moving to uninfected crops. Avoid workers and machinery moving through wet crops. To minimise spread, destroy all diseased and healthy plants for about 3 m around each patch.

Resistant varieties: Avoid susceptible varieties.

Disease-free planting material: Plant ***certified disease-tested*** seed.

Pesticides: Bactericides may slow disease development. Insecticides control bean blossom thrips which spreads pod twist.

Others: ***Bacterial wilt*** (*Pseudomonas solanacearum*), ***bacterial wilt*** (*Corynebacterium flaccumfaciens*), ***crown gall*** (*Agrobacterium* sp.).

FUNGAL DISEASES

Anthracnose (*Colletotrichum lindemuthianum*) is most commonly seen on ***pods***. Small reddish-brown, slightly sunken spots form, and rapidly develop into large black sunken craters which may have ***pink spore masses*** in the centre in moist weather. Spots similar to those on the pods are produced on stems and leaf stalks. Infection of leaves causes blackening along the veins, particularly on undersurfaces. Elongated dark brown lesions up to 12 mm long develop on stems on young seedlings. ***Practise crops rotations*** of 2-3 years between crops. Several races of the fungus occur and some bean varieties are ***resistant*** to some races. Plant ***disease-free seed. Fungicides*** are registered for use. See Fruit F 5.

Damping off (*Pythium* spp., *Rhizoctonia solani*, *Fusarium*) occurs on ***stringless cultivars*** especially if seed is damaged during harvesting or handling, or if soils are wet and temperatures low. If seed has not been treated with fungicide, apply a fungicidal dust. Avoid watering soon after sowing. If ground is too dry, pre-irrigate soil and let it dry for a few days before sowing. Delay spring sowing until the soil temperature is > 15°C at a depth of 50 mm. See Seedlings N 66.

Fungal leaf spots

Angular leaf spot (*Phaeoisariopsis griseola*, *Isariopsis griseola*) infects ***leaves, stems*** and ***pods***. Spots on the 1st leaves are large and circular, often looking like archery targets. On later leaves they are generally smaller and angular. Tiny black bristles develop on the lower surface of the lesions. Often occurs with rust. ***Overwintering*** in crop residues. and on older diseased crops. ***Spread*** by seed infection either by direct infection on plants or contamination of seed coats during harvesting. ***Favoured*** by cool, wet windy weather. It is a minor disease in well managed crops. Plant ***resistant varieties.*** Plough-in diseased crops immediately after harvest. Spray with recommended fungicides.

Ascochyta spot (*Ascochyta phaseolorum = Phoma exigua*). Circular grey spots 6-25 mm across develop on ***leaves***, often with concentric rings and well defined margins. Centres dry and crack leaving ragged holes. Many black fruiting bodies ***(pycnidia)*** can be seen embedded in the tissue. ***Pod infection*** causes large dark spots around injury sites. Infection of the floral remnants causes a dark dry rot of the pod extending to the stem end. The fungus gains ***entry*** though damaged leaves around rust pustules, insect feeding sites and other injuries. A minor disease.

Cercospora leaf blotch (*Cercospora canescens*) causes ***mature leaves*** to develop circular or slightly angular greyish spots, sometimes with reddish margins. Spots may dry and portions may fall out giving the leaf a ragged appearance. ***Overwinters*** as seed contaminant or survives in crop debris. Spores are ***spread*** by wind. Usually only seen on older senescing leaves.

Leaf and pod spot, pleiochaeta brown spot (*Pleiochaeta setosa*) causes reddish brown spots about 2 mm wide on ***leaves***. With age, centres fall out leaving ***ragged holes***. Small dark spots occur often on veins on leaf undersurfaces. ***Pods*** develop slightly sunken spots with dark centres and light brown margins. Spots are up to 3 mm wide and may coalesce. ***Favoured*** by growing beans on very light sandy soil. It is a wound pathogen and leaf and pod abrasion by sand during strong wind predisposes beans to attack. ***Eradicate*** alternative weed hosts, eg streaked rattle pod (*Crotalaria pallida*) and Gambia pea (*C. goreensis*). ***Establish windbreaks*** in exposed locations (Persley 1994).

Others: ***Zonate leaf spot*** (*Stemphylium* sp.), *Alternaria fasiculata, Leptosphaerulina trifolii.*

See Annuals A 5.

Grey mould (*Botrytis cinerea*) may infect ***pods*** touching the ground causing ***postharvest*** losses. See Greenhouses N 22, Vegetables M 6.

Root and stem rots, root rot complex

Aphanomyces black root rot, black root rot (*Aphanomyces euteiches*) affects beans and peas causing discoloured ***stems*** and ***roots***, leaves wilt, reduced yield. Often misdiagnosed as moisture stress. See Vegetables M 7.

Ashy stem blight, charcoal rot, (*Macrophomina phaseolina*) causes a pale ash-coloured rot of the ***stem*** at the base of the cotyledons of seedlings. Infection may extend along the stem and growing points are killed. In older plants symptoms are similar but are more pronounced on one side of the plant. Affected areas often have a dark margin and concentric markings with an ashy grey centre and small black resting bodies within. ***Roots*** may also be invaded. Affected plants ***die***. See Vegetables M 7.

Cottony leak and stem rot, pythium stem rot (*Pythium* spp., *P. aphanidermatum*): ***Stems***, at or above ground level, and sometimes ***leaves*** develop a soft rot which may be covered with a fine white cottony growth in wet weather. No sclerotia are formed. ***Roots*** of seedlings and mature plants may rot. ***Pods*** in transit and storage may develop abundant white cottony growth that mats pods together into nests which later become a soft leaking mass ***(cottony leak)***. Usually a minor disease but can be serious in hot wet weather. For ***stem rot in the field*** avoid close planting and deep sowing of seed. Cultivate carefully to avoid plant injury, do not plant in poorly drained areas. Prepare land to allow residues to break down. For ***cottony leak*** discard diseased pods and pack only dry pods, store in well ventilated areas at 12-15°C. See Vegetables M 7.

Fusarium root rot*,** red root, dry root rot (*Fusarium solani* f.sp. *phaseoli*): ***Tap roots may redden and dry, lower roots are destroyed and secondary roots may form above diseased areas. Plants are stunted and yellow. Loosen soil before planting or after plant emergence. Hill soil around each plant base to encourage new roots above diseased areas, providing the crop is not to be harvested mechanically. See Vegetables M 7.

Rhizoctonia stem rot (*Rhizoctonia solani*) may kill seedlings and mature plants. Sunken brick red lesions occur on ***lower stem*** and ***roots*** of ***seedlings*** often before they emerge (damping off). Cankers develop on ***stems*** of ***older plants*** but there is little yield loss. Plants may recover and give a satisfactory crop after producing new roots above diseased areas. Some plants are stunted. Reddish spots develop on ***pods*** in contact with soil. The fungus spreads rapidly during transit, often with brown fungal growth appearing on affected areas. A rapid ***postharvest*** transit rot with off-white fungal growth can develop. ***Favoured*** by large amounts of plant residues remaining in the soil, light soils where seedling loss and pod infection can be serious. ***Prepare land*** thoroughly so that plant residues are completely broken down before planting. ***Treat seed*** with recommended fungicide, hill plants to encourage new roots. See Vegetables M 7.

Root rot complex (*Aphanomyces euteiches*, *Fusarium* spp., *Fusarium solani*, *Pythium* spp.). Plants are ***stunted*** and older ***leaves*** turn yellow and wilt. The ***tap root*** and ***lower stem*** is reddened and rotted, and may die and be completely destroyed. Plants produce clusters of fibrous roots just below ground level. If growing conditions are good plants may recover. With cold, wet conditions yields are usually low. Soil inhabiting fungi are ***favoured*** by low temperatures and wet conditions during growth and when continual growth occurs in the same area for years. ***Deep-rip soils*** to improve drainage and aid root penetration. ***Avoid deep planting***; sow at depths of < 25 mm during winter months. On light soils ***hilling*** encourages new root growth, this is not recommended for heavy soils. ***Rotate beans*** with crops other than legumes. ***Cultivar selection*** is important (Persley et al. 1989, Persley 1994, Salvestrin 1991).

Sclerotinia rots, white moulds, (*Sclerotinia sclerotiorum, S. minor*) causes a ***white fungal growth*** on above-ground plant parts. Black ***sclerotia*** up to 12 mm long develop. The fungus often attacks the stem at ground level and the plant dies. A rapid rot of infected ***pods*** (nesting) may develop ***postharvest***. See Vegetables M 7

Sclerotium stem rot (*Sclerotium rolfsii*) causes a pale dry rot of ***stem*** and ***root***. White threadlike sometimes fan-shaped fungal growth, small, brown spherical ***sclerotia***, 2-3 mm in diameter develop on mycelium. A similar rot to that on stems develops on the pods in contact with soil. See Vegetables M 8.

Others: Thielaviopsis black root rot (*Thielaviopsis basicola*).

See Vegetables M 7.

Rust (*Uromyces appendiculatus*): Pustules develop on leaves, stems and pods. ***Leaves*** may yellow, wither and die. ***Pod*** pustules may be small, raised, firm watersoaked blisters or may be large with rust spores. ***Twospotted mites*** (*Tetranychus urticae*) are attracted to rust uredinia on older leaves and vector them to rust-free plants (Batra and Stavely 1994). ***Favoured*** by cool to warm, damp weather, heavy dews during autumn. Plant ***resistant*** cultivars or ones that are slow rusting. If growing susceptible cultivars choose planting time carefully. Races vary in their ability to attack bean varieties. ***Another rust*** (*Phakopsora pachyrhizi*) may also attack beans. See Annuals A 7.

Others: ***Powdery mildews*** (*Erysiphe polygoni, Sphaerotheca fuligena*), ***wilts***, eg *Fusarium oxysporum*, *Verticillium dahliae.*

NEMATODE DISEASES

Foliar nematodes (*Aphelenchoides* spp.)
Root knot nematodes (*Meloidogyne* spp.)
Root lesion nematodes (*Pratylenchus* spp.)
Stem and bulb nematodes (*Ditylenchus* spp.)
Spiral nematode (*Helicotylenchus dihystera*)
Stunt nematodes (*Tylenchorhynchus* spp.)
Also *Aphelenchus avenae, Filenchus exiguus*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Bean root aphid (*Smynthurodes betae*) infests bean ***roots*** in coastal areas. Aphids are small, globular and covered with white mealy material ***resembling mealybugs***. The white material can be seen in the soil beside the infested plants. Aphids produce ***honeydew*** which usually attracts ants. Aphids suck sap from roots causing only slight damage except possibly when bean crops are stressed by drought. ***Overwinters*** on roots of hosts. Pesticides are not recommended, ***good cultural care*** of the crop should provide adequate control.

Cowpea aphid (*Aphis craccivora*) is ***greenish black***, about ***2.5 mm*** long and may cluster on and suck sap from growing points and leaf undersurfaces, causing yellowing and distortion of ***foliage***. Young plants and plants in dry conditions may be stunted. During spring and autumn aphids swarm on to bean crops from other legumes. Infestations do not increase rapidly on French beans because they become trapped on epidermal hairs; high numbers on French beans depend on fresh arrivals of winged aphids. ***Natural enemies*** can eliminate infestations after swarms into crops cease. See Pea M 74.

Others: Green peach aphid (*Myzus persicae*) and ***pea aphid*** (*Acyrthosiphon pisum*).

Aphids transmit ***virus diseases***, eg cowpea aphid transmits bean yellow mosaic and subterranean clover stunt; green peach aphid and pea aphid transmit bean yellow mosaic. Pods may need ***washing*** after harvest before marketing to remove honeydew and aphid skins. See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)

Green mirid bug, blind eye bug (*Creontiades dilutus*) is slender, pale green to yellowish green about ***6 mm*** long. It sucks sap from ***axillary buds*** which develop into flower racemes. Small green buds wither and fall, leaving only the pair of bracts (blind eye) resulting in the absence of blossom and beans in spring. Plants can recover (if given sufficient moisture) and produce a crop of beans. ***Inspect*** bean plants frequently in spring, insecticides may be applied when bugs are first seen. See Vegetables M 12.

Green stink bug (*Plautia affinis*) is a green shield bug about ***8 mm*** long, with brown wing covers. It may invade bean crops in large numbers and damage ***pods*** by sucking juices. They are similar to green vegetable bugs but smaller and give off an offensive ***odour*** when handled.

Green vegetable bug (*Nezara viridula*) is a green shield bug about ***15 mm*** long. All stages suck ***pods*** dry, leaving them shrivelled, distorted, and containing only empty shrivelled seeds. Immature stages are smaller, brownish black, oval-shaped with orange markings. ***Monitor*** bugs at regular intervals before applying insecticide (Brough et al. 1994). See Vegetables M 12.

Harlequin bug (*Dindymus versicolor*) is about ***12 mm*** long. The head, inner margins of the forewings and wing tips are black, the thorax and bases of the forewings are reddish orange, and the undersurface of the body is yellowish green with red and black markings. Bugs may invade beans in large numbers and suck ***pods*** dry. See Vegetables M 12.

Podsucking bugs (*Riptortus* spp.) are native, slender, ***18 mm*** long, dark brown with a yellow stripe on each side, and spines on the thorax and hind legs. They may cluster in large numbers on ***pods*** and quickly suck them dry, reducing the seeds inside to husks.

Rutherglen bug (*Nysius vinitor*) is small, grey-brown, about ***5 mm*** long, about 1.5 mm broad. It swarms on to bean plants and sucks sap from ***leaves*** and ***stems*** causing them to wither. See Vegetables M 12.

See Vegetables M 12.

Caterpillars (Lepidoptera)

Bean podborer (*Maruca testulalis,* Pyralidae) infests legumes, eg beans and peas, in warm moist climates. ***Moths*** are brown with a wingspan of about 30 mm. They usually shelter in foliage during the day. When disturbed they fly rapidly to nearby sheltered areas. ***Caterpillars*** are cream, light yellow or green with small dark spots on the body, and up to ***25 mm*** long. They web ***leaves, blossoms*** and ***pods*** together. Young caterpillars bore into ***buds***, ***blossoms*** or ***young pods***; older caterpillars usually bore into pods and excrement extrudes through entrance holes. Occasionally they burrow down ***leaf stalks*** of French beans. Caterpillars pupate in the pod or on the ground. ***Monitor*** pod damage during early pod set before making a decision to apply insecticide (Brough et al. 1994).

Butterflies: ***Bean flower caterpillar*** (*Jamides phaseli,* Lycaenidae) feeds in ***flower buds*** of beans and is a minor pest. Mature caterpillars are pale brown with darker longitudinal lines and a brown head. ***Grass blue butterfly*** (*Zizina labradus,* Lycaenidae) is blue-grey with a wingspan of about 25 mm. It lays pale blue, mandarin-shaped eggs singly on leaves, buds and flowers during summer. ***Caterpillars*** are slug-like, about ***10 mm*** long, greenish, with a white strip down each side of the body covered with short hairs. They feed on the ***young leaves, buds, flowers*** and ***young pods*** of legumes, eg beans, peas, clovers, medics, virgilia (*Virgilia capensis*), darling pea (*Swainsonia greyana*) and indigo (*Indigofera* spp.). They also chew into developing pods to feed on ***seeds***, leaving round holes in the pods causing breakdown and rotting. Caterpillars may be attended by small black ants. ***Pea blue butterfly*** (*Lampides boeticus*) is also a pod borer (Common and Waterhouse 1981).

Noctuids (Noctuidae): ***Corn earworm*** (*Helicoverpa armigera*) and ***native budworm*** (*H. punctigera*) feed on ***buds, flowers, young leaves*** and ***pods***. Older caterpillars enter pods and eat seeds. Entry and exit holes are seen on buds and pods. Caterpillars pupate in the soil. ***Monitor*** pod damage from early pod set before applying an insecticide (Brough et al. 1994). See Sweetcorn M 89. ***Cutworms*** (*Agrotis* spp.) damage ***seedlings*** which may be girdled or cut through at the base so that they fall and die. Older plants may also be heavily infested and suffer partial or complete defoliation. See Seedlings N 68. ***Looper caterpillars*** (*Chrysodeixis* spp.) when young, partly chew small holes in ***young leaves***. Older caterpillars chew ragged holes in leaves and excavate deeply into maturing ***pods***, sometimes almost cutting them in two. See Vegetables M 13. ***Eublemma dimiclasis*** caterpillars damage pods of mung beans.

See Annuals A 8, Vegetables M 13.

Flies (Diptera)

Bean fly (*Ophiomyia phaseoli,* Agromyzidae) may be a serious pest of French beans. ***Flies*** are robust, glossy, black, about 2 mm long and are seen egg-laying in 1st pair of leaves. ***Maggots*** are tiny and mine in ***leaves*** then in ***stems*** at ground level within a week of seedlings emerging (Fig. 313). Seedlings then yellow, wilt and die (8-10 maggots can kill a seedling, though more may be present). If older plants are attacked, maggots tunnel down into ***branches*** and ***branchlets*** causing blistering and longitudinal cracks. Branches break during picking or wind. ***Pods*** may be tough and flabby. Maggots pupate in the outer tissue of the stems. There are many generations each year. ***Spread*** by adults flying. ***Favoured*** by humid weather during summer and autumn, successive bean crops in spring. ***Control: Hill plants*** about a fortnight after seedlings emerge and again when larger to support plants, bring more soil, and therefore more nutrients, into the root zone and help to overcome damage to lower stem. ***Pupae may be killed*** by low winter temperatures, predatory ground beetles and parasitised by wasps. ***Seed*** should be treated. ***Monitor*** damage daily after emergence before applying an insecticide (Brough et al. 1994).

Onion maggot (*Delia platura*) is yellowish white, legless, about ***6 mm*** long bores into ***stems*** hollowing them out ***below ground***, especially after topdressing with blood and bone fertiliser. Young plants at the 2-leaf stage wilt suddenly and topple over. Maggots may feed on more than 1 stem, as many as 20 may be found attacking one bean plant. Seed treatments have been used overseas but are not considered necessary in Australia. See Onion M 68.

Seedling bean midge (*Smittia aterrima,* Chironomidae) infests beans, early crops of cucumber, marrow, squash, decaying organic matter. ***Male flies*** are small, black midges about 2.5 mm long, slightly longer than females and have bushy antennae. They are seen in the evening dancing in swarms above soil. ***Female flies*** lay eggs amongst organic matter on soil. These hatch into maggots that normally feed on decaying organic matter, but are also attracted to slow-germinating bean seeds. ***Maggots*** are white, thread-like, about ***5 mm*** long and feed on ***seeds*** and ***leaves***. Secondary decay often follows, seedlings may be destroyed before they emerge or stems may appear with only seed leaves (blind stems). Mild injury results in lacy expanding primary leaves, plants are slow to develop. Usually only an odd plant is damaged but sometimes replanting is necessary. When fully-fed, maggots pupate in soil. ***Spread*** by flies flying short distances. ***Favoured*** by abundant organic matter (fresh poultry or farmyard manure or soil into which heavy growths of green material have recently been ploughed), by early crops planted in cold, wet, poorly drained situations in spring when soil temperatures are too low for rapid germination. ***Cultivation*** destroys large numbers. Only plant seed when ***germination*** is expected to be rapid.

Greenhouse whitefly (*Trialeurodes vaporariorum*) is small, delicate, white and about 1.5 mm long. It congregates on ***leaf undersurfaces*** sucking plant sap and secreting honeydew which encourages sooty mould, making pods unattractive. Severely infested plants may lose vigour and wilt. See Greenhouses N 24, Vegetables M 15.

Leafhoppers (Cicadellidae, Hemiptera)

Common brown leafhopper (*Orosius argentatus*) is ***brown***, speckled, wedge-shaped, about ***3 mm*** long and moves rapidly if disturbed. It sucks sap from ***leaf undersurfaces***. They normally feed on native and weed plants and fly into crops when their natural hosts dry off in warm, dry conditions. Nymphs are similar in shape to the adults but are wingless and may differ in colour. Adults ***transmit*** the bean summer death virus. See Vegetables M 15.

Vegetable leafhopper (*Austroasca viridigrisea*) is small, ***yellow-green***, about ***3-4 mm*** long. It also sucks sap from leaf undersurfaces. ***Leaves*** develop irregularly-shaped ***yellowish flecks*** especially near the margins. Specks may join together giving leaves a greyish-yellow appearance and stunting growth. Damage to ***seedlings*** can reduce vigour. See Vegetables M 15.

See Vegetables M 15.

Leafminer (*Phyllonorycter aglaozona*, Gracillariidae, Lepidoptera) is black and white. Caterpillars mine in ***leaves*** of Fabaceae, eg French beans, glycine, *Kennedia*, and soybean. See Azalea K 28.

Potato ladybirds (*Epilachna* spp.) and their spiny larvae may feed on beans after they have been numerous on neighbouring plants and weeds. By grazing only on the ***leaf surfaces*** ***(skeletonisation)*** they usually leave one surface uneaten giving the foliage a brown, lace-like appearance. Insecticides are registered for use. See Potato M 81.

Thrips (Thripidae, Thysanoptera)

Bean blossom thrips (*Taeniothrips nigricornis*) attacks legumes, especially dwarf French beans. ***Adults*** are very small, dark brown, about 1.5 mm long with fringed wings. Adult thrips enter ***flowers*** and attack developing ***pods*** which become distorted and are often pimpled and lumpy. Thrips feed in colonies, often causing rusty marks mostly near stalk ends of the ***pods***. In late autumn, bean pods injured by these thrips often develop ***secondary rots***, eg *Sclerotinia* rot and pod twist. Heavy infestation may produce rusty blemishes on ***leaf undersurfaces*** especially close to leaf stalks. Leaf margins turn down, foliage has a puckered appearance. There are ***many generations*** each season. In the autumn, bean flowers usually have some thrips in them. There may only be 20-30 per flower. Eggs are inserted into the soft tissue of flowers, leaves or pods. Nymphs are minute, pale yellow and wingless, but turn deep orange-red as they grow older. When fully-grown they drop to the ground and pupate in the soil. Winged adults return to the plant. ***Spread*** by windborne winged adult thrips. ***Favoured*** by warm, humid weather during late summer and autumn. Little is known of the ***natural agencies*** regulating thrips populations. ***Cold weather*** and absence of suitable host flowers must cause population decline each winter. ***Isolation of plantings***, or ***early destruction*** of harvested crops after a succession of bean plantings may be necessary. If thrips are obvious when flowering starts, ***insecticides*** may also be necessary.

Onion thrips (*Thrips tabaci*): Young bean plants may be severely damaged, if soil conditions are dry, as thrips move on to beans from other crops or weeds. Wingless nymphs and brown winged adults feed on ***leaf undersurfaces***, margins turn down, leaves yellow and may become brown and withered if the infestation is heavy. Adult thrips prefer to feed along the main veins on the ***leaf uppersurfaces*** causing greyish patches of feeding marks that give leaves a mottled appearance. Older leaves on bean plants become shiny and silvery. ***Heavy rain*** or overhead irrigation will provide control. See Onion M 68.

See Roses J 6, Vegetables M 17.

Twospotted mite, red spider

A worldwide pest which feeds on a variety of plants, it is probably the ***most important pest of beans***.

Scientific name: Tetranychidae, Acarina:
Bean spider mite (*Tetranychus ludeni*)
Twospotted mite (*T. urticae*)
These two species are so similar in habit that they can be considered together. ***Redlegged earth mite*** (*Halotydeus destructor*) which is deep blue, about the size of a pin head with bright red legs, may also infest French beans. See Vegetables M 17.

Host range: Wide range, ***ornamentals***, eg carnation, cymbidium, hollyhock, indoor plants, marigold, nasturtium, palms, perennial phlox (*P. decussata*), rose, umbrella tree, violet, ***fruit***, eg deciduous fruit trees (especially apple, pear), trailing berries, strawberry, ***vegetables***, especially French beans, cucumber, capsicum, eggfruit, tomato, cucurbits, rockmelon, ***field crops***, eg cotton, ***weeds***, eg broadleaved weeds.

Description and damage: ***Adult mites*** are just large enough to be seen with the naked eye but are easily seen with a hand lens. They are small, globular, almost translucent, up to ***0.5 mm*** long with 4 pairs of legs (Fig. 314). They vary in colour from green-grey to bright red (depending on the host plant and the season). The mites have distinctive dark markings on either side of the body. These are particularly large and prominent in the adult female. ***Adult females*** are rather pear-shaped, can move actively and spin fine webbing over the surface on which they are feeding, in winter they turn ***orange-red***. Adult females of the ***bean spider mite*** are red (Fig. 315) and easily distinguished from twospotted mite. ***Males*** are smaller and narrower. ***Nymphs*** are almost colourless and initially have 3 pairs of legs but later nymphal stages have 4 pairs. Nymphs and adults suck sap from ***leaf undersurfaces*** and spin fine webs on which they crawl around and to which they attach their eggs. In heavy infestations upper surfaces are also infested. Leaves become a dull speckled grey-green colour (Fig. 316), bleached and may wither and fall prematurely. On beans, infestation usually begins on lower leaves and progresses upwards. Severely infested plants yellow and stop growing, mites swarm to the topmost parts of plants, web production is stimulated and plants become covered in fine webbing (Fig. 317). All stages, eggs, nymphs and adults, empty egg-shells, nymph skins and webbing can be seen with a hand lens on ***leaf under surfaces***. When mite populations are high, tiny black predatory ***mite-eating ladybirds*** (*Stethorus* spp.), their larvae and black pupae which are about ***1 mm*** long, are found on infested leaves (Fig. 318). *Stethorus* beetles and their larvae feed on mites. ***Do not confuse*** twospotted injury to leaves with damage caused by leafhoppers, greenhouse thrips and greenhouse whitefly or deficiencies. See Trees K 24 (Table 3). ***Flowers*** of some plants may suffer severe damage. ***Mature pods*** look grey, are tough and are not crisp. Severe infestations every year retard growth and cropping. As mites move to weeds at the start of cold weather at the end of the growing season, mites are absent from leaves. Presence of mites on some crops, eg apples, may cause irritation and ***allergic reactions for fruit pickers***.

Pest cycle: Gradual metamorphosis (egg, nymph, adult) with many generations during the warmer months. Adult mites lay up to 70 small round translucent eggs at a rate of a few eggs per day on leaf undersurfaces, usually close to veins. Development from egg to adult may be ***7-11 days*** in summer. Young adult females move up to the nearest new leaf to lay their eggs but after that they stay on the leaf. All stages of the life cycle occur together, usually near the veins.

Overwintering: In cold areas as inactive non-feeding female adults mainly on broadleaved weeds and on litter. A few males survive and these, with mature females, turn bright red and hibernate and form bright red clusters on leaf undersurfaces or in dark crevices. ***On deciduous plants***, eg roses, they descend from plants and camp on the lower parts of main stems, in cracks or damaged bark, under debris at the bases of main stems. Some migrate to nearby perennial weeds where they feed and reproduce at a slow rate during winter. ***On evergreen hosts***, eg violets, females also change colour but often remain on plants, feeding and reproducing at a slow rate. ***In warm climates*** and in greenhouses, breeding is continuous.

Spread: By crawling from plant to plant or carried on windblown leaves, webbing, clothing, machinery, plant debris, visiting insects and birds, etc. By the movement of infested plants (with leaves) in containers and by propagation from infested plants (with leaves). New bean plantings are usually infested from older crops or weeds.

Conditions favouring: Hot, dry weather. Heavy falls of rain or good irrigation can reduce infestations. Availability of plant nutrients may also have some effect. Use of pesticides to kill other pests may reduce natural predators.

Control: Mites cannot be eradicated, the aim is to keep populations just below damaging levels.

Cultural methods: Frequent overhead irrigation directed to leaf undersurfaces, or rain, may reduce reproduction rate and need for chemical control. It also replaces sap lost through mites feeding. Foliage diseases may be increased on susceptible varieties. Container plants, eg violets outside, can be moved from hot, dry sites and replanted in cooler, shaded areas. Avoid planting susceptible species in hot, dry situations.

Sanitation: Keep surrounding areas free from ***weeds and other susceptible hosts***. Plough-in old bean crops after harvest. Avoid planting new crops ***close to the sites*** of old bean crops or introducing mites into plantings from infested weeds on cultivation machinery or clothing.

Biological control: ***Natural enemies*** include adults and larvae of the tiny, black, predatory ***mite-eating ladybirds*** (*Stethorus* spp.) which are the most important predators (Fig. 318). *Stethorus* is susceptible to insecticides and also to some fungicides. Other natural predators include ***mites***, ***lacewing larvae*** and ***thrips*** which provide some control. ***Natural control*** of twospotted mite may be inadequate. ***Imported predatory pesticide-resistant mites*** (*Amblyseius* spp., *Phytoseiulus persimilis* and *Typhlodromus occidentalis*) can be purchased or bred by growers (Fig. 318). These mites are not resistant to all pesticides so follow supplier's instructions. Successful use of predatory mites requires routine inspection of the plants by staff trained to ***identify and monitor*** mite and predatory mites (and other pests and diseases). Predators are often more effective in ***monocultures*** and may be effective on their own. A ***lacewing*** (*Mallada signata*) is also available. An application of a ***miticide*** may be necessary either before or after release of predators.

Resistant varieties: Some house plants are very ***susceptible***, eg umbrella plant, cocos palm.

Plant quarantine: Fruit carrying more than a certain number of mites may be ***refused entry*** to some countries, eg UK.

Pesticides: If predatory mites are used, any pesticides used on the crop must be carefully selected. Otherwise apply miticides at the first sign of infestation, repeat applications may be necessary. Some miticides are only effective against ***certain stages***, eg eggs, nymphs or adults. Good coverage of leaf undersurfaces is necessary to achieve control. Twospotted mite has developed ***resistance*** to many insecticides and miticides, bean spider mite has not to the same extent. ***Selective pesticides*** should be used, eg ones not toxic to natural enemies; broad spectrum pesticides increase mite populations.

Pest management: Mite resistance and the effect of pesticides on natural enemies has encouraged growers to use imported predatory mites in pest management programs. ***Monitoring*** of both mites and predators is essential for effectiveness.

Weevils (Coleoptera)

Bean weevil (*Acanthoscelides obtectus,* Chrysomelidae) is a widespread pest of bean, pea and cowpea seed in the ***field*** and ***postharvest***. Adults are not true weevils. They are stout, brown, ***3-4 mm*** long with white, grey, brown or black patches on the uppersurface, reddish legs and antennae. ***Larvae*** are up to ***3 mm*** long, legless. All stages are difficult to detect in lightly infested seed, which should not be planted as germination will be irregular and some plants may be stunted. There is a ***complete metamorphosis*** (egg, larva, pupa, adult) with several generations each year. Females lay eggs on mature and drying bean pods in the field. 1st stage larvae have legs and move through pods and bore into seeds. Later-stage larvae bore inside the bean seed, then pupate. Adults eat their way out, leaving ***circular holes*** and infest other seeds in store. ***Spread*** by adults flying from infested bean crops and stored bean seed. ***Favoured*** by warm, dry conditions in the field. In storage they may breed all year. If beans are harvested for seed, bag as soon as dry, fumigate or dust. ***Insecticide dusts*** kills emerging adults ***but not larvae or pupae inside seeds***. After treatment, store bean seed in beetle-proof sacks or muslin bags. See Seeds N 79 (Fig. 443).

Fuller's rose weevil (*Asynonychus cervinus,* Curculionidae) chew pieces from ***leaf edges***, producing ***a saw-toothed appearance*** in late summer and autumn. ***Larvae*** destroy fibrous roots and gouge out the main ***root***. Plants may ***die***, crop quantity and quality may be reduced. See Rose J 6.

Whitefringed weevil (*Graphognathus leucoloma*) larvae may damage beans sown in land previously ***under lucerne or pasture*** with a clover content, or which has been under a heavy growth of susceptible broadleaved weeds. See Vegetables M 17.

See Vegetables M 17.

Others: ***Green scarab beetles***, green spring beetles (*Diphucephala* spp.) are bright green, about 8 mm long, with a metallic sheen on their wings. They cluster in large numbers on bean plants in summer and chew ***foliage***. Larvae are curl grubs in the soil. A ***flat mite*** (*Brevipalpus* spp., Tenuipalpidae) is small, flat, shield-shaped, red-brown, sluggish false spider mite, almost hairless with thick stubby legs. There is no webbing. Tiny oval red eggs are laid near main veins on leaf undersurfaces. Damage is uncommon. ***Favoured*** by warm weather. Foliage, stems and pods become rusty brown, smooth and slightly shiny, especially at junctions of leaf blades with stalks. ***Others: Crickets, grasshoppers, locusts*** (Orthoptera), ***garden symphylid*** (*Scutigerella immaculata*), ***passionvine leafhopper*** (*Scolypopa australis*).

SNAILS AND SLUGS

Snails and slugs may damage foliage. See Seedlings N 70.

Non-parasitic

Environment: ***High temperatures*** may cause ***flower drop*** with resultant loss of crop. Adequate irrigation helps to reduce flower drop. ***Sunscald*** damage to ***pods*** (slightly sunken streaks) usually occurs on one side of the pod only. Islands of dead tissue develop on ***older leaves***. ***Inadequate cooling and ventilation*** during transport causes a ***red russet*** discolouration of the ***pods***.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for French beans (Weir and Cresswell 1993). ***Deficiencies***, eg of molybdenum, phosphorus and zinc, and ***toxicities***, eg of manganese, may occur.

Poor germination can be caused by fertiliser coming in ***direct contact*** with the seed; planting too early when the soil is too cold; crusting at the soil surface; overwatering; and damaged seeds. ***Nail head, bald head*** is caused by mechanical injury to seed. Seedlings have no growing tips, the stem above the cotyledons is a bare stump. Plants may die or may produce shoots in the axils of the cotyledons and grow into a small plant. Injury to young plants by the green mirid bug or rabbits can cause similar symptoms but usually occurs after the first true leaves have formed. Thresh and handle bean seed carefully at all times. Avoid dropping seed. Make sure that planters do not damage seed.

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State/Territory Departments of Agriculture/Primary Industry eg

Anthracnose Beans : Seed Quality and Sowing Rates (Tas Farmnote)
Anthracnose of French Bean (NSW Agfact)
Beans : Bacterial Blight (Vic Agnote)
Beans : Disease and Pest Control (Vic Agnote)
Beans (Phaseolaris) : Weed Control (Vic Agnote)
Disease of Beans (NSW Agfact)
Diseases of Green Beans (Tas Farmnote)
Dwarf Beans in the Home Garden (Vic Agnote)
French Beans : South Queensland : Insect Pest Control (Qld Farmnote)
French Bean Seed Production : Weed, Disease and Pest Control (Qld Farmnote)
Green Beans for Processing : Cultural Notes (Tas Farmnote)
Halo Blight of Bean (NSW Agfact)
Pest of Beans (NSW Agfact)
Pests and Diseases of French Beans (SA Fact Sheet)
Production of Dry Edible Beans (Vic Agnote)
Production of Fresh Beans (Vic Agnote)
Postharvest Diseases, Injuries and Disorders of Vegetables (NSW Agfact)
Subterranean Clover Stunt of Beans (NSW Agfact)

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

French beans are grown for the fresh market and for processing. An overview of the industry is presented by Coombs (1995). Bean plants do not have much ability to recover from injury so diseases and pests should be controlled. ***Select varieties*** suited to the local area and the market. Green beans are more frost sensitive than potatoes. Plant cultivars ***resistant*** to rust and other problems prevalent in the area. Plant certified ***disease-free seed*** to ensure freedom from seedborne diseases and pests. When storing or handing bean seed avoid contact of seed with possible sources of ***contamination***, eg machinery, bags or clothing. Handle seed with care. Seed is usually treated with fungicide prior to planting to reduce damping diseases. ***Practise crop rotations*** of 3-4 years with non-legume hosts. ***Prepare land early*** and keep ***weed-free*** for several weeks before planting to reduce incidence of soilborne pests, eg cutworms. Do not plant new crops close to old spent crops that could be heavily infested with twospotted mite. ***Plant in*** well drained fertile soil known to be free from *Sclerotinia* or *Fusarium*. Sow at correct density and row spacing into moist seedbeds to get even germination (irrigate if necessary 2-3 days before planting to ensure sufficient moisture is present). When plants are a few weeks old, hilling soil up on each side of the rows can reduce the effects of any early attack by bean fly. ***Wet foliage*** favours disease so wherever possible allow time after watering so that foliage is dry before nightfall. ***Fertiliser programs*** should be based on soil and tissue analyses. ***Control weeds***, eg onion twitch, with post-emergence herbicides ***before planting***. Control later weeds mechanically (avoid plant damage) or with pre- or post-emergence herbicides. ***Monitor crops*** regularly for serious ***diseases***, eg *Sclerotinia* rot and grey mould, from flowering onwards, and ***pests***, eg corn earworm and mite incidence, and apply control measures before significant damage develops. ***Commercial pest monitoring services*** are available in some areas, eg Qld. ***Harvest*** pods when recommended, they should be fast cooled (up to 4 hours) at 7°C and 90-95% relative humidity. ***Storage and transport:*** Avoid packing beans which are wet or showing signs of disease or injury. Where there is a risk of ***postharvest*** diseases, eg *Sclerotinia* rot, pods may need to be dipped in fungicide.

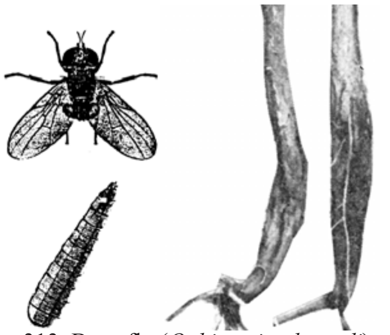

Fig. 313. Bean fly (*Ophiomyia phaseoli*).
Left : Adult fly (2 mm long) and maggot.
Right : Damage. Dept. of Agric., NSW.

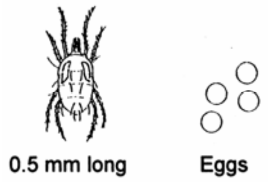

Fig. 314. Twospotted mite (*Tetranychus urticae*).

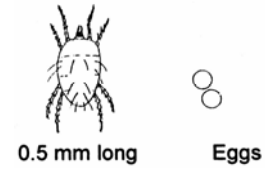

Fig. 315. Bean spider mite (*T. ludeni*).

Fig. 316. Damage by twospotted mite (*T. urticae*). Leaves become a sandy speckled grey.

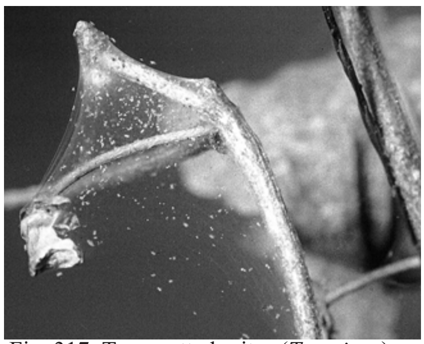

Fig. 317. Twospotted mites (*T. urticae*) swarm to the topmost parts of bean plants.

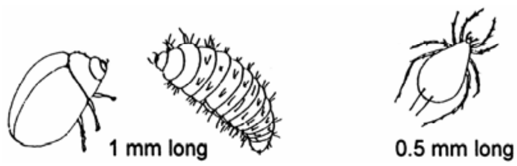

Fig. 318. Predators. ***Left :*** Beetle (*Stethorus* sp.) and larva about 1 mm long. ***Right :*** Mite (*Phytoseiulius persimilis*) about 0.5 mm long.

Beet

Beet (*Beta vulgaris*)
Beetroot (*B. vulgaris* ssp. *vulgaris*)
Silver beet (*B. vulgaris* ssp. *cicla*)
Spinach (*Spinacia oleracea*)
Family Chenopodiaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases are usually of minor importance. Some only affect beets while others affect a wide range of economic plants and weeds. Leaf symptoms include yellow spots, rings, mottles and pale green irregular blotches. Yield is not usually affected, an exception is beet mosaic.

Alfalfa mosaic virus (calico) affects vegetables, field crops and weeds, causing pale green irregular blotches on leaves, often affecting large areas of each leaf. Symptoms may fade and disappear. ***Spread*** by aphids (Aphididae), by mechanical inoculation, by grafting, by seed (10% in commercial seed), by pollen to seed, not by contact between plants.

Beet mosaic virus affects beet and weeds, causing yellow spots, rings or mottles on leaves. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*).

Beet western yellows virus may infect beets, cabbage, sunflower, soybean, rapeseed. Leaves yellow, significant losses in yield. Infected plants may taste slightly sweeter, sugars accumulate in yellowed leaves and plants are usually smaller causing sugars to concentrate. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), not by seed, not by pollen.

Others: Beet cryptic 1 virus, beet crypto 11 virus, beet pseudo-yellows virus, cucumber mosaic virus, subterranean clover red leaf virus.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial blight (*Pseudomonas syringae* pv. *aptata*)
Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*)
Bacterial wilt (*Pseudomonas solanacearum*)
Crown gall (*Agrobacterium* sp.)
Scab (*Streptomyces* sp.)
Also *Pseudomonas marginalis* pv. *marginalis.*

FUNGAL DISEASES

Cercospora leaf spot (*Cercospora beticola*) is probably the ***most serious foliage problem*** of silver beet, beetroot, related weeds (Fig. 319). Spots develop on ***leaves, flower stalks, seed bases*** and ***seed*** during warm (24-30^{o}C), wet conditions. Light grey spots up to 3 mm across with brown or red margins develop on the oldest leaves. Centres may become brittle and drop out leaving irregular holes. Leaves may die. ***Other leaf spots:*** *Alternaria* spp., *Phoma betae*. Overseas many others may be more serious. See Annuals A 5.

Damping off (*Aphanomyces cochliodes*, *Fusarium*, *Pythium*, *Rhizoctonia solani*) causes a ***soft decay of the tap root***, causing collapse and rotting of seedlings. Overseas severe pre-emergence and post-emergence damping off affecting spinach, is associated with warm, wet soils with a history of spinach production. Management practices usually include seed treatment with a fungicide. See Seedlings N 66.

Downy mildew (*Peronospora farinosa*) infects ***leaves, crowns, seed stalks*** and ***inflorescences*** of beetroot, silver beet, spinach, mangels and wild beets during cool moist weather. Young heart leaves of beetroot are very susceptible. In the late stages of disease, centres of plants are a rosette of distorted leaves which may be covered with buff-grey downy spores. See Annuals A 5.

Root and stem rots, wilts

Aphanomyces black root rot (*Aphanomyces cochlioides*) causes a browning or blackening of the tap root of young plants. Leaves commonly turn red. In older plants large, dark, circular and depressed lesions occur on the globe. ***Favoured*** by warm weather and high soil moisture.

Fusarium root rots, eg *Fusarium oxysporum* f.sp. *betae*. ***Fusarium wilt*** (*F. oxysporum* f.sp. *spinaciae*) is a ***serious disease*** of spinach worldwide and may cause ***damping off*** of seedlings or attack more ***mature plants***. See Vegetables M 9.

Phytophthora root rot (*Phytophthora* spp.) causes root rots of spinach.

Rhizoctonia stem rot (*Rhizoctonia solani*) may cause brown-black, circular to oval cankers on roots of older beetroot plants. Cankers may extend up to 12 mm into the fleshy root tissue.

Sclerotinia rot (*Sclerotinia sclerotiorum*) may cause a cottony rot in the ***field*** and ***postharvest***.

Sclerotium stem rot (*Sclerotium rolfsii*) may attack stems near ground level.

See Vegetables M 7.

Others: ***Common scab*** (*Streptomyces scabies*) causes lumps on beetroot. ***Powdery mildew*** (*Oidium* sp.) causes whitish spots on leaves. ***Rust*** (*Uromyces beta*) may affect beet and swiss chard. ***White blister rust*** (*Albugo occidentalis*) is a serious disease of spinach overseas.

NEMATODE DISEASES

Beet nematode, beet cyst nematode, sugar beet nematode (*Heterodera schachtii*) infests ***vegetables***, eg beets, spinach, bean, rhubarb, brassicas, tomato, ***weeds***, eg fat hen, shepherd's purse, docks, wild radish, wild mustard. ***Roots*** develop many small, branched rootlets (Fig. 320) in which lemon-shaped ***nematodes*** about 1 mm long are embedded. Nematodes are white initially, but later turn into brown ***hard resistant cysts*** containing hundreds of eggs. The external presence of cysts on roots distinguishes this disease from root knot. ***Plants lack vigour***, may be stunted and wilt during hot weather or may die. In NSW, beet nematode occurs mainly in some districts in the Sydney Metropolitan Area. ***Favoured*** by soil temperatures between 15-25^{o}C. Do not plant ***susceptible*** crops in infested soil for 3-5 years. Destroy all host weeds as soon as they germinate. Do not plant infected seedlings. Prevent transfer of infested soil and seedlings to other areas. ***Pre-plant*** soil nematicides may be necessary.

Others: ***Root knot nematodes*** (*Meloidogyne* spp.) causes stunting, paler green than normal foliage, and wilting during hot weather. Plants may ***die***, especially spinach. See Vegetables M 10. Also ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* spp.), *Aphelenchoides, Filenchus, Merlinius, Scutellonema, Xiphinema.*

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Mangold aphid (*Rhopalosiphoninus staphyleae*)
Potato aphid (*Macrosiphum euphorbiae*) may cause wilting and produce honeydew during cool, dry weather in spring and autumn. Aphids may transmit ***virus diseases***. See Roses J 4, Vegetables M 11.

Beet leafminer (*Liriomyza chenopodii*, Agromyzidae, Diptera) infests beetroot, silver beet, spinach, wallflower, chickweed. ***Flies*** are about 1 mm long, grey with a yellow head, the abdomen is black with transverse yellow bands. ***Maggots*** are white and mine in ***veins and stalks*** making thread-like lines which enlarge as maggots grow. If leaves are not killed, their value may be reduced. Maggots pupate in the mines. ***There is a complete metamorphosis*** (egg, larva, pupa, adult) with several generations each year. Circular raised corky scars mark the points at which the eggs were laid in the leaf stalk. ***Spread*** by adults flying and introduction of infested seedlings and plants. If necessary, spray plants regularly at the first sign of infestation. See Cineraria A 28.

Bugs (Hemiptera)
Green stink bug (*Plautia affinis*).
Green vegetable bug (*Nezara viridula*)
Harlequin bug (*Dindymus versicolor*)
Rutherglen bug (*Nysius vinitor*).
All stages suck sap from ***foliage and stems*** of many species of plants. See Vegetables M 12.

Caterpillars (Lepidoptera)

Beet webworm (*Hymenia recurvalis,* Pyralidae, Lepidoptera) is a sporadic pest of Chenopodiaceae and other plants; ***vegetables***, eg beetroot, silver beet, ***ornamentals***, eg *Celosia*, ***weeds***, eg saltbush, giant pigweed, fat hen, *Amaranthus*. ***Moths*** are about 20-25 mm across outspread wings, brown with white bands across the fore and hindwings. If disturbed, moths take flight and settle again under leaves. ***Caterpillars*** are initially cream, later greenish with dark markings and a dark line along the back and up to ***18-20 mm*** long. They initially ***skeletonise leaf undersurfaces***, foliage becomes covered with webbing and pellets of excreta. Older caterpillars chew ***holes in leaves*** and feed around the fleshy crown and tops of roots. Plants may be destroyed. ***There is a complete metamorphosis*** (egg, larva, pupa, adult) with many generations each season. Females lay eggs on leaf undersurfaces, caterpillars pupate just below the soil surface. ***Overwinter*** as larvae in cocoons in soil. ***Favoured*** by warm, wet weather, weed hosts result in an early buildup of pest numbers. Moths may be numerous in late summer and swarm to lights. ***Destroy host weeds*** near beet crops early in the season. Natural enemies exert some control.

Others: ***Budworms*** (*Helicoverpa* spp.), ***cabbage white butterfly*** (*Pieris rapae*), ***cluster caterpillar*** (*Spodoptera litura*), ***cutworms*** (*Agrotis*, *Diarsia*, *Neumichtis*), ***loopers*** (*Chrysodeixis* spp.).

See Annuals A 8, Vegetables M 13.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) attacks silver beet during late summer. Young ***inner leaves*** and stalks may become rusty or silvery and distorted. See Greenhouses N 26.

Redlegged earth mite (*Halotydeus destructor*) and blue oat mite (*Penthaleus major*) cause ***leaves*** to whiten, ***seedlings*** may wither. See Vegetables M 16.

Spider mites (*Tetranychus* spp.) may attack beetroot and silver beet, especially if planted near older infested crops during hot weather. ***Plants*** look grey, lose vigour. See Beans (French) M 29.

Others: ***African black beetle*** (*Heteronychus arator*) may move in from adjoining areas and feed on maturing roots. ***Black field cricket*** (*Teleogryllus commodus*) may chew tops of beets in wet autumn, or young plants at ground level and cut them off. ***Others:*** Earwigs (Dermaptera), flea beetles (Galerucinae), greenhouse whitefly (*Trialeurodes vaporariorum*), seedharvesting ants (*Pheidole* spp.), weevils, eg Fuller's rose weevil (*Asynonchus cervinus*) and vegetable weevil (*Listroderes difficilis*).

SNAILS AND SLUGS

After prolonged wet weather, ***various species*** may chew foliage, hide in leaves and disfigure leaves with their excrement. See Seedlings N 70.

VERTEBRATE PESTS

Birds such as sparrows and starlings are partial to seedlings. See Fruit F 13.

Non-parasitic

Environment: ***Hail*** may damage the large leaves. Beetroot prefer ***cooler weather*** as roots have a higher sugar content and a darker consistent colour. In ***hot weather*** alternate red and white rings develop in roots. In very hot weather, high transpiration rates can cause ***wilting***. Beetroot grown slowly will be ***tough***, so avoid water stress or competition from weeds.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available (Weir and Cresswell 1993). ***Boron deficiency*** affects beetroot. In excessively alkaline soils young leaves die, older leaves wilt and brown, grey to black spots appear on fleshy parts of roots. If boron is applied to correct the deficiency, ***avoid boron sensitive crops***, eg celery, rockmelon, peas, potato, squash, tomato, watermelon, French beans, cucumber and strawberries, ***in rotation***. Other deficiencies include calcium and manganese. ***Excess nitrogen*** fertiliser may make beet too leafy and rank.

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State/Territory Departments of Agriculture/Primary Industry eg

Beetroot Growing (NSW Agfact)
Beet Webworm (NSW Agfact)
Disease of Beets (NSW Agfact)
Leaf Spot of Beetroot and Silver Beet (NSW Agfact)
Pests and Diseases of Beetroot (SA Fact Sheet)
Pests and Diseases of Silverbeet (SA Fact Sheet)
Silver Beet (NSW Agfact)
Silver Beet and Red Beet : Weed Control (Vic Agnote)
Spinach Growing (NSW Agfact, Vic Agnote))
Spinach in the Home Garden (Vic Agnote)
Sugar Beet (Tas Farmnote)
Sugar Beet Nematode on Vegetables (WA Farmnote)

Associations, Journals etc.

Good Fruit and Vegetables
Queensland Fruit and Vegetable Growers

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Silver beet (*B. vulgaris*) prefers warmer summer weather, ***spinach*** (*Spinacea oleracea*) is grown in cooler parts of the year and will become leathery and run to seed in warm conditions with long days. Spinach continues to increase in popularity as a leafy vegetable crop and is highly regarded for its nutritional value. Development of non-chemical methods of disease and pest control allow spinach to meet one of the goals of modern horticulture production; to produce a nutritious and profitable crop with little or no pesticide use (Correll et al. 1994). An ***overview of the industry*** is presented by Coombs (1995). Select ***disease-resistant*** cultivars. Obtain ***certified seed*** or treat seed with hot water. Only plant ***disease-free seedlings***. Seed may be dusted with fungicide and insecticide prior to planting to protect against soilborne damping off diseases and pests. ***Propagated*** by seed. Practise ***crop rotation*** (3-5 years). Avoid planting beet in soil infested with nematodes, soilborne diseases or insect pests. Plant seedlings in well ***drained***, slightly acid soil, rich in organic matter. Ensure that all plant residues are thoroughly decomposed before sowing. Prevent transfer of infested soil to disease-free areas. If necessary ***treat soil*** 1-7 days before planting with nematicide or by solarisation to reduce soilborne disering cultivation. ***Pre-emergence herbicides*** may be used to control weed seeds and ***post-emergence herbicides*** to control emerged weeds. Use ***pesticides*** with short residual activity on foliage. ***Harvest beetroot*** at the correct stage of maturity, old beetroot roots become tough, woody, over-large and are unattractive to consumers; cool in about 12 hours at $0^{o}C$ at high relative humidity (> 95%); beetroot may be stored for 12 weeks or more depending on storage conditions. ***Silver beet*** requires fast cooling (up to 4 hours) at $0^{o}C$ at very high humidity (>95%), is sensitive to ethylene and has an estimated storage of 1-2 weeks.

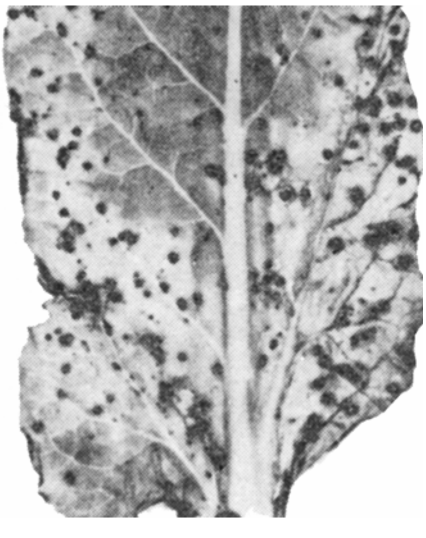

Fig. 319. Cercospora leaf spot (*Cercospora beticola*) Dept. of Agric., NSW.

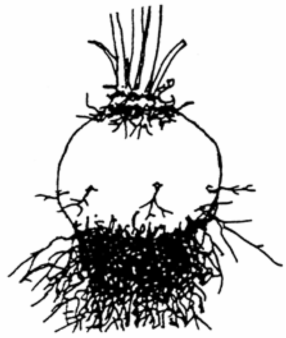

Fig. 320. Excessive branching of roots caused by the beet nematode (*Heterodera schachtii*)

Brassicas

Crucifers

Broccoli (*Brassicas oleracea* var. *italica*)
Brussels sprouts (*B. oleracea* var. *gemmifera*)
Cabbage (*B. oleracea* var. *capitata)*
Cauliflower (*B. oleracea* var. *botrytis*)
Radish (*Raphanus sativus*)
Rape (*Brassica napus*)
Turnip (*B. rapa*)
Family Brassicaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Beet western yellows virus may infect ***cabbage*** and rapeseed. Leaves turn yellow; significant losses in yield. See Beets M 33.

Broccoli necrotic yellow virus affects *Brassica* spp. including weeds. Broccoli (symptomless except when co-infected with cauliflower mosaic virus), Brussels sprouts (symptomless). ***Spread*** by aphids, eg cabbage aphid (*Brevicoryne brassicae*), by mechanical inoculation, not by seed.

Cauliflower mosaic virus affects brassicas. ***Veinclearing*** develops in the youngest leaves. Later ***veinbanding*** develops and is often more marked on one side of the leaf midrib. Leaf growth is restricted in affected sections causing leaves to bend to one side. Plants infected when young remain stunted, do not produce marketable heads. Symptoms persist and are usually most obvious during the cooler parts of the year. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), cabbage aphid (*Brevicoryne brassicae*), which carry the virus into a crop from older infected crops and brassica weeds, and from plant to plant within a crop, by mechanical inoculation.

Turnip mosaic virus, ***black ringspot*** affects annual and herbaceous plants in many families including ***Brassicaceae***, eg broccoli, cabbages, cauliflowers, stock, turnips and swedes, also alyssum, honesty, wallflower, nasturtium, ***weeds***, eg shepherd's purse, mustard, wild turnip. Only ***leaves*** are affected. Symptoms persist and vary with the temperature (cool temperate requirement for expression of severe symptoms). Avoid growing cabbages in very cold weather if the disease is prevalent. Use ***tolerant*** varieties. ***Cabbages, cauliflower and broccoli:*** Initially ***yellow ringspotting*** of the youngest leaves which later become mottled with light and dark green rings and blotches. Mosaic symptoms are more obvious at temperatures > 18^o C, at lower temperatures a definite black ringspotting of the outer leaves develops (Fig. 321). ***Turnips and swedes:*** ***Veinclearing*** of the youngest leaves, followed by a coarse mottle and ***dark green ring pattern***. ***Spread*** by 40-50 species of aphids especially green peach aphid (*Myzus persicae*), cabbage aphid (*Brevicoryne brassicae*), by mechanical inoculation (on cutting tools during flower gathering, on hands during crop inspection, flower gathering, planting out, etc), by vegetative propagation. Not by seed, not by soil.

See Vegetables M 4.

BACTERIAL DISEASES

Black rot, bacterial wilt (*Xanthomonas campestris* pv. *campestris*) affects brassica plants, including weeds, other hosts. ***Seedling*** stems develop small dark areas, leaves develop black veins, yellow and wilt. Seedlings may be dwarfed, die or develop on one side only. ***Leaves of older plants*** are infected through marginal water pores or wounds resulting in yellowish V-shaped spots which dry out. Bacteria then invade leaf veins, then stems and new leaves. Veins turn black, infected leaves yellow and fall. Black rot also infects leaves through stomates causing many irregular, pale brown spots. Spots become large, brittle, centres often tear and drop out, small veins surrounding the leaf spot blacken, leaves may die. ***On mature heads*** outer leaves are infected, or black rot may develop inside heads without external symptoms. These heads may be invaded by soft rot bacteria, becoming slimy with a putrid smell. Also ***bacterial wilt*** (*P. solanacearum*). See Vegetables M 6.

Bacterial leaf spots: ***Peppery leaf spot*** (*P. syringae* pv. *maculicola*) causes general flecking of cauliflower leaves in wet weather. ***Zonate leaf spot*** (*P. cichorii*) is common in soil and causes circular to watersoaked spots on cabbage, lettuce, Iceland poppy, clover and other plants in wet, windy weather. Avoid highly ***susceptible varieties***. See Vegetables M 5.

Bacterial soft rots (*Erwinia carotovora* pv. *carotovora*, *E. carotovora* pv. *atroseptica*) cause cabbage and cauliflower heads or turnip roots to become a soft rotten mass during ***transit and storage.*** Also ***bacterial soft rots*** (*Pseudomonas marginalis* pv. *marginalis, P. viridiflava*). See Vegetables M 5.

Others: ***Crown gall*** (*Agrobacterium* sp.), ***hairy root*** (*A. rhizogenes*).

FUNGAL DISEASES

Damping off (*Pythium*, *Fusarium*). ***Wirestem*** (*Rhizoctonia solani*) causes seedling stems to become thin and brittle. See Seedlings N 66.

Downy mildew (*Peronospora parasitica*) affects ***brassicas***, eg stock, hedge mustard. Pale green-yellow spots develop on ***leaves***, a white fungal growth develops on the undersurface, in cool damp weather spots enlarge. ***Seedling leaves and seedlings*** may ***die***. On older plants, lower leaves may be badly spotted or killed, younger leaves may be spotted. Under dry conditions, affected areas dry out to form large, irregular brown spots. ***Heads of cauliflowers*** may be attacked becoming black. ***Pods*** of seed crops may be distorted causing them to break open and expose the seed. See Annuals A 5.

Fungal leaf spots

Alternaria leaf spots (*Alternaria brassicicola, A. brassicae*): ***A. brassicicola*** causes dark brown spots up to 10 mm across on leaves of brassicas. Spots can also develop on the curds of cauliflower and on the flower stalk and seed heads of brassicas, resulting in reduction of seed yield. The disease is usually more important in seed than in market crops. ***A. brassicae*** produces much larger grey spots on the outer leaves of cauliflowers but seldom causes much damage, may cause a seedling blight. It is seedborne and favoured by warm moist weather.

Ring spot (*Mycosphaerella brassicola*) occurs in most brassica-growing areas, mainly on cabbage and cauliflower. Small, dark spots surrounded by a band of watersoaked tissue develop on ***leaves, flower stems*** and ***pods.*** Spots enlarge, become yellow-brown to grey-black, circular, about 10 mm across, and tiny black fruiting bodies of the fungus ***(pycnidia)*** develop in a series of concentric circles on the spots. Heavily infected leaves yellow and become curled, cracked and ragged at the edges and may fall, reducing yield and quality. ***Favoured*** by cool (15-20^{o}C), continuously wet conditions.

White leaf spot (*Pseudocercosporella capsellae*) infects brassicas (most severe in ***turnips***) and attacks ***cotyledons, leaves, petals*** and ***seed pods***. Spots have grey, brown or almost white centres with sightly darkened margins. Heavily spotted leaves may yellow and fall, affecting yield. Severely infected seedlings may ***die***.

Others: *Cercospora* spp., *Glomerella cingulata, Pyrenopeziza brassicae*.

See Annuals A 5.

Root, stem and base rots, wilts

Aphanomyces black root of radish (*Aphanomyces raphani*) causes dark irregular patches on ***roots*** of radish, eventually the entire root turns black. ***Spread*** by two types of spores. One is splashed by rain or carried by running water to other plants in the same or adjoining crops, the other can survive for several years in soil and is spread in soil or in crop trash. ***Favoured*** by warm temperatures and moist soil. Ensure good soil drainage. Long-rooted varieties are very susceptible. See Vegetables M 7.

Black leg (*Leptosphaeria maculans,* Ascomycetes) affects brassicas. ***Seedlings:*** A light brown depressed area develops near the base of the stem, these gradually enlarge, girdling the stem. ***Older plants:*** Brown spots may develop on leaves, seed, stems and pods, and small black fruiting bodies (pycnidia) of the fungus develop. Leaf edges may redden, plants wilt and may fall over. ***Fleshy roots*** of swedes and turnips in storage develop a dry rot on which the black fruiting bodies ***(pycnidia)*** develop. Spores produced in fruiting bodies on infected plants and crop debris are ***spread*** by rain or irrigation to nearby healthy plants. ***Favoured*** by wet weather, temperatures that favour the growth of crucifers.

Club root (*Plasmodiophora brassicae,* Eumycetes) affect ***brassicas***, especially cabbage, cauliflower. Some races affect only certain brassica. ***Plants are often dwarfed,*** paler green than normal and wilt during hotter part of the day. Symptoms are like nutrient deficiency or water stress. The only way to confirm diagnosis is to remove the plant and examine the roots. ***Tap roots,*** secondary and small roots and underground portions of stems develop abnormal swellings (Fig. 322). Affected roots are often spindle-shaped (thicker at centre and tapering towards the end) and may decay before the end of the season. Galls on roots caused by ***root knot nematodes*** (*Meloidogyne* spp.) are small (pea-sized) and evenly distributed on lateral feeding roots. Root knot has a very wide host range. ***Overwinters*** as resting spores in soil (7-8 years) and diseased crop debris. ***Spread*** by introduction of infected seedlings, contaminated soil by wind, soil on machinery, manure deliveries, by surface drainage water, not by seed. ***Favoured*** by high soil moisture, acid soil, temperatures between 18-25^{o}C. ***Liming*** reduces the severity of disease if light infestation but increases the time that the fungus can survive in the soil.

Phytophthora stem and root rot (*Phytophthora megasperma*) is uncommon. Leaves of affected plants wilt and usually have reddish or purplish margins. Plants may finally collapse. Lower stems are shredded and discoloured and the roots may be destroyed. Wide host range. See Trees K 6, Vegetables M 7.

Rhizoctonia base rot (*Rhizoctonia solani*) may cause ***damping off,*** young seedlings topple over, wither and die. Older seedlings may not die but become stunted, with the soft outer stem becoming brown and shrunken ***(wirestem)***. In older plants, stem and root rots may extend up the stem causing a dark, firm ***head rot.*** Sunken cankers may occur on swede, turnip and radish ***roots*** and develop into root rots during transport and storage. See Vegetables M 7.

Sclerotinia rot, watery soft rot, white rot (*Sclerotinia sclerotiorum, S. minor*) may develop on any above ground part of the plant. Under humid conditions rotted areas become covered with ***white fluffy mycelium*** on which ***sclerotia*** develop. See Vegetables M 7.

Wilts: ***Fusarium wilt, yellows*** (*Fusarium oxysporum* f.sp. *conglutinans*) causes lower leaves to yellow, leaves of young plants tend to bend sideways. Symptoms may show on one side of plant only. If stem is cut across near ground level, ***water conducting tissue*** is brown. Plant ***resistant*** cabbages and cauliflower. Also ***Verticillium wilt*** (*Verticillium dahliae*). See Vegetables M 9.

Others: ***Sclerotium* stem rot** (*Sclerotium rolfsii*), **fusarium basal rot** (*Fusarium tabacinum*), **fusarium root rot** (*F. solani*).

See Vegetables M 7.

White blister rust, white rust (*Albugo candida*) is a minor disease of ***brassicas***, eg radish, horseradish, turnip, cabbage, Brussels sprouts, cauliflower, also ***weeds***, eg shepherd's purse, wild radish, turnip weed, bitter cress, hedge mustard. Some races of white rust only infect some brassicas. Raised white pustules develop on ***leaves, stems*** and ***flowers***. See Gerbera A 37.

Others: ***Grey mould*** (*Botrytis cinerea*), ***powdery mildew*** (*Oidium* sp.), ***curd rot*** (*Alternaria alternata*), ***pink mould*** (*Trichothecium roseum*).

NEMATODE DISEASES

Beet nematode (*Heterodera schachtii*) causes large numbers of ***small branched roots***. Small lemon-shaped nematodes about 1 mm long on roots develop into hard brown resistant cysts. Affected plants are stunted and wilt during hot weather. See Beets M 34. ***Root knot nematodes*** (*Meloidogyne* spp.) are uncommon on brassicas but cause galls up to 25 mm across. Also ***root lesion nematodes*** (*Pratylenchus* spp.), ***citrus nematode*** (*Tylenchus latus*), ***spiral nematode*** (*Helicotylenchus dihystera*), also *Heterodera cruciferae, Merlinius brevidens, Paratrichodorus minor, Tylenchus, Tylenchorhynchus*. See Vegetables M 10.

INSECTS AND ALLIED PESTS

African black beetle (*Heteronychus arator*) is a squat shining black beetle about ***12 mm*** long that may attack young ***transplanted*** cabbage and cauliflower plants in old grassland. ***Stems*** are chewed just below ground level, leaves are then frayed out like teased rope. See Turfgrasses L 7, Vegetables M 16.

Aphids (Aphididae, Hemiptera) are ***serious pests*** of brassicas (Fig. 323).

Cabbage aphid (*Brevicoryne brassicae*) is a ***common and serious pest*** of brassicas (vegetable, ornamental and weed species) throughout the world. ***Adult aphids*** are globular, about ***2.5 mm*** long, ***slaty grey*** and covered with a ***mealy material***. Plant damage is caused by nymphs and adults piercing plant tissue and sucking plant juices and by their presence which causes buyer resistance. Infestation usually starts on ***leaf uppersurfaces***. A single winged female is surrounded by wingless young, leaves curl in and protect the colonies. All ***parts of the plant***, including flower stalks and buds, may be severely infested. Plants stop growing and leaves are distorted and mottled. If aphids are numerous, plants may wilt suddenly and die. A lesser infestation can make the plant unfit for market. There is a ***gradual metamorphosis*** (live nymphs, adults) with many generations each season. ***Overwinters*** in cooler areas as wingless forms; in colder areas as eggs; in warmer areas, young are born alive throughout the year. ***Spread*** by winged forms flying. ***Favoured*** by warm, dry conditions during late summer and autumn. In coastal areas they may also be important pests in spring. ***Control*** is difficult. Site plants away from obvious sources of infestation. Use repellent plants to assist with aphid control. In the USA, mulches of a wide range of materials, including aluminium and aluminium-polyethylene, have reduced aphid populations in vegetable plants by up to 96%. In addition, these mulches are opaque and prevent weed growth. Avoid year round growing of brassicas. ***Sanitation:*** Prompt disposal of harvested crops and control of brassica weeds will assist control. ***Natural enemies*** include the predatory ***common spotted ladybird*** (*Harmonia conformis*) and a ***wasp parasite*** (*Diaeretiella rapae*), which leaves many ***swollen empty aphids*** on plants, each with a small hole through which the adult wasp has emerged. Natural enemies do not prevent economic damage.

Green peach aphid (*Myzus persicae*) occasionally infests crucifers but seldom causes economic losses. The small green aphids cluster thickly on ***leaf undersurfaces*** in spring or autumn. Heavy infestations may cause cabbages and cauliflowers to wilt but damage is not as severe as that of the cabbage aphid. See Stone fruits F 129.

Turnip aphid (*Lipaphis erysimi*) infests brassicas, eg rapeseed, mustard, radish, turnip, cultivated stocks. ***Adult aphids*** are about ***2 mm*** long. waxy, grey-green. They are ***not as waxy as the cabbage aphid***. Aphids suck sap from floral parts during bud formation, flowering and pod development, causing distortion and loss of individual flowers and young pods, undersized seeds and seed abortion in maturing pods. On cultivated ***stocks*** the turnip aphid may cause curling of young leaves and severe stunting of plants. During winter, turnip aphid develops slowly and tends to be outnumbered by the other two aphid pests of brassicas, but in the warmer months, they have a higher rate of development and fecundity. Successive generations develop at intervals of 10-20 days, each female producing 40-60 nymphs. ***Favoured*** by warm, dry weather and drought-stressed crops. ***Control:*** As for cabbage aphid.

Aphids transmit ***virus diseases*** of brassicas. They produce honeydew which attracts ants and on which sooty mould grows. Abundant whitish nymph skins may be present. Crop residues should be ploughed in immediately after harvest; ensure transplants are aphid-free by screening seedling houses to exclude aphids prior to transplanting. ***Monitor*** aphids at regular intervals before applying an insecticide (Brough et al. 1994). See Roses J 4, Vegetables M 11.

Bugs (Hemiptera) are minor pests.

Green vegetable bug (*Nezara viridula*): Adults that have bred on other plants and migrated to cabbages sometimes heavily infest ***hearting cabbage crops*** in autumn. Heart foliage turns pale, soft and spongy and later brown. As cabbages will almost be ready for harvest, insecticides used must have short residual life. See Vegetables M 12.

Harlequin bug (*Dindymus versicolor*) may infest cabbages and other vegetables. ***Adults*** have ***orange, black and green patches*** and are about ***12 mm*** long. See Vegetables M 12.

Rutherglen bug (*Nyzius vinitor*) may limit production of ***seed crops***. They may cause severe wilting and foul plants with excreta. ***Adults*** are grey-brown and about ***5 mm*** long. ***Favoured*** by hot dry weather in spring and early summer. Adults and nymphs invade crops and suck sap from ***stems and leaves***. Young plants wilt and may die. Bugs breed in weeds and move into crops from weeds drying off. Nymphs can be stopped by a furrow around crop edges and spraying. See Stone fruits F 130, Vegetables M 12.

See Vegetables M 12.

Cabbage leafminer

Cabbage leafminer (*Liriomyza brassicae,* Agromyzidae, Diptera) is a minor pest of brassicas. ***Flies*** are grey, about 3 mm long and lay their eggs in leaf tissue. ***Maggots*** are up to ***5 mm*** long and mine in the ***leaves of seedlings*** producing pale fine meandering lines. Many mines may cause leaves to die. Plants growing in good conditions are generally not harmed significantly, but if growth is checked, eg by dry weather, leaf mining may do some damage. See Cineraria A 28.

Cabbage white butterfly *(CWB)*

This introduced butterfly is the ***most serious economic butterfly pest*** in Australia (Fig. 324).

Scientific name: Pieridae, Lepidoptera:
Cabbage white butterfly (*Pieris rapae*)
At least 3 other species of *Pieris* are recognised as pests of brassicas ***overseas***. If introduced they could intensify the damage caused by *P. rapae*.

Host range: All brassicas, ie ***vegetables***, eg cabbage, cauliflower, Brussels sprout, radish, broccoli, mustard kale, turnip, ***ornamentals***, eg stock, wallflower, ***weeds***, eg shepherd's purse, wild mustard. Beet, mignonette, geranium, nasturtium and *Cleome* may also be attacked.

Description and damage: ***Butterflies*** are usually a general grey-white and have a wingspan of 40-50 mm. Hindwings beneath are yellow and forewings paler. Females have 2 black spots on the upper surface of each forewing, while males have only one spot. Both sexes have one black spot on each hindwing. ***Caterpillars*** are ***velvety green***, covered with fine short hairs about ***30 mm*** long with a faint yellowish stripe down the back and along each side. Its colour resembles the colour of its host plant, and as it frequently rests parallel to the ***leaf midrib***, it is not readily seen. Young caterpillars feed mainly on ***leaf undersurfaces,*** older ones feed from the uppersurfaces and eat out large irregular holes from the outer leaves of the heart or curd of broccoli or cauliflowers. Greenish-brown pellets of excrement are caught in the angles of leaves. Growth is seriously reduced, heads of cabbages or cauliflowers are stunted or do not form at all; other leafy vegetables are rendered unfit for eating. ***Do not confuse*** with damage caused by ***other caterpillars***, eg cabbage moth, snails and slugs, and birds, or splitting due to overmaturity.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with at least 2 generations each season. Females visit blossoms to feed on nectar and lay yellow spindle-shaped eggs singly, usually on the undersides of the outer leaves. When fully-fed they pupate on the food-plant, some nearby object, or debris on the ground.

Overwintering: Usually in the pupal stage.

Spread: By butterflies flying, they are strong fliers and may be found many kilometres from host plants. Movement of infested plants carrying eggs, caterpillar and pupae.

Conditions favouring: Warm weather. Infestations may occur at any time of the year but are more troublesome in February and March. Caterpillars will not develop at < 10^{o}C and eggs will not develop at < 4^{o}C or > 30^{o}C.

Control:
- ***Cultural methods***: Minimise weeds especially ***brassica weeds***.
- ***Sanitation:*** If only a few plants are infested, caterpillars may be hand picked but because of their green colour they are often hard to find. Plough or dig in crop debris.
- ***Biological control:*** Eggs, caterpillars, pupae and butterflies all have ***many natural enemies***, including parasites, predators (birds) and fungal and viral diseases which reduce ***CWB*** numbers but often do not provide economic control. ***Three wasp parasites*** have been imported: ***Pteromalus puparum*** parasitises pupae of ***CWB*** and some other butterflies; ***Apanteles glomeratus*** and ***A. rubecula*** parasitise caterpillars. Cocoons of these parasites are commonly seen on fully grown caterpillars which stop feeding and die. ***Virus diseases*** may kill many caterpillars. A ***bacteria***, *Bacillus thuringiensis* ***(Bt)*** (Dipel®) is effective against this species. ***Bt*** gives caterpillars a disease, but is slower acting than chemical pesticides. However, it is selective and controls only leafeating caterpillars. It must be applied to young caterpillars.
- ***Resistant varieties:*** Some brassicas may be bred to produce ***Bt*** avoiding the need to spray.
- ***Physical and mechanical methods:*** Specially made clothes may act as a moth barrier.
- ***Pesticides:*** ***Monitor*** the crop weekly for caterpillars before applying insecticides (Brough et al. 1994). If regular applications of foliage chemical ***insecticides*** are to be made, they should be applied to seedbeds and in the field when caterpillars are first observed. Application must be made to ***leaf undersurfaces***. Effectiveness depends on killing ***young caterpillars***, older ones are less susceptible. See Annuals A 8.

Caterpillars

Caterpillars (Lepidoptera) are ***serious pests*** (Fig. 325) of brassicas (Hely et al. 1982).

Cabbage moth (CM), diamond-back cabbage moth (*Plutella xylostella,* Yponomeutidae) attacks brassica ***vegetables***, eg broccoli, Brussels sprout, cabbage, cauliflower, radish, turnip, ***garden flowers***, eg stock, sweet alyssum, wallflower, ***weeds***. ***Moths*** are small, brown and up to about 9 mm long. At rest, the ridge formed by the folded wings shows a row of yellow diamond-shaped markings. Moths are active and may fly out from plants in swarms if infestation is severe. ***Caterpillars*** are bright green and up to ***12 mm*** long, tapering at both ends. When disturbed they drop and hang from the plant by a silken thread. Young colourless caterpillars feed or mine in ***leaves***, causing small clear windows. Older green caterpillars chew large pieces from outer leaves. As the plants grow older, caterpillars tend to feed in ***central***

sheltered parts of plants, penetrating the heart and producing webbing and excreta. If numerous, they eat holes in leaves all over the plant, giving it a lacy pattern. Many generations each year. Female moths lay eggs on leaf undersurfaces. They pupate in flimsy net-like cocoons on leaves scattered over the plant. ***Overwintering:*** As moths sheltering among inner leaves of hosts, but in some areas caterpillars may feed. ***Favoured*** by hot, dry districts and is usually more important inland than on the coast. ***Parasitic wasps*** (*Apanteles* spp., *Diadegma eucerophaga*, *Diadromus collaris, Horogenes cerophaga*, *Hymenobosmina rapi*, *Thyracella collaris*) parasitise caterpillars and pupae but insecticides may still be needed. ***Pesticides:*** As for ***CWB***, but as caterpillars feed in sheltered positions careful spray application is necessary. ***Insecticide resistance*** to synthetic pyrethroid and organophosphates occurs in some areas.

Cabbage-centre grub (*Hellula hydralis, H. undalis,* Pyralidae) infests brassicas especially rape, turnip, broccoli, cabbage and cauliflower. ***Moths*** are about 12 mm long and hold their wings horizontally. Forewings are grey with brown markings. ***Caterpillars*** are thick-set, up to ***12 mm*** long, yellowish with brown ***longitudinal stripes***. Young caterpillars usually burrow into growing points and ***destroy seedlings*** which wither and die. In ***older plants***, main veins may be tunnelled. These are packed with webbing and frass, some terminal leaves may be bound together. Plants become stunted and develop lateral buds which produce multiple heads of no commercial value. ***Pest cycle:*** Female moths lays eggs on new growth. When fully grown caterpillars pupate in the tunnels. ***Favoured*** by hot dry weather in summer and autumn. It is most troublesome in autumn and may also occur in spring. ***Control:*** Regular treatments for ***CWB***, starting with the seedbed, will avoid damage. Early growth of crops needs to be protected against infestation. Older caterpillars are inaccessible so spray when young.

Cabbage cluster caterpillar (*Crocidolomia pavonana,* Pyralidae) infests brassicas. ***Moths*** are light brown and lay eggs on leaves. ***Caterpillars*** are up to ***20 mm*** long, green with ***longitudinal markings*** and black spots. Young caterpillars feed in groups, older ones spin webs over their feeding area, eating holes in leaves and heads. They pupate in soil. Many generations each season. May only be a problem in northern areas during summer and autumn. Control as for ***CWB***. See Cabbage moth above.

Cabbage white butterfly (*Pieris rapae*) is the ***most serious caterpillar pest*** of brassicas. See Brassicas M 39.

Cluster caterpillar (*Spodoptera litura,* Noctuidae) damage foliage ***severely*** and may penetrate ***hearts*** of cabbage and cauliflower in late summer to autumn in coastal districts. ***Caterpillars*** are distinguished from others by the feeding of young caterpillars in groups skeletonising ***leaves***. Older caterpillars are ***40-50 mm*** long, green to brownish-purple, smooth with a row of dark triangular spots on each side of the body. The feed on ***growing points*** and tunnel into heads from the bottom of outer leaves, so often they are not detected until harvest. Caterpillars mostly feed on leaf tissue but can also damage ***fruit*** such as tomatoes. Eggs are laid on leaves in clusters of up to 300 and are covered with a matt of grey-brown hairs from the body of the female. Pupae are formed in soil.

Corn earworm (*Helicoverpa armigera*) and *H. undalis*, may be pests of cabbage in coastal districts. ***Caterpillars*** are pale green to dark brown, up to ***40 mm*** long. Young caterpillars are solitary and skeletonise leaves, older ones tunnel into heads. A parasitic wasp (*Heteropelma scaposum*) parasitises the caterpillars. See Sweetcorn M 89.

Cutworms (*Agrotis* spp.) may nip off ***young seedlings*** during the night, re-planting may necessary. See Seedlings N 68.

Leafroller moths (Tortricidae): ***Lightbrown apple*** moth (*Epiphyas postvittana*) caterpillars roll and web ***leaves*** together and feed on leaf tissue at these sites. If disturbed they quickly ***wriggle*** backwards. See Pome fruits F 112.

Looper caterpillars (*Chrysodeixis* spp., Noctuidae) are ***30-40 mm*** long and eat ***large ragged holes*** (up 25 mm across) in backs of ***leaves*** and may feed on bean pods and tomato fruit. See Vegetables M 13.

Others: Many other moth caterpillars may attack brassicas (Common 1990).

Monitor caterpillars at regular intervals before applying an insecticide (Brough et al. 1994). ***Plough-in crop residues*** immediately after harvest. Avoid ***year round*** brassica crops. See Annuals A 8, Brassicas M 39.

Mites (Acarina)

Earth mites (Penthaleidae): ***Redlegged earth mite*** (*Halotydeus destructor*) and ***blue oat mite*** (*Penthaleus major*) may ***seriously damage*** young brassica plants on leaf uppersurfaces, producing silvery or ***whitish blemishes***, particularly along the ***main veins***. If the infestation is heavy, whole leaves may look bleached. See Vegetables M 16.

Twospotted mite (*Tetranychus urticae*) may also infest brassicas. See Beans (French) M 29.

Onion thrips (*Thrips tabaci*) feed on the undersurfaces of the ***lower outer leaves*** causing them to be shiny and light brown. During dry weather young cabbages and cauliflowers may seem to be slow growing. On brassicas, insecticides may be applied to leaf undersurfaces. See Onion M 68.

Striped flea beetle (*Phyllotreta nemorum*) feeds on brassicas, especially ***turnip*** and cabbage, they are small, black beetles about ***2.5 mm*** long with a longitudinal yellow stripe on each wing cover. If disturbed, they jump or fly readily, they chew small holes in ***leaves (shot-holed)***. Damage is usually minor. Control, where necessary, with insecticides. See Hibiscus K 82.

Weevils (Curculionidae, Coleoptera)

Spotted vegetable weevil (*Desiantha diversipes*) is brown-grey about ***6 mm*** long. It may feed on ***leaves*** and stock or turnip in some districts in autumn. Weevils may move into crops from adjacent pasture, eating plants as they go. See Vegetables M 17.

Others: ***Whitefringed weevil*** (*Graphognathus leucoloma*) larvae are thick-set, legless white or grey, up to ***12 mm*** long. They channel and girdle ***roots*** of young cabbage and cauliflower which wilt suddenly. Occasionally adults may feed on ***foliage*** of crucifers. Also ***vegetable weevil*** (*Listroderes obliquus*). See Vegetables M 17.

Others: ***Crickets, grasshoppers, locusts*** (Orthoptera), eg black field cricket (*Teleogryllus commodus*), wingless grasshopper (*Phaulacridium vittatum*) and yellow-winged locust (*Gastrimargus musicus*), may attack both seedlings and older brassica plants. ***Onion maggot*** (*Delia platura*) hollows out stems of seedlings below ground level, tops die and the stems, when pulled up, are soft and rotted. ***False wireworms*** (Tenebrionidae) and wireworms (Elateridae) may attack cabbages and cauliflowers transplanted into ground recently under pasture. They may nibble at roots and may tunnel in stalks, stunting and killing plants.

SNAILS AND SLUGS

Snails and slugs can be ***serious pests*** of brassicas (Fig. 326), mainly after planting or near harvest, especially if planted into ground previously under pasture or green manure crops prepared using minimum tillage. See Seedlings N 70.

VERTEBRATE PESTS

Birds may damage seedlings. See Fruit F 13.

Non-parasitic

Environment: ***Frost*** may injure cauliflower heads; damaged heads are often invaded by secondary fungal infections. ***Bolting*** (running to seed) may occur. ***Oedema*** is a physiological disorder believed to be caused by changes in temperature and humidity in the crop canopy, and affects all vegetable brassicas. Symptoms vary but include small warty outgrowths on leaves, black flecking in Brussels sprout buds and Chinese cabbage, dead tissue within cabbage heads. Plant ***tolerant*** varieties. See Geranium A 35.

Nutrient deficiencies, toxicities: ***Plant analysis standards*** are available for brassicas (Weir and Cresswell, 1993).

Boron deficiency (hollow stem) affects brassica, beetroot, peas, pome fruit (apple, pear), lucerne and celery. ***Cabbage and cauliflower:*** Hollows develop in the centre of stems. Leaf ribs may have rough cracked areas. Cauliflower curds may be discoloured and taste bitter, whether cooked or eaten raw. ***Turnips and swedes:*** Internal breakdown develops with watersoaked brown or hollow areas in the root. In severe cases the root surface may be rough and cracked. ***Favoured*** by application of agricultural lime. Some soils have sufficient boron in an insoluble form. Induced alkaline conditions resulting from excessive applications of lime, superphosphate can convert boron to an insoluble form. More boron is required in neutral and alkaline soils than in acid soils. Soils have low levels of boron due to being derived from rocks poor in boron or soils may have been leached. ***Prevent*** by applying borax to soil at recommended rates before planting, 1 application should supply enough boron for crop requirements for 3-4 years. If boron deficiency develops in young crops, plants may be sprayed with borax. Note that boron is a ***herbicide***.

Molybdenum deficiency (whiptail) usually affects patches of plants in an otherwise healthy crop. Requirements for molybdenum vary with the crop. ***Tomato, beet, lettuce and brassicas*** have ***high requirements***, beans and peas require high amounts once their initial seed reserves have been depleted. ***Cucurbits, clovers, medics, carrot and celery*** have ***intermediate requirements. Cereals, grasses and trees*** have ***low requirements***. Molybdenum deficiency causes different symptoms on different brassicas. ***Cauliflower:*** An abnormal leaf development called ***'whiptail'*** develops. Green leaf tissue is reduced and in advanced stages leaves may consist of a central midrib with a narrow margin of green leaf tissue on each side (Fig. 327). ***Other brassicas*** may not show such marked whiptail symptoms but interveinal yellowing, death of the leaf margins and stunting may occur. ***Favoured*** by acid soils, where the pH is 5.5 or less, molybdenum is unavailable for plant growth. ***Heavy liming*** may prevent molybdenum deficiency. Molybdenum can be applied to the soil, or as a foliage spray to seedlings or young crops.

Pesticide injury: Brassicas are sensitive to ***hormone herbicides***. Stems may split and gall-like growths develop on stems, petioles and roots. Plants are unthrifty and often develop a reddish pigment on petioles and leaf margins. Brassicas are as sensitive as tomatoes to low levels.

Others: Overmature cabbages may ***split*** (Fig. 328).

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State/Territory Departments of Agriculture/Primary Industry eg

Aphid Pests of Cruciferous Crops (SA Fact Sheet)
Insect Pests of Crucifer Vegetables
Blackleg of Cabbage, Cauliflower and Related Plants (NSW Agfact, Vic Agnote))
Black Rot of Cole crops (Vic Agnote)
Black Rot of Crucifers (NSW Agfact)
Brassicas : Insect Pests (Qld Farmnote)
Broccoli for Processing and the Fresh Market (Tas Farmnote)
Broccoli Growing (NSW Agfact)
Broccoli : Sowing Times and Maturity Guide (Vic Agnote)
Broccoli : Weed Control (Vic Agnote)
Brussels Sprouts for Processing (Tas Farmnote)
Brussels Sprouts in the Home Garden (Vic Agnote)
Brussels Sprouts : Weed Control (Vic Agnote)
Cabbage Growing (Vic Agnote)
Cabbage Moth (NSW Agfact)
Cabbage Moth or Diamond-back Moth (Vic Agnote)
Cabbage : Weed Control (Vic Agnote)
Cabbages, Cauliflowers, Brussels Sprouts for Processing (Tas. Dept. of Primary Industries and Fisheries)
Cauliflowers for Processing and the Fresh Market (Tas Farmnote)
Cauliflowers for the Fresh Market and for Processing (Vic Agnote)
Cauliflower : Planting Times and Maturity Guide (Vic Agnote)
Cauliflower Growing (NSW Agfact)
Cauliflower Growing in the SW (WA Agric)
Cauliflowers in the Home Garden (Vic Agnote)
Cauliflower : Weed Control (NSW Agfact)
Chinese Cabbage (Bull. WA Agric)
Clubroot of Cruciferous Crops (Vic Agnote)
Commercial Cauliflower Production in WA (WA Farmnote)
Crucifers : Pest and Disease Control (Vic Agnote)
Diseases of Crucifers (NSW Agfact, WA Farmnote)
Diseases of Vegetable Brassicas (Tas Farmnote)
Diseases of Forage Brassicas (Tas Farmnote)
Growing and Transplanting Brassica Vegetable Seedlings (Tas Farmnote)
Growing Broccoli (Vic Agnote)
Growing Cabbage in WA (WA Farmnote)
Growing Cabbages in the Top End (NT Agnote)
Growing Swedes and Turnips (Tas Farmnote)
Guide to the Sowing & Maturity of Cabbages (Vic Agnote)
Hollow Stem of Broccoli and Cauliflower (Vic Agnote)
Insect Pests of Brassica Vegetables (Tas Farmnote)
Insect Pests of Crucifer Vegetables (NSW Agfact)
Kohl Rabi in the Home Garden (Vic Agnote)
Production of Brussels Sprouts (Vic Agnote)
Radish Growing (NSW Agfact)
Ringspot of Cruciferous Plants (Vic Agnote)
The Red-legged Earth Mite (Vic Agnote)
Turnips in the Home Garden (Vic Agnote)

Associations, Journals etc.

Good Fruit & Vegetables
State/Territory Grower Services

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Brassicas are mostly grown for the fresh market and processing, some, eg swedes and turnips, are grown also as fodder crops. ***An overview of the industry*** is presented by Coombs (1995). ***Breeding programs*** attempt to improve disease and pest resistance, improve quality of harvested products and delay postharvest deterioration (Blazey 1994). Brassicas thrive best in cool climates with high relative humidities. Select cultivars with some ***resistance*** to local problems. Buy ***disease-free seed or seedlings*** from reliable producers and plant in disease and pest-free seedbeds and fields. ***Seed treatments*** may be recommended, eg hot water treatments (Salvestrin 1991). ***Site selection:*** Isolate seedbeds away from commercial crops, many diseases are spread by wind from crop residues in adjacent crops. Avoid sites known to be infested with club root, eg for turnips and swedes. As many diseases persist from year to year in crop residue (leaf spots) or over longer periods in the soil as resistant spores (club root, *Sclerotinia* rot) or as cysts (nematodes), ***practise crop rotations*** of 3-4 years, and minimise brassica weeds during that time. Choose correct soil, range of soil types, with good drainage and appropriate organic matter. ***Pre-plant soil treatments*** may include pasteurisation of seedbeds and potting mixes, pre-plant nematode treatments or lime may be suitable in some circumstances, eg club root. ***Get local advice*** on local diseases and appropriate treatments. Practise ***seedling hygiene.*** Sow at the correct time and at the correct spacing. Fertilise and irrigate appropriately. ***Monitor*** crops regularly for pest development, especially seedlings. Cutworms and black beetle rapidly destroy young plants, cabbage aphids can severely restrict their growth. ***Insect activity*** is largely governed by ***weather conditions***. During the colder months in many districts the insect pest activity of brassicas virtually ceases, at other times of the year it may be so great that regular control sprays may be needed. Small caterpillars of any species require less insecticide to kill them. Some, eg cabbage moth and budworms (*Helicoverpa*), that feed in sheltered positions are difficult to control adequately once they become well established in the crop. ***Control emerged annual and perennial weeds pre-plant*** mechanically or with post-emergence herbicides. Weeds must also be controlled ***after planting***. It can be difficult on some brassica crops to use herbicides after planting, so seedbeds should be weed-free before sowing. ***Removal of brassica weeds*** are very important in the control of crucifer diseases. ***Sanitation:*** Abandoned crops are sources of infestation for future crops plough-in crops and residues immediately after harvest. ***Pesticides:*** If spraying brassicas add a wetting agent because of the waxy leaves. ***Harvest swedes and turnips*** at the size and time preferred by the wholesalers or processors, oversize roots may be unsaleable. Roots are normally pulled either by hand or by mechanical lifters and trimmed immediately, bagged or placed into bulk bins. Handle roots with care to reduce injury and promote storage life. ***Store brassicas*** at recommended conditions for the prescribed period, eg $0^{o}C$ with 90-95% humidity, to prevent heads from drying. ***Uncooled broccoli*** has a high level of respiration and gives off much ethylene which should be removed by ventilation. Sprinkling with crushed ice helps to reduce the production of ethylene, premature maturity and yellowing of the product. ***Wrapper leaves*** significantly increase the respiration rate and therefore the rate of deterioration of ***cauliflowers***, but protects the head from damage and staining. ***Harvest broccoli*** while it is still tight and before there is any sign of yellowing in the buds, in the cool of the morning. Broccoli turn yellow rapidly if overheated (not the yellow of over maturity when buds open). Handle carefully. If it is to be ***stored*** it should be first forced-air cooled or hydrocooled and then stored at $0^{o}C$ (not lower or there may be freezing injury). Avoid ***feeding diseased residues*** to stock as some resistant spores may be spread in their droppings.

Fig. 321. Black ringspotting due to turnip mosaic virus. Dept. of Agric., NSW.

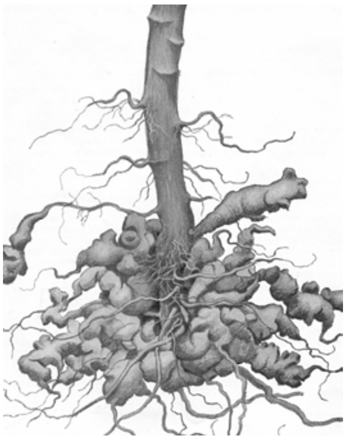

Fig. 322. Club root (*Plasmodiophora brassicae*). Dept. of Agric., NSW.

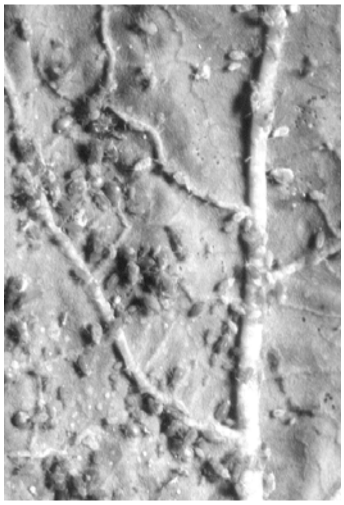

Fig. 323. Aphids (Aphididae) clustered on leaf undersurfaces.

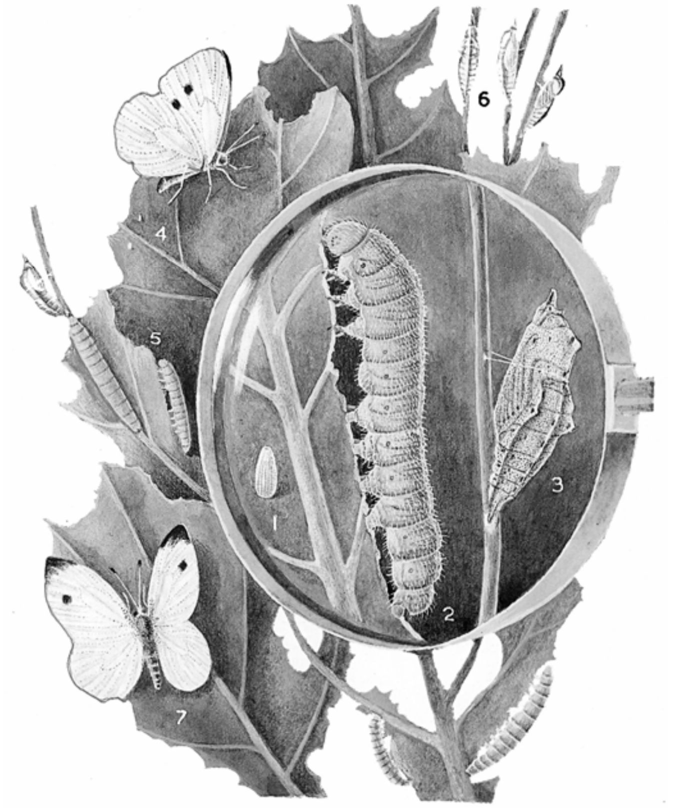

Fig. 324. Cabbage white butterfly (*Pieris rapae*). **1.** Egg (x10). **2.** Caterpillar. **3.** Pupa (x 2.5). **4.** Eggs on leaf. **5.** Caterpillar. **6.** Pupa attached to plant. **7.** Butterfly. Dept. of Agric., NSW.

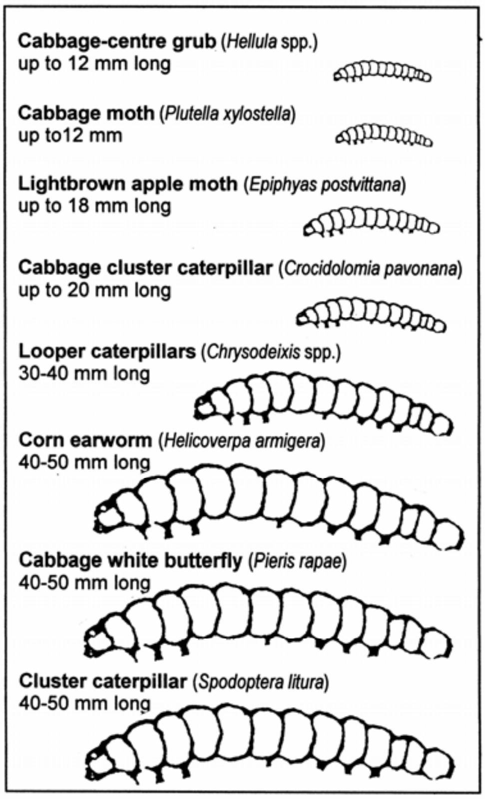

Fig. 325. Caterpillars infesting brassicas vary considerably in length and colour. Some have stripes or other identifying marks.

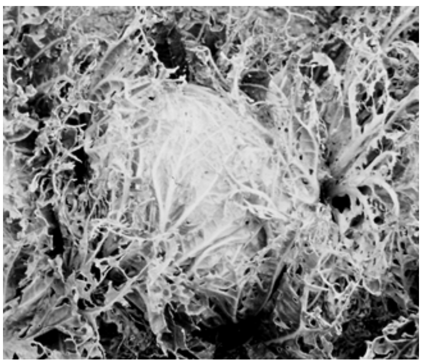

Fig. 326. Snail and slug damage to cabbages.

Fig. 327. Molybdenum deficiency (whiptail) on cauliflower leaves.

Fig. 328. Cabbage splitting due to over-maturity.

Carrot

Daucus carota
Family Apiaceae (carrot family)

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Bacterial blight
Bacterial soft rots
Fungal diseases
Damping off
Fungal leaf spots
Root and stem cankers, rots
Nematode diseases
Root knot nematodes
Insects and allied pests
Aphids
Bugs
Caterpillars
Flies
Mites
Vegetable leafhopper
Weevils
Snails and slugs
Non-parasitic
Deformed roots
Environment
Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Carrot motley dwarf: Carrot red leaf virus (***CRLV***) and carrot mottle virus (***CMotV***) were originally described in Australia as one virus, ie carrot motley dwarf virus, and are probably no longer economically important in Australia. ***Hosts*** include carrot, dill (*Anethum graveolens*), ***CRLV*** also parsley. ***Petioles*** may be twisted or shortened, leaves rosetted, yellow or red; seed stalks stunted, seed heads malformed; roots may rot prematurely, and seed may fail to set, seriously affecting yield. ***Spread: CRLV*** and ***CMotV*** as a complex by the carrot aphid (*Cavariella aegopodii*), not by seed, not by pollen. ***Favoured*** by large numbers of aphids, sowings from July to December. ***To minimise losses*** sow when seedlings will not be exposed to seasonal flushes of aphids. ***A wasp parasite*** of the vector was introduced into Australia in 1962. Plant ***virus-tolerant*** or ***aphid-resistant/repellent*** carrot cultivars. Where virus is a problem spray crops to control vector.

Others: Potato Y virus, tomato big bud mycoplasma.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial blight (*Xanthomonas campestris* pv. *carotae*): ***Leaves*** develop small, irregular yellow areas which later turn to brown watersoaked spots. Dark brown streaks may develop on ***stems*** and ***petioles***. Laterally elongated, black sunken craters may also form on ***roots***. Bacterial ooze may seep from infected sites. Rotate crops every 2-3 years. Hot water treatment of seed may be required. See Vegetables M 5, M 6.

Bacterial soft rots (*Erwinia carotovora* pv. *carotovora, E. carotovora* pv. *atroseptica*) causes a watery soft rot of the ***tap root*** and is usually a ***postharvest disease*** but may occur in the ***field*** after prolonged wet weather. See Vegetables M 5.

FUNGAL DISEASES

Damping off (*Pythium* sp. *Rhizoctonia*): Treat seed with recommended fungicide dusts. Do not plant into soil containing undecomposed plant debris. See Seedlings N 66.

Fungal leaf spots

Cercospora leaf spot (*Cercospora carotae)* is mainly ***severe on young leaves*** causing circular tan or grey spots, which may coalesce during humid weather to kill the whole leaf. Sunken elongated spots may occur on ***leaf stalks***.

Leaf blight (*Alternaria dauci*) causes dark grey to brown angular spots surrounded by yellow areas on leaves, severely affected leaves eventually die. ***Older leaves*** are attacked first, but in severe outbreaks younger leaves are also attacked.

See Annuals A 5.

Root and stem cankers, rots

Black rot (*Alternaria radicina*) causes a shallow dry black rot of the ***shoulder region***. ***Favoured*** by storage in ground after crop is mature. Destroy affected roots. Seedborne.

Cavity spot (*Pythium* spp.) infects ***lateral roots*** of young plants causing localised lesions which may be invaded by secondary organisms. See Vegetables M 7.

Rhizoctonia crater rot, root canker (*Rhizoctonia solani*). Small brown lesions on the sides of ***roots*** increase in size, then the rotted tissue contracts to form craters. Black ***sclerotia*** may form on the surface of carrot roots. Secondary rots often follow. See Vegetables M 7.

Rhizopus soft rot (*Rhizopus oryzae*, *R. stolonifer*) causes a ***postharvest*** soft rot with coarse open, black and white fungal growth. Avoid bruising and other injury during harvesting and washing. Transport and store in cool conditions. See Fruit F 6, Vegetables M 6.

Sclerotinia rot (*Sclerotinia sclerotiorum*) is a rapidly developing soft rot accompanied by dense white fungal growth and black, irregular ***sclerotia*** or resting bodies. ***Field*** and ***postharvest disease***. See Vegetables M 2 (Fig. 297), M 7.

Sclerotium rot (*Sclerotium rolfsii*) causes a soft rot with white threadlike growth on ***roots*** and surrounding soil. Small evenly-shaped brown ***sclerotia*** form on the root. See Vegetables M 8.

Others: Thielaviopsis black root rot (*Thielaviopsis basicola*) has been a major postharvest disease overseas, it affects carrots in NZ. ***Armillaria root rot*** (*Armillaria luteobubalina*), ***fusarium root rot*** (*Fusarium* spp. *Fusarium solani*), ***phytophthora root rots*** (*Phytophthora* spp., *P. megasperma* var. *sojae*), ***grey mould*** (*Botrytis cinerea*), ***sour rot, yeasty rot*** (*Geotrichum candidum).*

See Fruit F 6, Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) cause ***serious diseases*** of carrots. They cause swellings on roots. Avoid infested soil or treat infested soil. See Vegetables M 2 (Fig. 300), M 10.

Others: ***Stem and bulb nematode*** (*Ditylenchus dipsaci*), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus dihystera, Rotylenchus robustus*), *Paratrichodorus*, *Xiphinema*.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Carrot aphid (*Cavariella aegopodii*) affects willow (*Salix* spp.) and various Apiaceae, eg carrot, parsnip, celery, parsley, weeds. ***Adults*** and ***nymphs*** are small, ***green, yellow, brown or reddish*** and cluster on leaf undersurfaces, sucking sap, ***young leaves*** are distorted and curled. Plants grow poorly, yellow and become reddish. Aphids secrete ***honeydew*** which attracts ants and on which sooty mould grows. Carrot aphid is the ***insect vector*** for carrot motley dwarf virus complex. There are many generations each season. ***In cold climates*** the ***primary host*** is willow where eggs hatch in spring. Winged forms later fly to the ***secondary hosts***, eg carrot, parsley and fennel, on which many generations are passed. Periodically colonies, most frequently in autumn and late spring, produce winged forms that fly to new host plants. In autumn, aphids fly to the primary host (willow) and lay overwintering eggs. ***In warmer areas***, if suitable hosts are available throughout the year, breeding continues on secondary hosts. ***Spread*** by winged forms to the crop and within the crop. Cool, dry weather in winter ***favours*** aphid development and retards the crop. ***Sow early*** to allow crops to make good growth before aphids become abundant. In spring later-sown crops tend to escape the worst injury. ***Ladybirds***, hover fly and lacewing larvae, tend to be least active in winter when aphids are most destructive. A ***parasitic wasp*** has been introduced. Some varieties have some ***resistance*** to aphids and virus. Control host weeds. Insecticides may be applied when aphids are present.

Cowpea aphid (*Aphis craccivora*) is ***black*** and colonises growing ***shoots*** and later, leaf undersurfaces. Carrot crops sown after the middle of October usually escape infestation. See Pea M 74.

Fennel aphid (*Dysaphis foeniculus*) infests fennel, carrot, parsnip, related weeds. It is small, ***grey*** and feeds on ***roots***. In cloudy weather it may come up from roots and feed on crowns and leaf stalks. Leaves yellow, growth may be stunted. If young plants are attacked, roots may be malformed. Infested plants may be surrounded by mounds of ***small brown ants***. Insecticides may occasionally be necessary in some areas if aphids occur on roots in young plants.

See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)

Rutherglen bug (*Nysius vinitor*) swarms on carrots sucking sap from ***new growth*** and ***seeds***; growth is severely stunted and the developing seed dries up preventing seed production. Plants look scorched. Adults are most likely to be responsible for the attack. See Vegetables M 12.

Others: ***Green mirid*** (*Creontiades dilutus*) sucks sap from buds and flowers causing seed heads to fail to set seed. Also ***green vegetable bug*** (*Nezara viridula*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Cutworms (*Agrotis* spp.) may chew ***leaf stalks*** of young crops at ground level. See Seedlings N 68.

Leafroller moths (Tortricidae): ***Lightbrown apple moth*** (*Epiphyas postvittana*) and ***lucerne leaf-roller*** (*Merophyas divulsana*) caterpillars are slender, green, feed on foliage and web leaves together. They wriggle backwards if disturbed. See Pome fruits F 112.

See Annuals A 8, Vegetables M 13.

Flies (Diptera)

Carrot rust fly (*Psila rosae,* Psilidae), which is not known to occur in Australia, ***severely damages*** Apiaceae vegetables, eg carrots, celery, celeriac, coriander, caraway, dill, fennel, parsley, parsnip and weeds overseas. ***Flies*** are shining-green, yellow-headed and deposit eggs about the base of the plants. ***Maggots*** are slender, legless, up to 8 mm long, dirty white, and work their way down in the soil and attack the tips of ***tap roots***, destroying the entire root system. Carrots are stunted, the entire root may become scarred and riddled by maggots burrowing, burrows take on a rust-red colour. Injury may continue in ***stored*** carrots. ***Overwinters*** as pupae buried in the soil or as maggots on the roots.

Celery fly (*Melanagromyza apii*, Agromyzidae). See Celery M 48.

Mites (Acarina)

Spider mites (*Tetranychus* spp.) may infest carrots, especially ***unirrigated crops*** in hot weather. ***Leaves*** become grey-speckled then brown. See Beans (French) M 29.

Redlegged earth mite (*Halotydeus destructor*) pierces and sucks plant sap. Surface tissue turns white, large numbers of ***leaves*** may look bleached. Seedlings may wither. See Vegetables M 16.

See Vegetables M 16

Vegetable leafhopper (*Austroasca viridigrisea*)

is small and green. It sucks plant sap making ***foliage*** grey or yellow. See Vegetables M 15.

Weevils (Curculionidae, Coleoptera)

Vegetable weevil (*Listroderes obliquus*) larvae destroy ***growing points***, later they chew holes in foliage and furrows in ***crowns***. Adults attack ***tops*** and ***roots***, gouging out large craters, usually around the crown. Some varieties, eg Osborne Park, are less susceptible than others. See Vegetables M 17.

Whitefringed weevil (*Graphognathus leucoloma*) larvae furrow in ***roots***, going into the core. Bases and stems of ***seedlings*** may be chewed causing death. See Vegetables M 17.

Others: ***Garden weevil*** (*Phlyctinus callosus*) nibbles leaves while larvae chew tap roots especially in WA. ***Spotted vegetable weevil*** (*Desiantha diversipes*) is often called the carrot weevil in Tasmania.

See Vegetables M 17.

Others: Various ***crickets, grasshoppers, locusts*** (Orthoptera), ***European earwig*** (*Forficula auricularia*), ***lucerne flea*** (*Sminthurus viridis*), ***leafeating ladybirds*** (*Epilachna* spp.), ***wireworms*** (Tenebrionidae) and ***false wireworms*** (Elateridae), ***root mealybugs*** (*Rhizoecus falcifer*), ***seedharvesting ants*** (Hymenoptera).

SNAILS AND SLUGS

Snails and slugs may feed on foliage and leave their glistening slime trails. See Seedlings M 70.

Non-parasitic

Deformed roots may be caused by sowing too thickly, shallow compact soil, stones and other solid debris. Fresh animal manure, green manure or other fertilisers applied later than 3 weeks before sowing are likely to cause ***forked or hairy roots***. Some varieties are more prone to forking than others. ***Splitting*** is caused by overmaturity. See Vegetables M 3 (Fig. 312).

Environment: Carrots may be damaged by ***frost***. Some varieties of carrots may ***bolt*** (run to seed) without forming roots if planted in late autumn and winter in temperate zones.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for carrots (Weir and Cresswell 1993). ***Boron deficiency*** causes scurfing, roughening and cracking of roots. Boron is a herbicide; never apply soil and foliage treatments in same season.

Others: ***Black ring*** is ***common*** and ***serious*** on ***processing carrots*** and is caused by a complex of varietal, physiological and fungal factors. A black superficial ring develops at the top of the carrot and remains when leaves are removed. It does not develop into a rot. Affected areas can usually be easily removed during peeling but they can be difficult to remove during the commercial processing of carrots. ***Susceptible varieties*** have a pronounced dished top. ***Favoured*** by cultural practices, eg high plant populations and inadequate irrigation, which leads to premature leaf death. Select varieties with rounded tops, promote steady growth of the crop and avoid overcrowding (Persley 1994). Some ***organophosphates*** are toxic to carrots. ***Kerosene*** may taint carrots.

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State/Territory Departments of Agriculture/Primary Industry eg

Diseases of Carrots (NSW Agfact)
Diseases and Pests of Carrots (WA Farmnote)
Diseases of Carrots, Parsnips, Parsley and Celery (Tas Farmnote)
Carrot Growing (NSW Agfact)
Carrots and Parsnips : Root-knot Nematode (Vic Agnote)
Carrots : Pests and Diseases (Qld Farmnote)
Carrot Production (Vic Agnote)
Carrots : Weed Control (Qld Farmnote, Vic Agnote)
Commercial Carrot Production (WA Farmnote)
Growing Carrots : Cultural Notes (Tas Farmnote)

See Celery M 49, Herbs N 33, Parsnip M 71, Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Carrots are grown for the fresh market and for processing. An ***overview of the industry*** is presented by Coombs (1995). The ***length of the carrot*** must suit the depth of soil. Choose ***slow bolting*** varieties with some ***resistance*** to carrot motley dwarf, aphids, leaf spots, and root diseases and plant in the correct season. Plant ***certified disease-free seed*** (many diseases are seedborne) or use a prescribed seed treatment. ***Seed treatments*** with fungicides/insecticides prior to planting, reduce soilborne diseases and pests. ***Avoid land infested*** with root knot or treat several weeks before sowing. Avoid land infested with *Sclerotinia* for winter plantings and where *Sclerotium* occurs, for summer plantings. Choose a frost-free site. Practice crop rotations of 3-4 years. Carrots prefer cool growing conditions and well-drained open textured soils. They tolerate moderately acid soils. A regular water supply is necessary for the production of high quality carrots. Seed may be ***primed*** to improve performance (Salvestrin 1991). ***Planting:*** Seed is sown into permanent positions. ***Germination:*** Sow seed thickly and cover by no more than 10 mm soil with a very thin mulch on top. Keep soil damp at all times so that carrot seedlings can emerge easily. High temperatures during germination can cause poor results. ***Sanitation:*** Destroy diseased crop debris by burning or ploughing in promptly. ***Weed control*** in carrots is essential and is based on good land preparation, interrow cultivation and the use of ***pre-emergence*** and ***post-emergence herbicides***. Some weeds may be difficult to control adequately in carrots, eg slender celery and wild carrot. ***Growth regulators*** are used to control vegetative growth. ***Harvest*** at correct time, avoid overmaturity. Cool, or air dry, washed carrots and avoid bruising and other injury. Treat to ***prevent postharvest diseases*** (bacterial soft rots, *Fusarium*, grey mould, *Rhizopus* soft rot, *Sclerotinia* rot) during ***storage and transport*** (Salvestrin 1991).

Celery

Apium graveolens
Family Apiaceae (carrot family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot
  - Bacterial soft rot
- **Fungal diseases**
  - Fungal leaf spots
  - Sclerotinia rots
- **Nematode diseases**
  - Celery eelworm
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Flies
  - Mites
  - Thrips
  - Vegetable leafhopper
  - Vegetable weevil
- **Snails and slugs**

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities
- Overmaturity

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Celery mosaic virus affects celery, overseas also carrot, coriander, dill, parsley, parsnip, hemlock (*Conium maculatum*). Green to light green mottling, ***leaflets*** may be ***narrowed, cupped and twisted***, early infections result in stunting and petioles not growing upright. ***Overwinters*** in infected host plants. ***Spread*** by aphids, eg cotton aphid (*Aphis gossypii*), green peach aphid (*Myzus persicae*), not by contact between plants, not by seed. Found in WA and SA. Overseas a ***celery-free period*** where the virus does not infect weed hosts, eg wild hemlock, is recommended (Buchen-Osmond et al. 1988).
Others: Cucumber mosaic virus, lucerne (Australian) latent virus, tomato spotted wilt virus.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial leaf spot (*Pseudomonas syringae* pv. *apii*) causes bright yellow circular or angular ***leaf spots*** surrounded by a yellow halo. As spots enlarge they turn brown in the centre. Leaves with many spots die. ***Overwinters*** in diseased crop residues. ***Spread*** by introduction of infected seed, diseased seedlings to field plantings and by water splash and windblown rain. ***Favoured*** by a dense canopy which provides wet humid conditions ideal for infection and disease development. Practise crop rotation and destroy crop residues promptly after harvest. See Stone fruits F 124, Vegetables M 5.

Bacterial soft rot (*Erwinia carotovora* pv *carotovora*) is mainly a ***postharvest*** disease of celery especially under wet and humid conditions, often where plants have been injured. A wet slimy rot of ***leaves and stalks*** develops. In the field plants often show a soft wet rot of the ***base*** and the ***heart***. ***Favoured*** by hail damage, frost, chemical injury or wind. Fungicides can be applied as soon as damage and/or conditions favourable for disease occur. See Vegetables M 5.

Others: *Pseudomonas viridiflava.*

FUNGAL DISEASES

Fungal leaf spots

Anthracnose, leaf curl (*Colletotrichum acutatum, C. orbiculare*) is a sporadic disease of ***celery plants*** of all ages, also capsicum, anemone and ranunculus, avocado, papaw, strawberry, and ***weeds***, eg Noogoora burr and Bathurst burr. ***Young celery leaves*** and ***petioles*** may be distorted. ***Petioles*** occasionally show reddish-brown elongated lesions on the inside. Spores form in the crown and along the reddish lesions on the petioles. ***Older celery leaves*** are curled downwards with scattered yellow translucent spots on uppersurfaces. These later become brittle and crack along their length. Soft rotting organisms often invade infected growing points. Similar symptoms develop on anemone and ranunculus. ***Overwinters*** in undecomposed celery residues in the soil or on alternative crop and weed hosts. Spores are ***spread*** by wet windy weather. ***Favoured*** by wet weather. ***Destroy old crops*** immediately after harvest. Preferably plant ***resistant varieties***. If very susceptible varieties, eg Bishop or H122, are planted, ***rogue infected plants*** to prevent spread, and apply recommended ***fungicides*** in seedbeds and in the field. Avoid planting into soil containing infected crop residues. See Anemone C 11, Fruit F 5.
Cercospora early blight, early blight (*Cercospora apii)*. Yellow to grey irregular spots develop on ***leaves*** and ***leaf stalks***. Spots dry out and become papery. Fine grey fungal growth develops on spots in humid conditions. Spots may coalesce, leaves appear blighted causing them to shrivel and ***die***.
Septoria spot, late blight, fire blight (*Septoria apiicola*) is probably the ***most serious disease*** of celery. Small, pale spots appear on ***older leaves*** and ***leaf stalks***. These spots may enlarge, turn brown, become spotted with small black fruiting bodies ***(pycnidia)***. If infection is severe spots may join up causing leaves to wither and ***die***. ***Favoured*** by cool, damp weather.
Others: *Alternaria dauci, Drechslera apii.*

See Annuals A 5.

Sclerotinia rots, foot rot, pink rot, white mould (*Sclerotinia sclerotiorum, S. minor*) may occur in the ***field*** and ***postharvest.*** They cause a soft watery pink rotting of ***leaf petioles***, accompanied by a ***whitish fungal growth***. Later small black ***sclerotia*** (up to 6 mm across) develop. Celery may show damping off symptoms when infected from sclerotia in the soil. Mature celery is susceptible to infection from airborne spores resulting in a pink rot. See Vegetables M 7.

Others: ***Damping off*** (*Pythium* sp., *Rhizoctonia solani*), ***rhizoctonia crater rot*** (*Rhizoctonia solan*), ***black rot*** (*Alternaria radicina*), ***grey mould*** (*Botrytis cinerea*), ***rust*** (*Puccinia thuemeni*).

NEMATODE DISEASES

Celery eelworm (*Pratylenchus hamatus*) is associated with severe stunting and chlorosis of celery and parsley in USA when field populations are high; it is not known to occur in Australia. See Vegetables M 11.

Others: ***Cyst nematode*** (*Heterodera* sp.), ***root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***stem and bulb nematode*** (*Ditylenchus dipsaci*), ***stubby root nematode*** (*Paratrichodorus* spp.), *Merlinus brevidens, Rotylenchus brevicaudatus.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Carrot aphid (*Cavariella aegopodii*) is green-winged or wingless and ***3 mm*** long. It sucks sap causing puckering and distortion of ***young leaves*** and growing tips. Leaves may become yellow and russetted. The presence of aphids and honeydew reduces marketability. ***Monitor*** aphids from seedlings to harvest before making a decision to apply an insecticide (Brough et al. 1994). See Carrot M 45.

Others: ***Fennel aphid*** (*Dysaphis foeniculus*), ***parsley aphid*** (*D. apiifolia*) and ***green peach aphid*** (*Myzus persicae*) may also injure celery.

See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)
Green vegetable bug (*Nezara viridula*)
Rutherglen bug (*Nysius vinitor*)
See Vegetables M 12.

Caterpillars (Lepidoptera)
Corn earworm (*Helicoverpa armigera*)
Cutworms (*Agrotis* spp.)
Lightbrown apple moth (*Epiphyas postvittana*)
Looper caterpillars (*Chrysodeixis* spp.)
Lucerne leafroller (*Merophyas divulsana*)
See Annuals A 8, Vegetables M 13.

Flies (Diptera)

Celery fly (*Melanagromyza apii,* Agromyzidae, Diptera) ***maggots*** feed within ***celery stalks*** and bore their way down to the base of the plant. ***Leaf stalks*** yellow and remain stunted or may die if there are enough maggots present in the stem. Little is known of the life history of this fly but it is similar to that of the bean fly. ***Favoured*** by successions of celery crops growing in the same area. If control is considered necessary, use the materials and type of spray program recommended for bean fly. See Beans (French) M 28.

Celery leafminer, celery fly (*Euleia haraclei*) is a serious pest of celery overseas.

Mites (Acarina)

Redlegged earth mite (*Halotydeus destructor*) sucks plant sap. Surface tissue turns white, with large numbers of mites, ***leaves*** may be bleached. See Vegetables M 16.

Spider mites (Tetranychidae): ***Twospotted mite*** (*Tetranychus urticae*) may infest celery, especially unirrigated plants, in hot weather if they have been planted too close to older mite-infested crops, eg beans. ***Leaf undersurfaces*** may become covered with fine webbing among which can be seen the tiny spider mites and their eggs. See Beans (French) M 29.

Thrips (Thripidae, Thysanoptera) may deform ***young leaves***. Damage is usually obvious only after thrips have gone. It may be necessary to apply an insecticide. See Vegetables M 17.

Vegetable leafhopper (*Austroasca viridigrisea*) is a small, green, weak, flying insect that makes foliage grey or yellow by sucking sap; ***leaves*** may curl and die. ***Monitor*** leafhoppers at regular intervals before applying an insecticide (Brough et al. 1994). See Vegetables M 15.

Vegetable weevil (*Listroderes difficilis*) and its larva can cause ***serious damage***. In ***spring*** most damage is caused by the ***adults***. In ***winter*** most damage is caused by the ***larvae*** which are small, legless, pale green or yellow and are found in the soil under the plants. As the larvae grow larger, they attack ***foliage*** and the ***crowns***, making holes and furrows. See Vegetables M 17.

Others: ***Black field cricket*** (*Teleogryllus commodus*), ***wingless grasshopper*** (*Phaulacridium vittatum*), ***leafeating ladybirds*** (*Epilachna* spp.).

SNAILS AND SLUGS

Common garden snail (*Helix aspersa*) and various slugs including ***striped field slug*** (*Lehmannia nyctelia*) may feed on ***stems*** by grazing away the surface tissues and spoiling their appearance. They also feed on ***leaves*** and ***shoots*** after plants have been earthed up. See Seedlings N 70.

Non-parasitic

Environment: ***Bolting*** (going to seed) is ***common***. Celery needs ***more care*** than many other vegetables, requiring about 4 months of mild cool weather for best results (temperatures between 13-24°C and high humidity). Once established, celery will tolerate higher temperatures in the first 4-6 weeks, but not later. Celery will stand light frost, but exposure to temperatures of 4-13°C for 10 days or more induces bolting. ***Heavy frosts*** near harvest may cause blistering on stems. If pale stems are required, ***exclude light*** for the last 3-4 weeks by covering stems with several layers of paper (preferably waterproof) tied top and bottom. Leaves should be left exposed to sun. Plants must be ***irrigated well*** especially in the last 6 weeks. Water stress checks growth and can contribute to

black heart (see below). In light soils it may be necessary to water every day but this favours fungal diseases. Celery will not tolerate ***waterlogging***.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for celery (Weir and Cresswell 1993). ***Black heart*** (calcium deficiency) causes heart leaves of maturing plants to brown then blacken, growing tips ***die***. Tissues become black and leathery, unless soft rot bacteria invade damaged areas to cause a watery decay. During warm, cloudy weather in well irrigated crops, transpiration is reduced so that the translocation of calcium to young tissues is reduced and tissues collapse from ***localised calcium deficiency.*** Maintain an even moisture supply, do not allow soil to dry out, maintain recommended soil pH and apply recommended fertilisers. ***Cracked stem*** (boron deficiency) is often described as ***cat scratch***, ie transverse cracking of the stringy sides of stems. ***Leaves*** may be mottled, longitudinal streaking and pithiness of ***stems*** may also occur. Apply recommended borax fertilisers either prior to or after planting. Avoid growing crops ***susceptible*** to ***boron toxicity*** in rotation after a boron application, eg rock melon, cucumber, pea, potato, tomato, French bean and strawberry. Celery must be ***grown quickly*** otherwise it will be tough and stringy so it must be well fertilised with ***nitrogen*** and other fertilisers.

Overmaturity: Old celery becomes pithy and hollow in the ***stems*** and contains large amounts of stringy fibre which make it unpalatable.

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State/Territory Departments of Agriculture/Primary Industry eg

Celery Growing (NSW Agfact, Vic Agnote)
Celery : Weed Control (Vic Agnote)
Late Blight of Celery (NSW Agfact)
Pests and Diseases of Celery (SA Fact Sheet)
Postharvest Diseases, Injuries & Disorders of Vegetables (NSW Agfact)
Storage Conditions for Fruit & Vegetables (NSW Agfact)

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Celery is grown mostly as a cool season crop for the fresh market. Warm days keep the celery growing and cool nights make the stalks crisp and firm. ***An overview of the industry*** is presented by Coombs (1995). Avoid varieties ***susceptible*** to anthracnose. Plant certified ***disease-free seed*** or seed from disease-free plants from a reliable source. Seedborne diseases include bacterial soft rot, anthracnose, fungal leaf spots and grey mould (*Botrytis cinerea*). Growers usually hot water-treat seed, eg 50^{o}C for 30 minutes, to control seedborne diseases. Treated seed should be ***dusted with a protective fungicide*** before sowing in disease and pest-free seedbeds. Seed > 2 years old may not require treatment because some fungi die before the seed loses its viability. ***Seedlings are transplanted*** at 8-10 weeks, depending on the season. ***Practise crop rotation*** (2-4 years), do not plant celery in land where an infected crop has been grown in the previous 2 years. Soil should be rich and well drained. Avoid overhead irrigation and keep humidity low as foliage fungal diseases may be serious problems. ***Plough in crops and debris*** deeply immediately after harvest to prevent infection of later crops and practice ***on-farm hygiene*** to prevent reinfection. ***Pre-plant soil treatments*** may include nematicide treatments for nematodes. ***Weed management:*** Roots are shallow so avoid damaging them during cultivation. ***Pre-emergence herbicides*** are registered for control of broadleaved and grass weed seeds; ***post-emergence herbicides*** are registered for control of a wide range of broadleaved weeds and some grasses. ***Pesticides*** are registered for leaf spots (the most destructive diseases) and aphids, thrips, caterpillars and other problems. Pesticides should be applied at the first sign of infection or infestation, repeat applications may be required especially during cool weather. It may be necessary to spray seedbeds. Avoid copper sprays late in the growing season as they stain foliage. ***Blanching:*** For those who like light coloured celery wrap each plant with several sheets of newspaper or by placing black plastic about 500 mm wide around the 2 rows of plants. Blanched celery contains less vitamin A than unblanched celery. ***Harvest*** when the desired height is reached and before it is fully mature, old celery becomes very pithy and hollow in the stems and contains large amounts of stringy fibre which make it unpalatable. ***Storage and transport:*** Celery requires fast cooling (up to 4 hours); it is sensitive to ethylene. Store celery under recommended conditions, eg at 0^{o}C and > 95% relative humidity. Estimated storage life is 6-10 weeks, but this would depend on the precise storage conditions.

Cucurbits

Cucumber (*Cucumis sativus)*
Pumpkin, squash (*Cucurbita maxima*)
Rockmelon (*Cucumis melo*)
Watermelon (*Citrullus vulgaris*)
Zucchini, squash (*Cucurbita pepo*)
Family Cucurbitaceae

PESTS AND DISEASES

Parasitic

- **Virus and virus-like diseases**
  - Cucumber mosaic
- **Bacterial diseases**
  - Bacterial leaf spots
- **Fungal diseases**
  - Damping off
  - Downy mildew
  - Fruit rots
  - Fungal leaf spots
  - Powdery mildews
  - Root and stem rots, wilts
- **Nematode diseases**
  - Root knot nematodes
- **Insect and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Flies
  - Fruit flies
  - Greenhouse whitefly
  - Ladybirds
  - Leaf beetles, flea beetles
  - Leafminers
  - Mites
  - Stemborers
  - Thrips
  - Weevils
- **Vertebrate pests**

Non-parasitic

- Environment
- Fasciation
- Fruit set
- Nutrient deficiencies, toxicities
- Pesticide injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

*Viruses may cause **severe loss** of yield (10-100%) through reduced fruit set and fruit distortion. Mosaic symptoms on leaves are common. Yellow rings and lumps develop on fruits (Fig. 329).*

Cucumber mosaic

Scientific name: Cucumber mosaic virus ***(CMV).*** Strains differ in their host range, symptoms produced, method of spread and other properties and characteristics.

Host range: This virus has, perhaps, a wider host range and attacks a greater variety of plants than any other virus. ***Ornamentals***, eg delphinium, gladiolus, hydrangea, lily, petunia, zinnia, ***fruit***, eg passionvine, ***vegetables***, eg brassicas, cucurbits, peppers, spinach (spinach blight), tomato, celery, beets, bean, banana, ***weeds***, eg shepherd's purse, ***field crops***, eg lupins.

Symptoms: Symptoms vary with the host but usually include mottling or discolouration of ***leaves, flowers*** and ***fruit***, stunting, death of plants (up to 50% may be killed) and reduction in quality and yield. ***Young cucumber seedlings*** are usually infected in the field when about 6 weeks old and growing vigorously, 4-5 days after infection, young leaves become mottled, distorted and wrinkled and their edges begin to turn downward. All later growth is reduced drastically and plants are dwarfed with a bushy appearance, leaves form a rosette-like clump near the ground, plants produce few runners, flowers and fruit. ***Older leaves*** initially yellow, later margins brown and eventually fall, leaving part or most of the older vine bare. ***Fruit*** produced after infection show pale green or white areas intermingled with dark green rough, wartlike projections causing distortion. Cucumbers formed in the later stages of disease are misshapen, smooth grey-white with some irregular green areas. They often have a bitter taste and become soft and soggy when pickled.

Disease cycle: In spring, first infections are initiated by aphids carrying virus from infected weeds and other hosts or by using infected seed. Spread of the virus from these infected plants to other plants in the crop is by aphids or by plant handling. Entire crops are infected. Whether the virus is transmitted by insects or via sap, infection is systemic in most hosts.

Overwintering: Infected perennial weeds, flowers and crop plants, seed.

Spread: By more than 60 species of aphids, eg green peach aphid (*Myzus persicae*) and cotton aphid (*Aphis gossypii*), by mechanical inoculation, by handling and by sap carried on hands, clothes and tools especially at picking time, by seed in 19 species (but in variable percentage).

Conditions favouring: Cool climates.

Control: Once a plant is infected with virus nothing can be done. Measures to minimise losses:
Sanitation: Eradicate perennial weed hosts from around greenhouses and nurseries.
Resistant varieties have been developed for several host crops, including cucumber.
Plant quarantine: Isolate susceptible crops from other hosts, eg geranium, lily.
Disease-free planting material: Plant virus-tested seed. For species propagated vegetatively, plant virus-tested cuttings, rhizomes, etc.
Pesticides: Insecticides control aphids before they carry virus into commercial seedbeds.

Others

Papaya ringspot virus (PRV) type W (= watermelon mosaic virus type 1) infects cucurbits and weeds, eg wild gherkin (*Cucumis anguria*), causing an obvious light and dark green ***mosaic on leaves***. Recently infected new growth stands more erect with mosaic patterns developing later. Zucchini leaves may be ***claw-like*** with a severe blister mosaic. Fruit set may be reduced and ***fruit*** may be lumpy, distorted or warty. ***Spread*** by aphids, eg cowpea aphid (*Aphis craccivora*), green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), by mechanical inoculation, not by seed.

Squash mosaic virus (SMV) may infect cucurbits, eg cucumber, honeydew, marrow, melon, pumpkin, Florida beggarweed (*Desmodium tortuosum*). ***Leaves*** develop mosaic, often with ringspots and deformation. ***Seedlings*** grown from infected seed develop green veinbanding on the 1st or 2nd leaf. Subsequent leaves tend to cup upwards and produce a light or dark green mosaic. Squash plants have regular projections from the veins on the leaf margins resulting from unequal growth of leaf tissue. New foliage may be symptomless or develop yellow spots, veinclearing or leaf distortion. Infected plants are stunted with fewer branches and fruit. ***Fruit*** may develop mild mottling to severe deformation, yield is reduced. ***Spread*** by cucurbit ladybird (*Epilachna cucurbitae*), by mechanical inoculation, by seed in *Cucumo melo* (+ or -10% and even up to 35%) and in *Cucurbita pepo* (+ or -10%), not by pollen (Buchen-Osmond et al. 1988). Only produce ***seed*** in areas where virus is not prevalent. Control of ***beetle vectors*** restricts spread.

Watermelon mosaic virus type 2 (WMV2) affects cucurbits especially pumpkins, watermelons, rockmelons, squashes, gramma and zucchini, also *Lagenaria siceraria*, ***field crops***, eg medic, sesame, ***weeds***, eg small-flowered mallow. ***Leaves*** develop a light and dark green mosaic, occasional distortion. ***Fruit*** are rarely distorted. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), cotton aphid (*Aphis gossypii*), by mechanical inoculation, not by seed. Overseas also by potato aphid (*Macrosiphum euphorbiae*) and leafminer (*Liriomyza sativa*).

Zucchini yellow mosaic virus (***ZYMV***) sporadically affects marrow, pumpkin, rockmelon, watermelon and zucchini, causing a severe ***yellow mosaic*** and distortion and blistering of leaves. Plants are often stunted with poor fruit set. There may be different strains. ***Fruit*** may not set, those that do may be small, distorted, lumpy with blotches, mottles and rings. Symptoms persist. Yield of crops is severely affected. ***Spread*** by aphids, eg *Aphis citricola*, *A. gossypii*, *Myzus persicae*, *Macrosiphum euphorbiaceae*, by mechanical inoculation, not by seed. Minimise losses by early planting. Some varieties are ***resistant***.

Others: Beet pseudo-yellows virus, cherry rasp leaf virus, potato Y virus.

Avoid ***overlapping crops*** of cucurbits. Reflective plastic mulches may deter aphids from landing on cucurbit leaves, eg those where runners do not rapidly cover mulched areas, if used in conjunction with weekly sprays of mineral oil insecticide. Regular insecticide applications often have ***little effect*** on the spread of most of these viruses. Feeding times are so short that a significant amount of spread occurs even when aphids just move through a crop making only brief feeding probes at leaves. Select varieties with some ***resistance*** to both ***PRV*** and ***ZYMV***. Only use ***virus-free seed***. ***Plough-in*** all harvested cucurbit crops especially zucchinis. See Vegetables M 4.

BACTERIAL DISEASES

Bacterial leaf spots

Angular leaf spot (*Pseudomonas syringae* pv. *lachrymans*) affects cucumber, rockmelon and other cucurbits. Small spots ***3 mm*** across develop on leaves. Bacterial ooze on the lower surface appears white, leaves are ragged. It also affects fruit stalks and fruit. See Vegetables M 5.

Bacterial leaf spot (*Xanthomonas campestris* pv. *cucurbitae*) affects cucumber, marrow, pumpkin and squash. Small watersoaked spots 2 mm across develop on ***leaf undersurfaces*** with corresponding yellowing on uppersurfaces. These areas enlarge to become rounded or angular with papery centres and wide, yellow halos. ***Fruit*** develop watersoaked markings with light brown ooze that dries to a yellow crust. See Vegetables M 5.

Others: ***Bacterial soft rot*** (*Erwinia carotovora* subsp. *carotovora*), ***bacterial wilt*** (*E. tracheiphila*), ***bacterial fruit blotches and rind breakdown*** (*Pseudomonas* spp.). Although these diseases may not be common, some of them may be seedborne.

FUNGAL DISEASES

Damping off (*Fusarium oxysporum* f.sp. *niveum, Pythium* spp., *Rhizoctonia solani*). See Seedlings N 66.

Downy mildew (*Pseudoperonospora cubensis*) attacks cucumber, rockmelon. Yellow angular to round spots develop on ***leaf uppersurfaces***. Purple to brown fungal growth on undersurface in humid or wet weather. Leaves shrivel and ***die*** if spots are numerous. Cucurbits and cultivars vary in susceptibility. See Annuals 5.

Fruit rots: As fruit lie on the ground, several diseases affect both the fruit and growing crop.

Alternaria fruit rots (*Alternaria* spp.) causes circular to oval whitish or brown spots on ***fruit*** of ***rockmelon*** (occasionally others) that may become sunken. Skin is soon covered with a dark mould and olive-green or dark grey spores. ***Favoured*** by sunscald, prolonged storage or storage at too low temperatures.

Anthracnose (*Colletotrichum orbiculare*) affects cucurbits especially ***watermelons***, also ***rockmelons*** and ***cucumbers***. ***Leaves*** develop reddish-brown to black round spots with watery edges. ***Stems*** develop long dark sunken spots which may girdle stems causing that part of the runner to wilt and die. Round sunken spots with masses of ***pink spores*** form on the ***fruit***. Fruit healthy when picked may develop anthracnose in transit. Grow ***resistant*** varieties. Several varieties of watermelon and cucumber in the USA have some resistance to some races. Seldom troublesome in Australia because of the use of ***disease-free seed***. See Fruit F 5, Vegetables M 6.

Blue mould (*Penicillium* spp.) affects mostly ***melons*** and ***cucumbers***, circular watersoaked spots become covered with blue-green spores, there is a musty odour. See Fruit F 6.

Brown etch (*Fusarium)* and ***gummy stem blight*** (*Didymella bryoniae*) are soil fungi which commonly invade ***butternut pumpkin*** (occasionally other pumpkin varieties) where ground contact occurs during warm wet weather. Bronze areas with concentric bands develop on fruit, mostly on the lower surface, areas may be large with cracked centres. The bronze colour changes to a light grey. If secondary rots enter through cracks complete breakdown may occur. In areas where disease is common, plant less susceptible varieties during summer. See below.

Fusarium* fruit rot** (*Fusarium* spp.) is a common ***postharvest disease of cucurbits especially ***rockmelon*** and may occur with ***bacterial soft rot.*** Symptoms usually begin at the ***stem end*** as scattered spots on the skin. Spots become spongy or corky and are later covered with ***white or pink fungal growth***. It is a common soil inhabitant and often infects ***fruits*** on the underside but spores may be splashed onto any part of the fruit during rain or irrigation. Some ***wounding*** is necessary for infection. Hot wet weather during harvest favours rapid breakdown of fruit (Persley 1994).

Pink mould rot (*Trichothecium roseum*) is a common soil inhabitant which causes a ***postharvest*** disease of ***rockmelon***. It affects the ***blossom end*** of the fruit; later extending over the surface. Affected skin becomes tough and shrivelled, a viscous liquid may ooze from lesions and a furry pinkish fungal growth may develop. Diseased flesh is spongy, light brown and bitter. Spores are ***spread*** by air movement, irrigation water and insects. Fruit are invaded through soil contact, injuries in the cut stem during harvest. ***Favoured*** by warm weather.

Root and stem rots, ground rots: Several of these fungi cause diseased areas on the undersides of fruit where it touches the ground. Symptoms vary with the fungus. These rots cause ***pre- and postharvest losses*** of fruit especially in ***rockmelons*** and ***cucumber***. Use mulch, eg plastic, to reduce fruit contact with soil and do not market affected fruit. ***Rhizoctonia ground rot*** (*Rhizoctonia solani*) causes small circular watersoaked spots to light brown sunken areas with surface cracking. It is a minor disease. ***Sclerotinia rot*** (*Sclerotinia* sp.) causes a white cottony rot followed by black sclerotia. ***Sclerotium rot*** (*Sclerotium rolfsii*) causes large decayed areas with prominent white thick fungal growth on affected areas. See below.

Rhizopus soft rot (*Rhizopus stolonifer*) can be a ***serious postharvest disease*** of ***rockmelons***. It may occur in association with bacterial soft rot. *Rhizopus* causes a soft rot with white fungal growth and black spore heads. ***Favoured*** by wet weather when dying blossoms are invaded allowing the fungus to enter the stem end of fruit. Infection can also occur through wounds. See Fruit F 6.

Sour rot, yeasty rot (*Geotrichum candidum*) is a ***major postharvest disease*** of ***rockmelon***. It enters stem ends during wet weather, rots the inside of fruit leaving a hollow shell with an unpleasant smell and a white cheesy fungal growth on decayed tissue. Sour rot is often confused with, and may occur with ***bacterial soft rot***. ***Overwinters*** in soil. ***Spread*** after harvest from fruit to fruit in contaminated wash water, by ferment flies. Avoid harvesting in wet weather, handle fruit carefully to minimise injury, cool fruit rapidly after harvest and apply recommended fungicides postharvest. See Citrus F 34, Pineapple F 104.

Others: Grey mould, fruit rot, lower stem rot (*Botrytis cinerea*), ***septoria leaf spot*** (*Septoria cucurbitacearum*), ***fruit spot***, blossom rot (*Choanephora* sp.), ***storage rot***, dry rot (*Gibberella avenaceum*), also *Gomerella cingulata* var. *minor, Fusarium equiseti, Pythium* spp.

See Fruit F 5.

Fungal leaf spots

Alternaria leaf spot (*Alternaria cucumerina*) Small tan spots develop on ***leaves*** enlarging to roughly circular brown areas which may have ***concentric ring markings***. Spots coalesce to almost cover the entire leaf. ***Favoured*** by warm moist weather, disease is more important on some cucurbits than others. Generally a minor disease. Bicarbonates and film-forming oil products are being researched for control overseas (Ziv and Zitter 1992).

Septoria leaf spot (*Septoria cucurbitacearum*) causes small brown spots with brownish centres studded with black pinpoint fruiting bodies ***(pycnidia)***. Lesions on ***fruit*** are small, circular, light brown raised scabs with star-shaped cracks occurring in the centre of mature lesions. ***Favoured*** by cool weather. Mainly a disease of pumpkin but may also be found on other cucurbits.

Others: Gummy stem blight and black rot *(Didymella bryoniae = Mycosphaerella melonis)* may also cause leaf spots (see below). ***Also*** *Ascochyta phaseolorum, Cercospora citrullina, Corynespora cassicola.*

See Annuals A 5.

Powdery mildews

Powdery mildews (*Oidium* spp.) are ***common*** and ***serious diseases*** of cucurbits. White powdery spots spread to cover upper and lower leaf surfaces and stems, older ***leaves*** may die. ***Fruit*** may be sunscalded due to death of leaves. ***Fruit*** of ***zucchini*** may itself be infected with powdery mildew. ***Vines*** may be stunted, lose vigour, fruit production may be reduced. Late crops are usually affected more severely than early or mid-season crops. ***Favoured*** by mild summers, sheltered shaded positions and greenhouse conditions. Wet weather and very hot, dry weather are ***unfavourable***. Use a ***resistant variety*** if available. All varieties of pumpkin, squash and gramma, and some cucumber varieties, eg apple cucumber, and rockmelon are susceptible. Leaf disk assays are used overseas to detect resistance of melons to the ***different races*** of powdery mildew (Cohen 1993). Bicarbonates and film-forming oil products are being researched for control overseas (Ziv and Zitter 1992). See Annuals A 6.

Root and stem rots, wilts

Fusarium root rot (*Fusarium solani* f.sp. *cucurbitae*) affects pumpkin, squash and marrow, rarely cucumber. ***Seedling leaves*** become pale and wilt. There may be a yellow or red rot at the ***stem base*** (soft tissues at the base of the plant disintegrate, leaving only the reddish-brown stringy water-conducting fibres). ***Roots*** initially appear healthy but in advanced cases they turn brown. Plants may wilt. Symptoms in older plants are similar. ***Fruit*** may rot and a white fungal growth develop. Seedborne. See Vegetables M 7.

Gummy stem blight and black rot *(Didymella bryoniae = Mycosphaerella melonis*, Ascomycetes) is a ***serious worldwide disease*** of cucurbits. Spots on ***leaves*** are black and often appear tattered, they may contain small black fruiting bodies. Watersoaked cankers develop around the crown of ***stems*** and may become sunken, light brown or whitish and covered with small fruiting bodies. Cankers may split open and exude a reddish gum. If they girdle stems the runner wilts and dies. Round or irregular sunken leathery spots are formed on ***fruit***, and may cause losses in the ***field, in transit or storage***.

Overwinters in infected crop trash and seed. Spores are ***spread*** by wind and air currents. ***Favoured*** by moist conditions. Bicarbonates and film-forming oil products are being researched for control overseas (Ziv and Zitter 1992).

Phomopsis black stem, black root rot (*Phomopsis sclerotioides,* Imperfect Fungi). Infected ***roots*** turn brown with black lines and spots on their surface. Plants wilt and eventually die

Sudden wilt or vine decline (interaction between several soil fungi and plant stress). During fruit set, especially ***rockmelon*** and ***honeydew melon*** which appear to be developing normally, suddenly yellow, wilt and die, leaving most of the crop immature and unmarketable. *Pythium*, *Fusarium* and *Macrophomina phaseolina* in Qld destroy feeder roots and invade larger roots, restricting water uptake so that the high demand for water during fruit enlargement cannot be met and vines wilt. ***Favoured*** by saturated or poorly aerated soils. Varieties with vigorous root systems are more tolerant. Avoid ***highly susceptible*** varieties, manage ***irrigation*** to avoid overwatering, especially at fruit set. ***Phosphonic acid*** reduces sudden wilt and increases yield. ***Manosporascus root rot and vine decline*** (*Monosporascus cannonballus*) is a severe disease of melons in Texas and other countries (Martyn and Miller 1996)

Wilts: ***Fusarium wilt*** (*Fusarium oxysporum*) is common and widespread. *F. oxysporum* f.sp. *melonis* attacks rockmelon, *F. oxysporum* f.sp. *niveum* attacks watermelons and *F. oxysporum* f.sp. *cucumerinum* attacks cucumber. These fungi may cause ***damping off*** of cucurbits in early sown crops (cold weather), seedlings wilt and die. ***Older plants*** wilt, leaves yellow near the crown, later the whole plant wilts, plants may be stunted, the plant finally dies. If the tap root or stem near the base is split open, vascular tissue is reddish-brown. ***Fruit*** from affected vines are small with poor flavour and colour. Considerable losses can occur. ***Verticillium wilt*** (*Verticillium dahliae*) has been recorded on cucurbits. See Vegetables M 9.

Others: ***Grey mould*** (*Botrytis cinerea*) infects dead flower, pruning wounds and damaged stems which turn soft and mushy. ***Sclerotinia rot*** (*Sclerotinia* spp.) infects dead flower parts, pruning wounds and damaged stems, causing white cottony rots. ***Also rhizoctonia stem rot*** (*Rhizoctonia solani*), ***sclerotium stem rot*** (*Sclerotium rolfsii*), ***stem rot*** (*Cladosporium cucumerina*) and ***thielaviopsis black root rot*** (*Thielaviopsis basicola*).

These diseases are ***controlled*** using cultural practices, eg crop rotation, seed treatments and fungicides. See Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) cause stunting and yellowing of plants, symptoms similar to those of water and nutrient deficiency. Swellings or galls, varying in size from small up to ***25 mm*** in diameter, form on ***roots***. Severe infestations will kill plants. See Vegetables M 10.

Other: ***Root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus dihystera*, *Rotylenchus* spp.), *Paraphelenchus pseudoparietinus*, *Paratrichodorus* spp., *Radopholus vangundyi, Tylenchorhynchus capitatas*.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) suck sap from ***new growth*** causing distortion and retarding growth. They secrete honeydew on which sooty mould grows disfiguring fruit. Aphids are most important as ***vectors of virus diseases.*** Early infection of plants by ***WMV*** and ***CMV*** may be serious.

Cotton aphid, melon aphid (*Aphis gossypii*) ***ornamentals***, eg cosmos, dahlia, hibiscus, sunflower, ***vegetables***, eg cucurbits, especially melons, pumpkins, cucumbers, ***field crops***, eg cotton, pastures. ***Adult aphids*** are about ***3 mm*** long and may be yellow-green to dark green or almost black, darker forms predominant on cucurbits. It often has a mealy or waxy bloom. Large populations can buildup in a short time. Aphids feed on young growing shoots or ***leaf undersurfaces*** and may stunt growth. Leaves may wither, exposing fruits to sunburn. Honeydew and sooty mould make fruit unsightly. Cotton aphid is the main vector of ***WMV.*** Crops may suddenly be infested by winged greenish black aphids that are ***windborne*** from their breeding sites on inland pastures during spring and autumn. ***Natural enemies: Predatory*** ladybird beetles, eg common ladybird (*Harmonia conformis*), hoverfly and lacewing larvae, and wasp ***parasites***, may control aphids but do not prevent virus transmission.

Others: ***Green peach aphid*** (*Myzus persicae*) are prevalent on cucurbits in spring and autumn but usually do not buildup to large numbers on cucurbits. ***Potato aphid,*** tomato aphid (*Macrosiphum euphorbiae*) may feed on seedlings causing leaves to curl. In older plants, development is retarded and yield reduced. Potato aphid may transmit ***WMV***. Also ***cowpea aphid*** (*Aphis craccivora*).

Insecticides does not usually prevent infection because only a few aphids are sufficient to transmit virus diseases, but it may stop further spread within the crop. Preventing aphids from breeding on the infected plants may prevent spread. Use virus ***resistant cultivars*** if these are available. Spray young plants to protect them from infection. Avoid planting successive crops of susceptible cultivars. For valuable crops, consider using reflective mulches and insecticides to reduce ***WMV***. See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)

Cucurbit shield bug, pumpkin bug (*Megymenum affine,* Dinidoridae) feeds on ***stems, leaf stalks*** and ***young fruit*** of ***pumpkins*** and other ***cucurbits***. They are brown to blackish, corrugated, not very active and ***10-14 mm*** long.

Green mirid (*Creontiades dilutus*) sometimes attacks cucurbit plants in coastal districts during the spring. It is pale green, narrow, active and about ***6 mm*** long. It sucks the juices from the ***growing points*** of young plants and the points turn yellow and drop out. On cucurbits, this bug has not been very destructive but it probably delays the growth of some early crops. See Vegetables M 12.

Green vegetable bug (*Nezara viridula*) is green, shield-shaped and ***25 mm*** long. Immature stages are smaller, brownish or blackish with orange markings. They attack cucurbits causing pale dry patches on fruit. Damage to stalks sometimes prevents the proper maturation of fruits. See Vegetables M 12.

Rutherglen bug (*Nysius vinitor*) is ***5 mm*** long, brown with silvery wings folded over the body. It can fly rapidly. Bugs suck sap and may attack and ***kill cucurbits***. Sometimes swarms of winged forms are responsible, but it is not uncommon for hordes of young wingless bugs with a few adults to crawl into crops from nearby weedy areas where they bred. ***Favoured*** by hot weather. See Vegetables M 12.
Others: Fruitspotting bug (*Amblypelta nitida*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Cucumber moth (*Diaphania indica,* Pyralidae) affects cucurbits, eg cucumbers, watermelons, overseas also cotton. ***Moths*** are about 25 mm across outspread wings which are translucent-white with a broad dark brown edging. The abdomen has a brush of long yellow scales at the tip. Moths lay eggs on leaf undersurfaces. ***Caterpillars*** are white when small, but become yellow-green and about ***25 mm*** long. Young caterpillars graze on ***leaf under surfaces***. Later leaves become ragged and webbed together with silk. Leaves may be completely destroyed and caterpillars may burrow in the ***stem*** and gouge irregular-shaped holes in ***fruit***. They mature after about 4 weeks, pupate in light silken cocoons which are spun inside webbed leaves or leaf fragments. The moth emerges about a week later. ***Spread*** by the moths flying. ***Favoured*** by warm climates, heavy rain. ***Monitor*** damage before applying insecticides (Brough et al. 1994).
Cutworms (*Agrotis* spp.) are dark, smooth caterpillars up to ***35 mm*** long that curl up in a circle when disturbed. They shelter in soil during the day and feed at night eating young plants at ground level. Found in the soil around plant bases. See Seedlings N 68.
Others: Banana fruit caterpillar (*Tiracola plagiata*, Noctuidae), *Anadevidia peponis*. ***Overseas*** melonworm (*Diaphania hyainata*) caterpillars feed on leaves and fruit, pickleworm (*D. nitidalis*, Pyralidae).

See Annuals A 8, Vegetables M 13.

Flies (Diptera)

Seedling bean midge (*Smittia aterrima*) maggots may attack ***cucumber*** and ***marrow*** planted early in spring when soil temperatures are too low for rapid germination. Tiny white, thin worm-like maggots up to ***5 mm*** long, that normally feed on ***organic matter*** may enter seeds through the bursting ***seed coat***. When seedlings emerge above ground they may be only blind stalks with one or both seed leaves missing. If the growing point is damaged but not destroyed, the plant will be badly stunted. See Beans (French) M 28.
Onion maggot (*Delia platura*) damages cucurbit ***seedlings*** which wilt and die soon after appearing above the ground. The stem underground will have been hollowed out by the small white maggots and it will usually have rotted. See Onion M 68.

Fruit flies (Tephritidae, Diptera)

Cucumber fly (*Bactrocera cucumis*) is a subtropical pest of cucurbits, tomato and papaw in coastal and sub-coastal districts. ***Flies*** are generally similar to the Queensland fruit fly, about 7 mm long, but have a yellow median stripe on the uppersurface of the thorax. Flies become numerous after mid-summer and lay their eggs in ***mature, damaged or sunburned fruits***. If flies are abundant they attack immature fruits in which eggs usually fail to hatch. These unsuccessful punctures appear later as ***callused deformities*** on the fruit. ***Maggots*** are white and tapering. The life history is similar to that of the Queensland fruit fly. Unlike it though, it is attracted to packing sheds and can infest produce at packing.
Overseas: Also ***melon fly*** (*Dacus cucurbitae*), ***lesser pumpkin fly*** (*D. ciliatus*).

See Fruit F 9.

Greenhouse whitefly (*Trialeurodes vaporariorum*) are small, white-winged, moth-like insects about ***1 mm*** long that infest cucurbits in humid protected places. ***Gross attack*** will result in some wilting, reduced vigour and an excessive contamination of fruit by honeydew and sooty mould. Heavy infestation does not necessarily cause damage. See Greenhouses N 24.

Ladybirds (Coccinellidae, Coleoptera):

Cucurbit ladybird (*Epilachna cucurbitae*) is a native insect which feeds on a wide range of plants, as well as cucurbits. It is an efficient vector of ***SMV***. This is unusual because nearly all viruses are transmitted by sap sucking insects. ***Adults*** are about ***7 mm*** long, oval, humped and a dull yellow-orange with 28 spots on wing covers (Fig. 330). They ***skeletonise leaf uppersurfaces***. Females lay eggs in a cluster on leaf undersurfaces. ***Larvae*** are yellowish, spiny and mainly ***skeletonise leaf undersurfaces***. They may also feed on rind of fruit. When fully grown they pupate on leaves. ***Do not confuse*** with the common spotted ladybird (*Harmona conformis*) which feeds on aphids (Fig. 330). Yield is reduced and fruit may be sunscalded.
Potato ladybirds (*Epilachna* spp.) in humid areas and in irrigated crops, commonly skeletonise ***leaf uppersurfaces***, often starting at the margins. They may chew holes right through leaving only the veins. The spiny ***larvae*** usually feed on ***leaf undersurfaces.*** Severely skeletonised leaves wither. Sometimes young cucurbit fruit have parts of their skin eaten. See Potato M 81.

Leaf beetles, flea beetles

(Chrysomelidae, Coleoptera)

Metallic flea beetles (*Altica* spp.) are about ***6 mm*** long, purple blackish and jump when disturbed. They damage foliage by chewing ***small round holes*** either through or into the leaf so that leaves look as if they have been peppered with fine shot. See Hibiscus K 82.
Pumpkin beetle (*Aulacophora hilaris*) is a ***serious pest*** of cucurbits, especially ***rockmelons***, also pumpkins, melons, squashes, related plants, wild melons, which are probably the natural hosts; very occasionally, figs, cherries. ***Beetles*** are ***elongated***, ***6 mm*** long, bright orange-yellow with ***2*** large black marks on each wing cover (Fig. 331). ***Plain pumpkin beetle*** (*A. abdominalis*) is uniformly yellow-orange and is usually found with the pumpkin beetle and has similar habits. Pumpkin beetles are especially damaging to ***seedlings, flowers*** and ***small fruit.*** Spring seedlings may be attacked shortly after germination. Relatively few beetles on each plant can defoliate and destroy seedlings. Beetles often cluster together in scattered groups on younger leaves and terminals of ***older plants*** and can check

growth if they are numerous. However, once ***runners form***, plants outgrow attack. Beetles destroy flowers and feed on the skin of fruits producing disfiguring blemishes. ***Larvae*** are cream, 10-12 mm long and may cause minor damage to roots, lower stems and fruit on the ground, there. There is economic loss due to delay in crop maturity and marketing. There is a ***complete metamorphosis*** (egg, larva, pupa, adult) with probably only 1 generation each year. In spring overwintering adults fly to host plants and lay eggs in small clusters on dead leaves or moist soil under plants. Adults may live for up to 10 months and egg-laying may go on for several months with the female producing as many as 500 eggs. Eggs hatch in about 10 days. Larvae are fully fed in about 5 weeks and pupate in the soil. ***Overwinters*** as adult beetles in sheltered situations, eg under loose bark. ***Spread*** by adults flying strongly, also by the movement of infested seedlings. ***Favoured*** by calm, warm, dry conditions during summer following wet or windy weather. ***Control is only required*** from when germination occurs until runners are formed. Plant extra seed in each hill to provide for any losses of young plants. Little is known about natural enemies. Apply ***insecticides*** whenever plants emerge. After about 3 weeks plants grow vigorously, outgrowing attack and spraying is usually no longer required. Home gardeners may dust hydrated lime or flour daily for 3 weeks whenever plants come through the soil.

Redshouldered leaf beetle (*Monolepta australis*) is about ***6 mm*** long, yellow with red bases to the wing covers and is a sporadic pest of cucurbits. Beetles feed in swarms mainly in the ***flowers***. Infested plants look as if scorched by fire due to the perforation of foliage by the beetles. Lesser infestations may interfere with ***fruit setting***. Each swarm can be controlled individually by spraying. See Fruit F 11.

Overseas: Pale striped flea beetle (*Systena* spp.), ***striped cucumber beetle*** (*Acalymma villata*), ***spotted cucumber beetle*** (*Diabrotia undecimpunctata*).

Leafminers: ***Serpentine leafminer***

(*Liriomyza trifolii*, Agromyzidae, Diptera) is a ***serious pest*** overseas of ornamentals and vegetables due mainly to pesticide resistance. Neem oil has been used successfully overseas to control this pest. See Cineraria A 28.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) is tiny, active and whitish. It infests vigorously growing cucumbers and chokos in humid conditions, causing ***leaves*** to become narrow, ***strap-like***, mottled with a pronounced ***down-curling*** of the margins. Mites are found in curled leaves. See Greenhouses N 26.

Clover mite (*Bryobia cristata)* is tiny, brown and has long front legs. Mites feed at night and rest on plants during the day. ***Finely peppered greyish spots*** occur on ***leaves***. Colonies may injure young cucurbit plants slightly when migrating. Control as for spider mites if necessary. See Beans (French) M 29.

Earth mites (Penthalidae) may suck sap from ***leaf uppersurfaces*** of early-sown cucurbits causing ***silvery or whitish blemishes*** particularly along the main veins. If infestation is heavy, leaves may look bleached. Mites feed at night or by day in cloudy weather. See Vegetables M 16.

Spider mites (Tetranychidae): ***Bean spider mite*** (*Tetranychus ludeni*) and ***twospotted mite*** (*T. urticae*) are common pests of cucurbits, especially ***cucumbers*** and ***rockmelons***, in dry seasons in land which previously carried infested crops or weeds. Infested ***leaves*** become greyish, yellowish, then before wither. Fine, grey webbing occur on leaf undersurfaces. ***Favoured*** by hot dry weather, infested areas nearby. Eggs are laid near the veins on leaf undersurfaces and nymphs and adults are initially concentrated near these regions. Damage is first seen as pale bronzed areas near the midrib and leaf veins. See Beans (French) M 29.

Stemborers

Cucurbit stemborer (*Apomecyna histrio,* Cerambycidae, Coleoptera) is a ***longicorn beetle***, about ***10 mm*** long. Eggs are laid singly in cracks along the stem and ***larvae tunnel downwards in stems*** producing swellings at the leaf nodes. ***Mature larvae*** are cream, about ***20 mm*** long, they pupate in the stem. Commonly infests cucurbits but usually only causes obvious symptoms on ***rockmelon*** in Qld, it does not seem to cause economic loss. Large numbers establish on ***choko vine*** because of its perennial habit. Normally cucurbits make such rapid growth that they flower and bear a crop even when stemborer attack is heavy. See Trees K 11.

Others: Overseas ***melon stemborer*** (*A. binubila*) and ***squash vine borer*** (*Melittia cucurbitae*, Aegeriidae, Lepidoptera) damage cucurbits.

Thrips (Thysanoptera)

Melon thrips, eastern yellow thrips (*Thrips palmi*) infests a wide range of ornamentals, vegetables and weeds, eg cucurbits, grasses, Solanaceae in the NT, Qld and northern NSW (Macdonald and Elder-Layland 1994). ***Adults*** are about 1.5 mm long, ***yellowish***, many other species are brownish-black. Damage to ***leaves*** is similar to that of other leaf-feeding thrips, ie crinkling and browning, deformed growing tips. ***Fruits*** may be scarred. To prevent spread to other areas, some states have ***quarantine requirements*** regulating the entry of all plants, fruits, vegetables and flowers. See Greenhouses N 24.

Onion thrips (*Thrips tabaci*) may damage young cucurbit plants in dry weather slowing plant growth. ***Leaf undersurfaces*** become bronzed or dull silver and rather shiny. Leaf margins turn down and there is some mottling. Damage to ***flowers*** and malformation of the ***fruit*** occurs. Insecticides may be applied when damage first appears. See Onion M 68.

Weevils (Curculionidae, Coleoptera)

Fuller's rose weevil (*Asynonychus cervinus*) larvae are small white, legless and feed on ***roots*** and ***underground stems***, which are gouged and pitted, growth is slowed. See Roses J 6, Vegetables M 17.

Whitefringed weevil (*Graphognathus leucoloma*) larvae are creamy and thickset, may attack cucurbits sown on land recently under lucerne or clover. They attack ***main roots*** and ***underground stems*** which may be ringbarked or extensively furrowed. They are found on the roots and in the soil beside them. Plants become stunted, some may die. See Vegetables M 17.

Others: ***Vegetable leafhopper*** (*Austroasca viridigrisea*), ***mealybugs*** (Pseudococcidae).

VERTEBRATES PEST

Rats and mice feed on ***stored cucurbits***, eg pumpkins. See Fruit F 13.

Non-parasitic

Environment: Cucurbit foliage is sensitive to ***frost***. Cold winds or low temperatures retard growth. ***Optimum seed germination*** is obtained at soil temperatures > 20 °C, seeds will not germinate satisfactorily at < 16 °C. ***Exposure of butternut pumpkins to cold conditions*** either in the field or in storage late in the season causes red-brown markings on the skin (Fig. 332). Sow butternut pumpkins early so that the crop is matured and gathered before the cold weather and do not store in cold conditions. ***Cucurbits need a lot of water***, do not allow soil to dry out. On hot days leaves may wilt but recover in the evening if soil moisture is adequate. Regular watering will help prevent blossom-end rot on watermelons (see below). ***Pumpkins*** may become ***corky*** (Fig. 333) due to high humidities close to the ground ***(oedema)***. ***Wind and hail*** can damage the large leaves.

Fasciation commonly occurs in apple-type cucumbers. The ***stem*** becomes wider and flatter than normal, resembling a ribbon. Multiple buds may develop. Control is unnecessary. See Daphne K 53.

Fruit set: Fruit may ***fall off*** if the vine has produced ***more than it can mature***. Young fruit may yellow, wither and drop or rot, this may be caused by ***moisture stress*** or ***excessive nitrogenous fertilisers***. A ***poor fruit crop*** may be due to lack of male and female flowers (usually cucurbits bear both male and female flowers), absence of bees to pollinate flowers, prolonged wet weather preventing bees from working, excessive hot weather causing death of pollen, or use of insecticides nearby. If there are no bees the flowers can be ***hand pollinated*** in the early morning. Pick a male flower, remove the petals and rub the pollen into a female flower. Male flowers are borne singly on a long spindly stem, female flowers have a bulge between the petals and the stalk. Place a hive of bees in or near the crop if necessary.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for cucurbits (Weir and Cresswell 1993). ***Blossom-end rot*** is caused by a deficiency of calcium at the blossom end of the fruit which dies, turns black or brown and has a firm texture. See Tomato M 124. ***Molybdenum deficiency*** (yellows) may cause stunting, yellowing and, if severe, death of leaf edges. Leaves become mottled and yellow around the edges, which roll up. Cucurbits are very susceptible, crops are usually affected in patches. ***Favoured*** by acid soils and use of large amounts of sulphate of ammonia on poorly buffered soil. Spray affected young plants with ammonium molybdate. Where it has occurred before, apply a fertiliser containing molybdenum (ammonium molybdate or sodium molybdate) before the crop is sown. If soil pH is < 5.5, apply lime or dolomite.

Pesticide injury: ***Copper oxychloride*** applied to cucurbits before they begin to run may cause injury. ***Sulphur dust and wettable sulphur*** may cause severe leaf scorching of cucumbers and rockmelons, particularly in hot weather (> 30 °C).

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Cucurbits : Pest and Disease Control (Vic Agnote)
Diseases of Cucurbits (NSW Agfact, WA Farmnote)
Growing Choko (Chayote) (NSW Agfact)
Growing Cucumbers (Vic Agnote, WA Farmnote)
Growing Greenhouse Cucumbers (WA Farmnote)
Pests of Cucurbit Vegetables (NSW Agfact)
Pests and Diseases of Cucurbits (SA Fact Sheet)
Powdery Mildew of Cucurbits (NSW Agfact)
Pumpkin Growing (NSW Agfact)
Watermelon Growing (NSW Agfact)
Watermelon Mosaic Virus of Cucurbits (NT Agnote)
Cucumbers in the Home Garden (Vic Agnote)
Zucchini and Button Squash Growing (NSW Agfact)
Zucchinis in the Home Garden (Vic Agnote)

Associations, Journals etc.

Australian Melon Conference Procs
Good Fruit and Vegetables

See Vegetables M 19

MANAGEMENT

Cucurbits are grown for the fresh market. They are frost sensitive. An overview of the industry is presented by Coombs (1995). Where a particular disease is troublesome select ***resistant varieties***. Only plant ***disease-free seed***, many diseases are seedborne. Save seed only from healthy fruit, do not save seed from crops affected with anthracnose, gummy stem blight, *Fusarium* wilts, angular leaf spot and other diseases. Treat seed with a recommended fungicide to control seedborne infection and to reduce seed rotting and damping off after planting. ***Propagation:*** By seed; plants are grown in soil, grow bags and hydroponic systems. ***Monitor*** regularly for pests ***when plants are young***. Pumpkin beetles and cucurbit ladybirds attack and destroy young plants quickly. Insect attack is not usually so important when plants are larger and growing vigorously. When plants cover the ground, spraying them with insecticide becomes impractical. Aphids can infect plants rapidly with virus diseases. Bean spider mite or twospotted mite infestations may damage plants severely. ***Cultural methods:*** Practise ***crop rotations*** of 3-4 years. ***Prepare land for planting early*** and keep clear of weeds for several weeks before planting to reduce soilborne pests, eg cutworms. Do not plant new crops near old, spent crops that could be heavily infested with bean spider mite or twospotted mite. Crops require appropriate temperatures, spacing, training, pruning, pollination, irrigation and fertilisation. ***Weed control:*** Apply ***pre-emergence herbicides*** before and after planting to control a range of broadleaved weeds and grasses. ***Post-emergence herbicides*** control a wide range of annual and perennial grasses. ***Sanitation:*** Destroy/burn crop debris where possible. Plough-in older, diseased crops as soon as they are finished. Pre-plant treat soil infested with root knot nematodes. ***Pesticides:*** Cultivars susceptible to a particular disease should be protected by an appropriate fungicide. Overseas, bicarbonates and various film-forming products are being researched for control of foliage diseases, eg powdery mildew, gummy stem blight and *Alternaria* leaf spot (Ziv and Zitter 1992). ***Harvest:*** Avoid ***marketing or storing fruit*** from ***infected crops*** as fruit unblemished at time of harvest may show symptoms after storage or when marketed, eg do not store ***pumpkins*** from a crop with black rot infection. Keep fruit as cool as possible and market promptly. Pick ***cucumbers*** when fully developed in length and diameter. Break or cut fruit so that 10-20 mm of stalk remains at the end of the fruit. Cucumbers should be pre-cooled to 10^{o}C to ensure good shelf life. Pick fruit carefully and market it promptly. ***Store*** only good sound fruit, check regularly and remove any rotting ones before the infection spreads. Do not store ***butternut pumpkin*** under cold conditions. ***Packaging:*** Handle fruit carefully to minimise injury. Pack as recommended to reduce moisture loss and wilting.

Fig. 329. Virus symptoms on cucumbers.

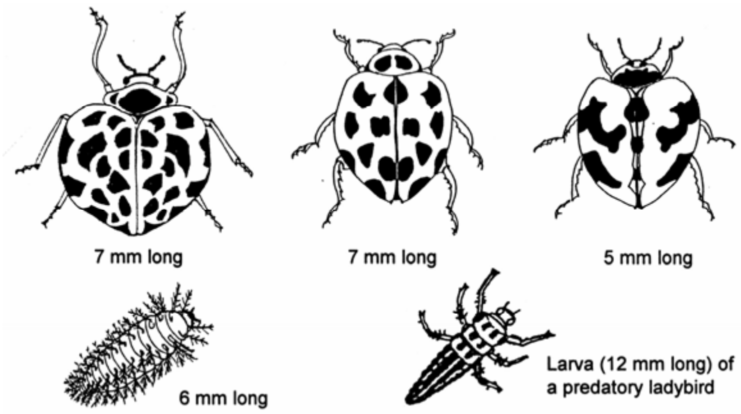

Fig. 330. ***Left :*** Cucurbit ladybird (*Epilachna cucurbitae*) and its spiny larva. ***Centre :*** Predatory common spotted ladybird (*Harmonia conformis*). ***Right :*** Predatory transverse ladybird (*Coccinella transversalis*).

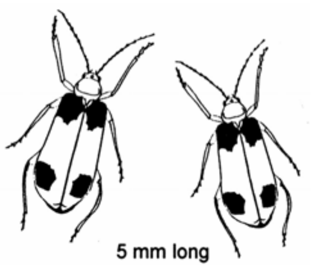

Fig. 331. Pumpkin beetles (*Aulacophora hilaris*).

Fig. 332. Cold injury to butternut pumpkin.

Fig. 333. Oedema on pumpkin.

Lettuce

Lactuca sativa
Family Asteraceae (daisy family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial leaf spot
  - Bacterial rots
- **Fungal diseases**
  - Damping-off
  - Downy mildew
  - Fungal leaf spots
  - Grey mould (*Botrytis*)
  - Root and stem rots
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Cineraria leafminer
  - European earwig
  - Mites
  - Onion thrips
  - Weevils
- **Snails and slugs**
- **Vertebrate pests**
  - Birds

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

With the exception of lettuce big vein virus, virus diseases cause similar symptoms and are difficult to distinguish from one another and from other problems. ***Plants*** may be stunted. ***Leaves*** may have light and dark green mosaic patterns or be distorted and have yellow patches. ***Veins*** may be brown and inner leaves often have large brown patches.

Lettuce big vein virus affects lettuce, especially in ***hydroponic systems***. ***Leaves*** become thick and have large transparent veins. ***Hearts*** are small, coarse and are generally unattractive and slow to mature. Plants infected early are stunted. ***Spread*** by swimming spores (zoospores) of the fungus (*Olpidium brassicae*) in soil which infect lettuce roots and transmit the virus. The fungus and virus are common in wet, heavy, poorly drained areas soils. Symptoms are severe in ***cold weather***, but masked in warm weather. Disease is common in winter. The fungus can ***survive*** in the soil for long periods as resting spores. There is no appropriate soil treatment. Crop rotation does not control big vein, so avoid fields where disease has occurred. All commercially grown varieties are ***susceptible***.

Lettuce mosaic virus affects lettuce, weeds, eg fat hen, and common sowthistle, causing light and dark green, mosaic patterns on ***leaves*** and sometimes vein browning. Affected plants are stunted, pale in colour and generally do not produce marketable heads. ***Spread*** by aphids, eg cotton aphid (*Aphis gossypii*), green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), by seed, and may build up rapidly if a succession of plantings are made. ***Minimise losses*** by planting virus-tested seed, or produce seed in dry areas with little summer aphid activity. Destroy old lettuce crops immediately after harvest. Weed hosts may not be important.

Lettuce necrotic yellow virus is a ***common disease*** of lettuce, also garlic, garden calendula, *Carthamus* sp., *Cicer arietum*, *Erodium*, *Hypochoeris* spp., lupin, common sowthistle, *Xanthium* spp. It causes yellowing, wilting, stunting, ***death of plants***, or partial recovery with small, slightly distorted heart leaves. Lopsided development and fine crinkling of leaves occurs. Infection after hearting causes dead internal areas but no other signs. ***Yield*** is severely affected. ***Overwinters*** in infected common sowthistle and other hosts. ***Spread*** by sowthistle aphid (*Hyperomyzus lactucae*), by mechanical transmission, not by seed. ***Favoured*** by autumn weather when there is a prevalence of sowthistle aphids and host weeds in surrounding areas. Destroy all milk thistles both in the crop and nearby. Keep crops weed free. There is no means of controlling the low percentage of infections carried in by aphids from far away.

Tomato spotted wilt virus causes stunting and yellowing, and ***brown circular leaf spots***. Symptoms are difficult to distinguish from lettuce necrotic yellows virus. There is a lopsided development of the plant. Plants affected after hearting have an internal rotting but no external symptoms. A minor disease which occurs more commonly during spring and early summer in cooler areas. See Tomato M 96.

Others: Alfalfa mosaic virus, beet pseudo-yellows virus, tobacco necrosis virus, beet western yellows virus, cucumber mosaic virus, turnip mosaic virus.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial leaf spot, bacterial wilt, dry leaf spot, head rot (*Xanthomonas campestris* pv. *vitians*) may be ***common***. It causes small, angular, watersoaked spots which later brown, spots may join together and ***leaves*** may yellow, brown and ***die***. Plants infected early in the season may not develop hearts or hearts may rot. ***Favoured*** by prolonged wet periods particularly cool, wet winters. It can be ***serious*** in some varieties, eg Salinas-Vanguard. See Vegetables M 5.

Bacterial rots are common.

Bacterial soft rots (*Erwinia* spp., *E. carotovora* pv. *carotovora*) causes a wet slimy rot of ***heads***. Decay begins on bruised or damaged leaves following tip burn and other diseases. Mainly ***postharvest*** and may be serious in summer crops if heads are harvested in wet, hot weather. Avoid marketing heads with severe tip burn and other leaf diseases, unless carefully trimmed. ***Store*** heads in a cool well ventilated place and avoid harvesting in wet weather. See Vegetables M 5.

Head, leaf and marginal rots (*Pseudomonas* spp.): ***Pseudomonas spp.*** can occur in lettuce growing in the field or in hydroponic systems. Avoid overhead irrigation, do not water in evening or at night if using overhead irrigation. Use recommended chemicals for control in hydroponic systems. ***Varnish spot*** (*P. cichorii*) causes symptoms to develop as heads mature. Shiny brown inner leaves, larger veins turn orange-brown. Areas do not decay hence often called ***varnish spot.*** ***P. marginalis*** and ***P. viridiflava*** cause leaf spotting, vascular blackening in cooler weather, and soft rotting especially during warm hot weather (Persley 1994).

See Vegetables M 5.

Others: ***Corky root*** (*Rhizomonas suberifaciens*) affects lettuce in North America and Europe and has been found in Qld. It has the potential to spread to others areas of Australia. Plants lack vigour and remain small and stunted, roots show a yellow brown banded discolouration which becomes dark brown, raised and roughened ***(corky)*** and brittle to touch. Little root system eventually remains (Persley 1994). In Australia, also ***crown gall*** (*Agrobacterium* sp.).

FUNGAL DISEASES

Damping off, seed rot (*Alternaria alternata*, *Pythium* spp., *Rhizoctonia solani*). Symptoms include slight drooping of the leaves, watersoaked areas of stem at ground level and ***death*** of the seedling. Seeds may rot. See Seedlings N 66.

Downy mildew (*Bremia lactucae*) is a ***common disease*** of lettuce. There may be several strains in Australia. Pale green or yellow spots develop on ***leaf uppersurfaces*** later turning brown. White, fluffy growth develops on ***leaf undersurfaces*** (Fig. 334). Sliming and rotting caused by secondary bacterial infection may follow. Some varieties are ***resistant***. See Annuals A 5.

Fungal leaf spots

Anthracnose (*Marssonina panattoniana*) is a sporadic disease of lettuce. Small pin-point watersoaked spots develop on ***leaves***. Spots enlarge and become yellow then brown, circular to angular spots with a reddish margin up to ***4 mm*** in diameter. Centres may drop out of old leaf spots. Spots on ***midribs*** are elliptical and slightly shrunken. Heavily infected plants may be ***stunted***. ***Favoured*** by cool temperatures and wet weather. See Fruit F 5, Vegetables M 6.

Septoria leaf spot (*Septoria lactucae*) may occur in head lettuce crops and seed crops. Also infects prickly lettuce (*Lactuca serriola*). Irregular, pale brown spots on leaves, dotted with tiny black spore producing bodies ***(pycnidia).*** Spots may occur on the ***leaves, stalks and flower heads***.

Others: *Cercospora longissima, Pleospora herbarum.*

See Annuals A 5.

Grey mould (*Botrytis cinerea*) causes a soft brown rot of ***stems*** at ground level. On rotted areas, which are often surrounded by red margins, a powdery, grey-brown fungal growth develops. Small black ***sclerotia*** (resting bodies) then develop in the fungal growth. Plants ***die*** if the stem is completely rotted or are stunted if the stem is only damaged on the outside. See Fruit F 5, Greenhouses N 22.

Root and stem rots

Phytophthora stem rot (*Phytophthora porri*) and ***Pythium root rot*** (*Pythium* spp.) occur in hydroponic systems, plants are stunted and slow to develop, roots are brown and rotted. See Vegetables M 7.

Sclerotinia rots, drop, watery soft rot, sclerotinose (*Sclerotinia sclerotiorum*, *S. minor*). A soft watery rot, usually at ***ground level***. ***White cottony fungal growth*** develops on the rotted area. Affected plants can collapse completely. Firm, black irregular bodies ***(sclerotia)*** up to 25 mm long form on the white fungal growth. Deep ploughing to bury and bio-degrade sclerotia is not effective. See Vegetables M 7.

Thievaliopsis black root rot (*Thievaliopsis basicola*) affects a wide range of crops and weeds. Plants are affected in seedling nurseries and in the field. Infected plants are stunted and yellowish. Affected areas on ***roots*** are dark brown to black. Root lesions may be small or may coalesce to affect the whole root. Root systems of severely affected plants are reduced in volume and in extreme cases reduced to stubs. ***Overwinters*** in soil (for long periods). ***Favoured*** by poor drainage and moderate soil temperatures (17-25^{o}C). High soil temperatures in summer reduces disease severity. Areas affected by disease and disease severity increase gradually with successive crops. ***Practise crop rotation***, avoid close cropping with other susceptible crops, eg soybean, cowpea, clover or lucerne. Ensure free draining soil. Some varieties have good ***resistance***. Soil fumigation may be necessary (Persley 1994). See Vegetables M 8.

Others: ***Ashy stem blight,*** charcoal rot, wilt (*Macrophomina phaseolina*). ***Rhizoctonia base rot,*** bottom rot (*Rhizoctonia solani*) is uncommon. Plants decay at ground level. Pale brown fungal growth may develop and produce occasional small pale brown sclerotia. Plants wilt and die.

See Vegetables M 7.

Others: ***Rust*** (*Puccinia hieracii, P. prenanthus*).

NEMATODE DISEASES

Nematodes only cause minor diseases of lettuce. Those recorded in association with lettuce include ***root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus dihystera, Rotylenchus robustus*), ***stubby root nematodes*** (*Paratrichodorus* spp.), *Paratylenchus* sp., *Scutellonema brachyurum.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Potato aphid (*Macrosiphum euphorbiae*) is green and may injure hearting lettuce in cool dry weather in autumn, winter or early spring. Aphids cluster thickly on plants, causing wilting and producing sticky honeydew. Market appeal is spoilt. See Potato M 80.

Others: ***Foxglove aphid*** (*Aulacorthum solani*), ***green peach aphid*** (*Myzus persicae*), ***sowthistle aphid*** (*Hyperomyzus lactucae*). ***Overseas***, also lettuce aphid (*Nasonovia ribisnigri*), and lettuce root aphid (*Pemphigus busarius*).

Aphids cause wilting, honeydew and also spread ***virus diseases*** of lettuce. Plough-in residues after harvest and reduce aphids on surrounding crops, remove weeds. ***Monitor*** aphids at regular intervals before applying an insecticide (Brough et al. 1994). See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)
Green vegetable bug (*Nezara viridilis*)
Rutherglen bug (*Nysius vinitor*)
These bugs may be ***troublesome*** on hearting plants and on seed-crop lettuce. See Vegetables M 12.

Caterpillars (Lepidoptera)

Budworms (*Helicoverpa* spp.) feed during spring and summer on foliage and then ***bore directly into the heart***. Caterpillars may be up to 40 mm long and are grey-green in colour with variable markings (Fig. 335). Control is difficult and ***damaged plants*** are often not worth saving. See Sweetcorn M 89.
Cluster caterpillar (*Spodoptera litura)* may feed in patches on ***leaves of well-developed plants*** in late summer or early autumn. Later they feed singly and eat large holes. See Brassicas M 40.
Cutworms (*Agrotis* spp.) may nip off ***seedlings*** during the night. See Seedlings N 68.
Looper caterpillars (*Chrysodeixis* spp.) are slender, pale green, feed on leaf undersurfaces and in spring and late summer ***chew large holes.*** See Vegetables M 13.
Lucerne leafroller (*Merophysas divulsana*) may also feed on leaves. See Pome fruits F 112.

Monitor caterpillars before applying insecticides (Brough et al. 1994). See Annuals A 8, Vegetables M 13.

Cineraria leafminer (*Phytomyza syngenesiae*) maggots may infest lettuce in winter and early spring. See Cineraria A 28.

European earwig (*Forficula auricularia*) nibbles lettuce leaves until ragged and invade lettuce hearts which they spoil by their presence and excrement. See Vegetables M 14.

Mites (Acarina)

Redlegged earth mite (*Halotydeus destructor*) and blue oat mite (*Penthaleus major*) may damage lettuce grown in autumn, winter or early spring in inland districts. ***White patches*** develop on ***leaves***. See Vegetables M 16.
Twospotted mite (*Tetranychus urticae*) may damage ***unirrigated lettuce***, especially if ***infested*** beans or cucumbers were grown nearby. See Beans (French) M 29.

Onion thrips (*Thrips tabaci*) may feed on ***leaf undersurfaces*** and stunt plants. Onion thrips may transmit ***tomato spotted wilt virus*** which may be a serious disease of lettuce. Plough-in old residues, plant upwind of older crops to retard the flight of thrips on to newer crops. Remove weeds from crops and surrounds. ***Monitor*** thrips at regular intervals before applying an insecticide (Brough et al. 1994). See Onion M 68.

Weevils (Curculionidae) feed on lettuce (Fig. 336).

Vegetable weevil (*Listroderes difficilis*) larvae may attack lettuce sown or set out in autumn, winter or early spring. ***Cream or pale green legless larvae*** up to ***12 mm*** long, feed on plant centres and chew small holes in leaves. Later in spring ***adults*** chew ***foliage*** ragged at night. See Vegetables M 17.
Whitefringed weevil (*Graphognathus leucoloma*) larvae may damage lettuce planted in land that has been under lucerne or clovers. ***Grey white legless larvae*** up to ***13 mm*** long, nip off or channel roots causing lettuce to wilt suddenly. Damage usually occurs in late spring when larvae are nearly fully grown. See Vegetables M 17.

See Vegetables M 17.

Others: ***Cotton whitefly*** (*Bemesia tabaci*), ***Grasshoppers and locusts*** (Orthoptera), ***metallic flea beetles*** (*Altica* spp.), ***redshouldered leaf beetle*** (*Monolepta australis*), ***twentyeight-spotted potato ladybird*** (*Epilachna vigintisexpunctata*), ***vegetable leafhopper*** (*Austroasca viridigrisea*).

SNAILS AND SLUGS

After prolonged wet weather ***snails and slugs*** may damage leaves. See Seedlings N 70.

VERTEBRATE PESTS

Birds may eat on seedlings. See Fruit F 13.

Non-parasitic

Environment: ***Bolting*** is the failure of lettuce to heart and the premature running to seed. It is caused by transplanting or hot weather. Autumn lettuce may bolt in spring. Lettuce tolerates ***light frosts*** but may be ***scalded*** in summer.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for asparagus (Weir and Cresswell 1993). Deficiencies may occur but the more common problem is ***excessive fertiliser*** or ***use of fertiliser at the wrong time***. Excessive applications of fertiliser may lead to browning of the edges of inner leaves ***(tip burn)*** and indicates that the proportion of sodium, potassium or magnesium salts is too high compared with the proportion of calcium salts available to the plant. Additions of lime are beneficial. ***Symptoms*** vary with season, soil type and fertiliser used. ***Summer:*** Failure to heart, dark green leathery leaves, yellowing and death at leaf edges. ***Winter:*** Stunting, temporary wilting, internal yellow, red or brown discolouration of vascular tissue (Fig. 337). ***Spring/autumn:*** Slimy rotting of stem centre. See Vegetables M 18.

Others: ***Hormone herbicides*** may injure lettuce. ***Excess ethylene*** may cause russet spotting of leaves.

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State/Territory Departments of Agriculture/Primary Industry eg

Diseases of Lettuce (NSW Agfact)
Downy Mildew (NSW Agfact)
Lettuce : Pest and Disease Control (Vic Agnote)
Lettuce Growing (NSW Agfact)
Lettuce Growing in Northern Victoria (Vic Agnote)
Lettuce Growing in Southern Victoria (Vic Agnote)
Lettuce : Weed Control (Vic Agnote)
Pests and Diseases of Lettuce (SA Fact Sheet)
Pests of Lettuce (NSW Agfact)
Winter Lettuce in the Home Garden (NSW Agfact)

See Hydroponic systems N 43, Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Lettuce are grown for the fresh market. ***An overview of the industry*** has been presented by Coombs (1995). Choose varieties suitable to the area and season. Select varieties which have some ***resistance*** to local problems. Only plant ***disease-free*** seed or transplants. Hot water ***seed treatments*** may be necessary. Dust seed with fungicide to protect them from soilborne damping off diseases. Lettuce may be grown in soil or hydroponically. ***Avoid planting in sites*** contaminated with nematodes or weevils. Seedbed soil may need to be treated. ***Practise crop rotation*** with non-hosts. ***Uneven germination*** is likely to result if seed is sown deeper than ***10 mm***. Space seedlings adequately to discourage diseases, eg downy mildew and grey mould. ***Unless growth is continuous***, leaves may be coarse and bitter and the plant may go to seed. Even growth depends on regular irrigation and a good supply of fertiliser high in nitrogen. The ***crop is more susceptible*** to damage at the seedling stage and when hearting commences. Between those stages plants can tolerate some feeding damage without the loss of yield and quality and a reduction in insecticide sprays may be possible at this time. Keep the crop and surrounding areas ***weed-free***. The growth habit of lettuce is such that spraying is difficult. ***Harvest*** lettuce at the correct stage of maturity, cool quickly. ***Postharvest diseases and pests*** include bacterial soft rots, grey mould and sclerotinia rot. Rots in damaged or diseased heads may develop further to affect other lettuces in the container ***(nesting)***. Only ***store and transport*** lettuce which is well formed, clean, of uniform size and fresh appearance; it must be ***free from*** insect pests, snails and slugs, visible seed stem, burst heads, sunburn, breakdown and disease. Lettuce is sensitive to ethylene. ***Regulations*** govern the packaging and labelling of lettuce for sale. ***Stored lettuce*** should be held at 0^{o}C and at > 95% relative humidity and may keep for 2-3 weeks.

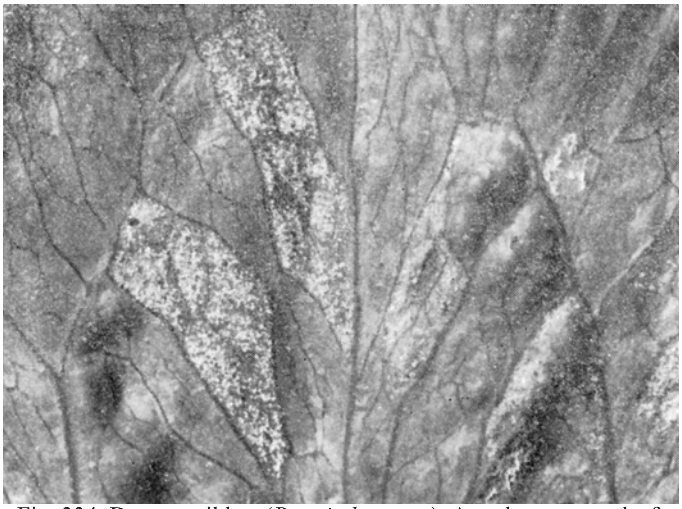

Fig. 334. Downy mildew (*Bremia lactucae*). Angular spots on leaf undersurface with fluffy fungal growth. Dept. of Agric., NSW.

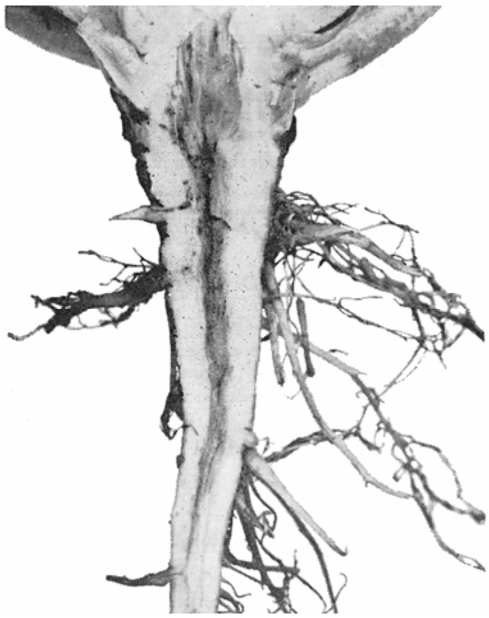

Fig. 337. Internal discolouration of stem due to fertiliser toxicity in winter. Dept. of Agric., NSW.

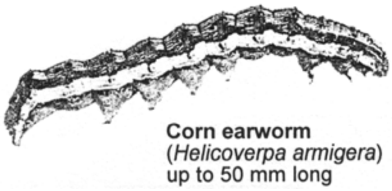

Fig. 335. Various caterpillars (Lepidoptera). Dept. of Agric., NSW.

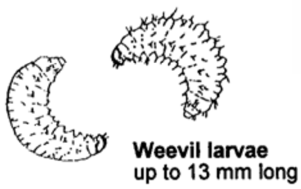

Fig. 336. Weevil larvae (Curculionidae) are legless.

Mushrooms

Cultivated mushroom (*Agaricus bisporus*)
Agaricales, Basidiomycetes

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus disease complex

Scientific name: At least 6 virus diseases occur in mushrooms, singly or in combination. Positive methods of diagnosis include electron microscopy. Some Departments of Agriculture will test specimens for commercial growers.

Host range: Cultivated mushroom, other species.

Symptoms: Severe infection leads to bare patches in mushroom beds, reducing yields and complete crop failure. ***Stalks*** may be very long, bent, split, swollen, thick or tapering, ***caps*** may be small, open early or be light brown (Figs. 338, 339). There seems to be no consistent association of individual viruses with specific crop symptoms.

Overwintering: Virus-infected mushroom mycelium can survive in mushroom trays.

Spread: By infected fungal spores, by trays and shelves contaminated with infected mycelium which spread the disease from one crop to another, by insect pests which carry infected spores.

Conditions favouring: Infection at spawning is likely to lead to severe disease, while infection at casing and cropping is likely to lead to moderate and low levels of disease respectively.

Control: Virus control/prevention programs are available (Nair 1984).
Cultural methods: To prevent virus spread pick mushrooms while veils are still closed.
Sanitation: Strict hygiene is essential to prevent infection and spread. See Mushrooms M 65.
Resistant varieties: All commercially grown strains of *A. bisporus* are ***susceptible*** but strains of *A. bitorquis* are known to be resistant.
Disease-free planting material: Only use virus-free spawn.

BACTERIAL DISEASES

Brown blotch (*Pseudomonas tolaasii*) causes superficial pale brown, slightly sunken blotches on the ***caps*** and occasionally on ***stalks***.
Drippy gill (*P. agarici*) causes brown spots on the side and bottom of ***gills***. Grey droplets or streaks of bacterial ooze may form on the gill surface.
Mummy disease (*Pseudomonas* sp.) causes tilted ***caps*** and bent stalks.

Overwintering: Contaminated compost, soil, casing. Mummy disease also by infected mycelium.

Spread: By contaminated mycelium, compost, casing, soil, water, water splash. Drippy gill also by mushroom flies.

Conditions favouring: High humidity and fluctuating temperatures in the growing area.

Control:
Cultural methods: Manipulate the crop ***environment***, eg prevent water splash, keep surfaces dry, ventilate and control temperatures.
Sanitation: ***Disinfect*** compost, casing. Observe strict hygiene. See Mushrooms M 65.
Resistant varieties: All commercially grown strains of cultivated mushrooms are ***susceptible***.

FUNGAL DISEASES

Aphanocladium disease (*Aphanocladium album*) and ***brown spot*** (*Acremonium* sp.) causes brown spots commonly on the ***gills***, a grey white mycelium develops in high humidities.
Dry bubble (*Verticillium fungicola*) similar to brown blotch except that a grey fungus grows on the brown spots. Bubbles develop on ***caps***.
Mildew, cobweb (*Cladobotryum* sp. (= *Dactylium* sp.) causes a cottony fungal growth on the ***fruiting body*** which spreads to the ***casing***.
Wet bubble (*Mycogone perniciosa*) causes malformed ***stalks*** and ***caps*** that drip a brown liquid.
Others: Damping off, wilt (*Fusarium* spp.), cat's ear (*Clitophilus passickerianus*), mat disease (*Myceliophthora lutea*), mushroom bed sclerotium (*Xylaria vaporaria*).

Overwintering: Soil dust, casing, trash, spent compost.

Spread: Spores by air, water splash, by workers during cultural operations.

Conditions favouring: High humidity, 15-18^{o}C for dry bubble.

Control:
Cultural methods: Decrease temperatures and humidity and have a short picking cycle.
Sanitation: Promptly ***dispose*** of spent compost and debris, and ***disinfect*** mushroom beds. ***Pasteurise*** soil if it is being used. Regularly and appropriately ***disinfect*** work areas and harvesting tools.
Resistant varieties: Most commercially grown strains of cultivated mushrooms seem to be ***susceptible***.

NEMATODE DISEASES

Many species of nematodes are associated with mushroom crops, including those that feed on fungal mycelia and bacteria in mushroom crops.

Fungal-feeding nematodes (*Aphelenchoides* spp., *Ditylenchus* spp., *Paraphelenchus* sp.) can be easily seen with a ***microscope*** (Fig. 340), but not with the naked eye. They pierce the fungal cells in ***mycelium*** and suck out the contents. Yields may be reduced dramatically. Infestation is often only observed at cropping time and by then it is too late. Cropping quickly stops and there is an obvious lack of mycelium in the bed. ***Compost*** may have a characteristic ***smell*** and becomes ***dark and soggy***. ***Straw*** often carries fungal-feeding nematodes as these are common in soil in wheat field. ***Store peat*** used in casing layers dry as nematodes can breed in damp peat moss. Practise ***nursery hygiene***. See Mushrooms M 65. If soil, spent compost, or peat (containing nematodes), is to be used, it must be ***pasteurised***. Pasteurisation favours development of certain weed fungi. Nematodes in compost can be controlled with ***nematicides***. ***Insect control*** reduces the chances of nematodes being introduced and spread.

INSECTS AND ALLIED PESTS

Insect and mite problems may arise during all stages of production. They are controlled by careful pasteurisation of the compost, keeping flying pests from the cultivation rooms and strategic treatments with insecticides.

Flies (Diptera)

Mushroom cecids (Cecidomyiidae), eg ***mushroom white cecid (MWC)*** (*Heteropeza pygmaea*) and ***mushroom yellow cecid (MYC)*** (*Mycophila barnesi*). ***Adults*** rarely develop. They are fragile, bright orange flies about 1-1.5 mm long. *M. barnesi* produces both male and female adults but *M. pygmaea* usually produces only female adults. ***Maggots*** of both species feed on ***mycelium*** in the compost where they do no harm. They may also swarm over mushrooms towards the end of production, usually after watering, causing market losses of up to ***30%***. Market losses from ***MYC*** is sporadic and often less than from ***MWC***. ***Maggots of MWC*** are slender and white and about ***5 mm*** long (but usually about 2 mm long when they swarm). ***Maggots of MYC*** are bright orange-yellow and about 4 mm long and this stage has been observed swarming. ***Pest cycle:*** Each maggot can develop 12 or more maggots within itself. In the case of ***MWC*** a resistant 'hemipupa' is formed and the daughter larvae develop within it. ***MYC*** daughter larvae form within the parent larvae and burst out from it. 12 daughter larvae can be produced every 10 days resulting in ***huge populations*** of larvae in the compost. ***MWC*** also forms a hard cyst that can survive for several years and eventually produces larvae when favourable conditions return. These cysts can survive in the timbers of the tray. They can be present in both imported peat and local peat taken from surface layers of peat bogs. This can establish infestations in mushroom culture rooms (Clift 1983).

Mushroom phorid (*Megaselia halterata,* Phoridae). ***Flies*** are small, black, about 2-3 mm long with a hunchback appearance. They are attracted to newly spawned compost, but will reinfest both compost and casing layer. Eggs are laid on the compost and casing and hatch within 2 days. ***Maggots*** are translucent to white and do not have distinct heads. They feed for 10-14 days and are ***5-7 mm*** long when fully grown. The adult emerges from the pupa in 5-7 days and females start laying eggs within 3 days. Maggots feed on ***mushroom mycelium*** but only reduce yield if present in great numbers. They occur infrequently and very rarely in problem numbers.

Mushroom sciarids (*Lycoriella* spp., Sciaridae) are dark coloured flies with long antennae. ***Flies*** are dark brown or almost black and ***3-4.5 mm*** long depending on the species. They fly readily and are often seen on walls, around lights and running over compost, casing layer and mushrooms. ***Maggots*** are slender and translucent to white with a black head. Gut contents are often visible (Fig. 341). They are ***10-15*** mm long (larger than cecid and phorid maggots). Some species prefer mature mushrooms while others prefers infested compost. Maggots destroy the ***spawn, developing pinheads*** and ***more mature mushrooms***. A moderate infestation of sciarids can cause ***20%*** drop in yield. There is a complete metamorphosis (egg, maggot, pupa, adult) with many generations each year. Flies lay eggs on the compost or casing. Life cycle is 18-28 days depending mushroom species. ***Spread*** by adults flying from where they have bred in wastes or spilt compost that has not been cleaned up, in other culture rooms, or in surrounding bushland. Adults transfer mites and diseases. ***Fungus gnats*** (Mycetophilidae) maggots also feed on decaying fungi and on damp organic matter. See Greenhouses N 28.

Mites (Acarina) often do not directly damage mushrooms. See Mushrooms M 84.

Australian mushroom pygmy mite (AMPM) (*Brennandania lambi, Microdispidae*), ***mushroom red pepper mite (MRPM)*** (*Siteroptes mesembrinae,* Pygmephoridae). ***Both species*** can cause ***allergic reactions*** to mushroom pickers. Only ***AMPM*** damages mushrooms (Fig. 341). It breeds in ***spawned compost*** and can reduce yields of *A. bisporus* by up to ***30%***, it has not been recorded as a pest of *A. bitorquis*. It is carried by sciarids, trays nearest the door of culture rooms are worst affected. ***MRPM*** feeds on weed moulds, indicating incompletely prepared or contaminated compost. ***The biology of both species is similar.*** The swarming stage (the form usually seen) consists only of fertilised females, about ***0.25 mm*** long, translucent pink with a white stripe on the dorsal surface. They swarm when they have run out of food and climb on to mushrooms or raised pieces of casing and are transferred by sciarid flies, clothing and pickers' knives to new locations. When a suitable mycelium has been found, females feed, swell, then deposit 30-50 eggs. Life cycle from egg to egg is about 10-12 days. Males are smaller than females and remain near host fungi.

Tyroglyphid mites (*Caloglypus*, *Rhizoglyphus*, *Tyrophagus*). ***Caloglyphus, Rhizoglyphus*** feed mainly on bacterial blotch, bacterial pitting or other damage. After consuming the bacteria, they feed on dead mushroom tissue. ***Tyrophagus*** has similar feeding preferences but also eats spawn grains, often causing failure of the mycelium to colonise the compost. ***Mites*** are about ***0.5-0.75 mm*** long, oval and whitish and indicate incompletely prepared or incompletely pasteurised compost. All 3 mites may be present in poultry manure, cottonseed hulls and baled straw. ***Control:*** By pasteurising the compost. The first two mites form resting stages which are ***tolerant*** of adverse conditions including high temperatures. ***Other mites*** infest mushrooms beds. See below.

Mushroom springtails (*Hypogastrura armeta, H. denticulata*, Collembola) usually feed on decaying organic matter but may also feed on fungi and be minor pests (Fig. 341). ***Adults*** are whitish or slate grey and ***2-3 mm*** long. ***Nymphs*** resemble adults in general form. See Turfgrasses L 14.

Others: ***Various beetles*** (Coleoptera), eg ***black fungus beetle*** (*Aliphitobius laevigatus*, Tenebrionidae), ***fungus-eating ladybird*** (*Illeis galbula,* Coccinellidae), ***fungus weevils*** (Anthribidae) and ***hairy fungus beetle*** (*Typhaea stercorea,* Mycetophagidae). Also ***red fungus bug*** (*Achilus flammeus,* Achilidae, Hemiptera).

Non-parasitic

Chemical injury: ***Rose comb*** is the term commonly used to describe a ***malformation of the mushrooms*** in which the caps produce gills on the upper surface or in which the tissues of the cap are seamed and patterned. It can result in such restriction of gill formation that the mushroom appears to be almost devoid of gills. In most cases the condition is caused by the presence of ***kerosene or other oils*** in the mushroom beds.

Genetic disorders: ***White gill*** (pale gill) causes mushrooms to be small, with short pale or white gills. White gill usually appears in 2nd or later flushes. Its occurrence is unpredictable, one flush may produce many pale-gilled mushrooms, yet mushrooms in the next flush may be normal. The cause is not known although it is possibly ***genetic,*** and associated with certain strains of mushrooms. There seems to be no constant association with any particular strain of spawn.

Mites (Acarina)

Histiostoma mite (*Histiostoma feroniarum*) feed exclusively on ***bacteria*** found on pasteurised compost and those causing mushroom bacterial blotch (*Pseudomonas* sp.). ***Adults*** are small, slow-moving and about ***0.5 mm*** long with a distinct granular appearance. They are very prolific, often producing hypopi which are readily carried about the farm by flies, clothing and tools. Hypopi may have a role in transferring bacterial blotch. This mite is often found during the early stages of bacterial blotch, but rarely on completely decayed mushrooms.

Predatory mites: Several species of rapidly moving, white or red mites about ***0.5-0.75 mm*** long are often seen on mushroom farms. These mites are active ***predators*** of ***nematodes***, their presence indicates imperfect pasteurisation.

See Mushrooms M 83.

Nematodes (Nematoda) feed on ***bacteria*** and ***small particles of organic matter***. Patches of mushroom bed surface become dark and soggy and the ***mushroom mycelium*** deteriorates. Depending on the nematode species yield may be reduced. Bacterial-feeding nematodes usually have little effect on the appearance of ***spawn and compost***. The spawn is normal or even heavy, but spawn has trouble establishing in the casing, cropping is slow to start and yields are light. ***Casing soil*** appears to be a ***main source of infection***. ***Bacteria-feeding nematodes*** occur in manures and other moist organic matter, and also water, peat, field soil, airborne dust and insects that infest mushroom sheds. ***Control:*** As for fungal-feeding nematodes. See Mushrooms M 63. ***Disinfection*** of the casing layer should help reduce the level of infestation. Off-white strains of the cultivated mushroom appear to be ***more susceptible*** than white strains.

WEED MOULDS

Weed moulds are often called ***indicator*** (indicate improper composting) or ***competitor moulds*** (compete with mushrooms for nutrients). Weed moulds may reduce the mushroom crop by ***40%***. There is no effective chemical control of weed moulds once they have developed. ***Sterilisation of mushroom trays*** with steam at 70^{o}C for 12 hours after harvest, eradicates these moulds and prevents spread of their spores to new crops. Probably > 20 species of fungi may occur as weed moulds, some often with very descriptive names, eg ***olive-green mould*** (*Chaetomium olivaceum*), ***lipstick mould*** (*Geotrichum* sp.) and ***white plaster mould*** (*Scopulariopsis* spp.).

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Insect and Mite Pests of Mushrooms (NSW Agfact)
Mushroom Virus Diseases (Vic Agnote)
Nematodes in Mushroom Crops (NSW Agfact)
Associations, Journals etc.
Australian Mushroom Growers Association (Catalogue of Books, Videos etc. Tel. 045 776877)
Good Fruit and Vegetables
Horticultural Research & Development Corporation (HRDC)
See Compost N 18, Vegetables M 19

Remember, always check for recent references

MUSHROOM MANAGEMENT

Mushrooms are grown for the fresh market and processing. ***An overview of the industry*** is presented by Coombs (1995). A truffle industry is developing in Tasmania. Truffles and their cultivation overseas is reviewed by Giovannetti et al. (1994). Most commercially grown mushroom varieties are ***susceptible*** to diseases and pests. ***Plant quarantine:*** Importations of new mushroom cultures are screened for viruses and other diseases and pests, ensuring that only clean spawn is passed on to the grower. ***Disease-free planting material:*** Only use spawn free from virus and other diseases and pests. ***Propagation*** by mushroom spawn (mycelium). For ***effective control*** of mushroom diseases, pests and weed moulds, good design and hygiene (sanitation) is essential. ***Design layout*** so that there is one-way movement from the 'clean' to the 'dirty' area during normal operations and install filters to treat air entering spawn-running rooms, growing rooms and work areas used for spawning and casing. Design them for ease of maintenance, eg environmental control (temperature, humidity and ventilation), easy cleaning and disinfection (concrete floors in all storage areas, peak heat rooms and growing rooms), controlling insects (flywire all rooms), and disposal of effluent to avoid spread of nematodes. ***Sanitation (hygiene): Establish an effective routine of cleaning and disinfection.*** Thoroughly clean, wash and disinfest composting, spawn running and growing areas, beds and boxes. Routinely disinfect all machines used for filling, spawning and casing after each operation as well as work areas and growing rooms. ***Regularly collect all mushroom wastes***, spent compost, spilt compost, especially pasteurised compost, damp loose straw and other debris, and either compost them or remove them several kilometres from the building. ***Regular and correct cook-outs with steam at the end of each crop*** kills all stages of insects and mites. Sterilise mushroom trays after cropping by steaming at the recommended temperature for the recommended length of time. After steaming remove trays from growing rooms, and disinfect the emptied trays. ***Physical methods: Infestation of compost*** is usually caused by non-uniform heat distribution during composting, peak heating or pasteurisation. Ensure that ***composting*** and ***pasteurisation*** is carried out properly to eliminate undesirable moulds, bacteria, nematodes, mites, and insects especially sciarids. Prevent reinfestation by ***excluding adult sciarids*** from the pasteurising room. ***Pesticides:*** Treat compost preferably at spawning and casing layers with recommended insecticides. Regularly use a surface spray on walls around doors, vents and ceilings of all rooms. Fogging in combination with a surface spray is useful in reducing sciarid populations. Insecticides can be effectively mixed with casing but there is no single effective treatment for compost if pasteurisation is incomplete or if sciarids reinfest after cool-down. ***Harvest stage:*** Mushrooms are sold in 3 stages of growth - button, cup and flat. Pull the mushroom from the bed with a gentle twisting action. Lightly water the bed after picking and filling. ***Store*** in the refrigerator, place in cloth or paper bag, not in plastic

Fig. 338. Healthy mushroom (*Agaricus bisporus*) Dept. of Agric., NSW.

Fig. 339. Various symptoms of virus diseases. Dept. of Agric., NSW.

Fig. 340. Nematodes are easily observed under a microscope.

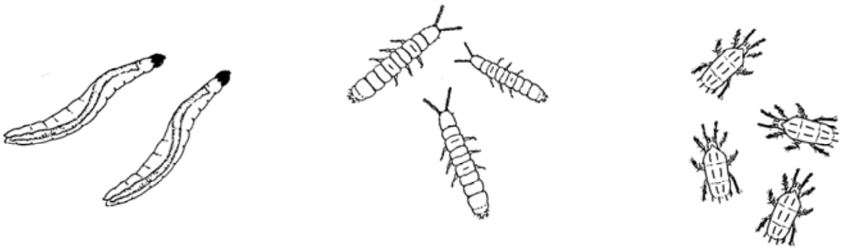

Fig. 341. ***Left :*** Mushroom sciarid (*Lycoriella* sp.) larvae (10-15 mm long). ***Centre :*** Springtails (Collembola) (2-3 mm long). ***Right :*** Australian mushroom pygmy mite (*Brennandania lambi*) is microscopic (about 0.25 mm long).

Onion

Chives (*Allium schoenoprasum*)
Garlic (*A. sativum*)
Leek (*A. porrum)*
Onion (*A. cepa*)
Shallot (*A. ascalonicum*)
Family Liliaceae

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Onion yellow dwarf virus affects onion, garlic and ornamental species of *Allium*. Infected plants may not show symptoms. Infection of ***young plants*** may cause yellowing and stunting (yellow dwarf), ***leaves*** of older plants may have yellow flecks, blotches and streaks, crinkling and drooping of leaves and thickening of the neck. Symptoms persist. Leaf mould attack may follow virus infection. Yield is moderately affected. Symptoms on ornamental species are not well documented. ***Overwinters*** in infected bulbs from previous season, including those saved for seed production, volunteer plants. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), not by contact between plants, not by seed, not by pollen. ***Destroy*** unmarketable and volunteer onions. ***Insecticides*** may be used to control aphid vectors in commercial crops.

Others: Garlic may also be affected by ***garlic mosaic virus*** and ***garlic yellow streak virus*** causing yellow flecking, blotching and streaking of leaves. Affected plants may be stunted. ***Overwinters*** in diseased garlic cloves. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), which are present in all garlic crops. Use ***virus-free planting material***. ***Lettuce necrotic yellows virus*** may also affect garlic.

See Bulbs C 4, Vegetables M 4.

BACTERIAL DISEASES

Bacterial rots

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) may cause a general soft rot. See Vegetables M 5.

Internal brown rots (*Pseudomonas* spp.): *P. aeruginosa* and *P. marginalis* pv. *marginalis* cause browning of 1-2 internal ***scales*** or general ***soft rot*** of outer scales. ***P marginalis pv. marginalis*** is a saprophyte in soil but may invade damaged tissue. ***Favoured*** by humid conditions, wounding. Avoid damaging onions, allow crops to fully mature before harvest, tips should be allowed to dry before lifting and topping. Minimise sunscald and bruising, cure bulbs well before storage and store in well ventilated conditions. Cream gold and related cultivars are ***mostly susceptible***. Overseas ***bacterial internal decay*** (*Enterobacter cloacae*) at very high temperatures, may also cause internal decay.

Others: Slippery skin (*P. gladioli* pv. *alliicola* = *P. putida*) causes a soft rot of outer scales. ***Sour skin*** (*P. cepacia*) causes a slimy yellow vinegar smelling rot. Overseas, ***P. viridiflava*** may be so severe on onions that crops cannot be harvested (Gitaitis et al. 1991).

See Vegetables M 5.

FUNGAL DISEASES

Damping off (*Phytophthora*, *Pythium*, *Rhizoctonia solani, Sclerotinia*). See Seedlings N 66.

Downy mildew (*Peronospora destructor*) affects onion, garlic, shallot and leek, causing pale ***yellow spots on leaves***, leaf yellowing and furry purplish growth on affected areas. ***Favoured*** by cloudy, mild days and cool. still dewy nights. Provide good ventilation, wide row spacings. Some varieties appear to be ***less susceptible***. Fungicides may be necessary. See Annuals A 5.

Fungal leaf spots

Stemphylium leaf blight, leaf mould (*Pleospora* sp. = *Stemphylium botryosum*) is a widespread ***saprophyte*** on crop debris. A black mould grows on ***leaves*** previously injured by other diseases, mechanical handling, chemicals, poor growing conditions. Good crop management and control of other diseases and pests will reduce crop losses.

Purple blotch (*Alternaria porri*) is a minor disease. Small, white sunken lesions with purple centres occur on ***leaves*** and ***seed stalks*** and enlarge to become purplish with light and dark zones which girdle stems and may cause losses in seed crops. ***Bulbs*** can be infected when topped at harvest, storage rots may develop. ***Overwinters*** in onion residues. ***Spread*** by spores during wet windy weather or overhead irrigation. Fungicides may be necessary.

See Annuals A 5.

Root and bulb rots

Anthracnose, smudge (*Colletotrichum circinans*) Small greenish dots develop on ***outer scales*** just before harvest. These become black and develop further ***postharvest***, often with a zonate pattern on the outer scales. Bulbs may shrink and sprout prematurely. ***Overwinters*** on onion residues. White cultivars are susceptible while most coloured cultivars have some ***resistance*** Store bulbs under cool, dry conditions. See Fruit F 5.

Aspergillus rot, black mould (*Aspergillus niger*) may occur in the ***field*** but it is more serious ***postharvest***. Black, powdery masses of spores develop on the surface of ***outside scales*** and later between scales which shrivel and become brittle. Spores can easily be rubbed off (onion smut spores occur in blisters in the scales and are not easily rubbed off). Spores ***spread*** by wind and air currents. ***Favoured*** by hot, dry conditions and mechanically harvesting immature onions. Practise crop rotation. White cultivars are generally ***less susceptible*** than coloured cultivars. Rapidly and thoroughly cure bulbs and store under cool, dry conditions. See Fruit F 5, Vegetables M 6.

Fusarium basal rot, fusarium wilt (*Fusarium oxysporum* f.sp. *cepae*) affects *Allium* spp., eg garlic and onion. Leaves yellow and die, generally starting with the younger leaves. ***Necks*** may rot and bulbs may become distorted or bloated. The basal plate becomes brown, roots rot. ***Damping off*** of young ***seedlings*** may occur in early sown crops. The fungus invades the cord root of susceptible varieties directly, through injuries or through old root scars and enters the vascular system. ***Favoured*** by warm weather (27-32^{o}C). Practise ***crop rotation***. ***Avoid injuring*** bulbs during cultivation, harvesting, curing and bagging. Sort onions carefully and only bag sound ***disease-free bulbs***. Subsequent losses may be minimised by storing under well ventilated, cool conditions, eg 4^{o}C with a relative humidity of about 65%. Destroy all diseased onions and debris left after sorting. See Bulbs C 5, Daffodils C 19, Vegetables M 9.

Grey mould, botrytis, neck and bulb rot (*Botrytis cinerea, Botrytis* spp.) is a ***minor postharvest*** disease of onion bulbs causing a softening and rotting of the ***neck region*** of onion bulbs. A grey brown fungal growth with a crust of black resting bodies ***(sclerotia)***, may develop. Grey mould can also grow downwards from leaf tips into ***leaf sheaths***. Breakdown then occurs during storage although this might be quite slow. ***Spread*** by contact. Harvest at the correct stage of maturity, handle bulbs carefully to reduce injury, hold under cool, dry conditions to cure the neck quickly. ***Favoured*** by application of nitrogen fertiliser late in the season, or in excess, which produces thick-necked bulbs which are difficult to cure; moist conditions near harvest; imperfect curing of bulbs. Practise ***crop rotation***. ***Avoid injury*** during harvesting and handling. Do not store sunburnt or damaged onions. ***Avoid damp***, unfavourable growing conditions. ***Cure artificially*** if weather does not permit field curing. Overseas, onion bulbs are cured in a rapid air current at 36-40^{o}C. See Fruit F 5, Greenhouses N 22, Vegetables M 7.

Penicillium moulds, blue and green moulds (*Penicillium* spp.) occur on damaged, wet onions. The fungus is usually a blue or green powdery coating on the ***bulbs***. ***Favoured*** by curing under damp conditions or in association with neck rot, windrowing bulbs with large amounts of soil. Adequate drying relieves the problem. See Bulbs C 5, Fruit F 6.

Pink root (*Pyrenochaeta terrestris = Phoma terrestris*) is a common soil inhabitant which affects onions and cereal crops, eg maize, sorghum, wheat and barley. Plants look unthrifty, yellow and withered, the tips of older ***leaves*** die first. ***Roots*** turn pink, then darken to red or purple and finally brown or black. Roots die initially near the centre of the basal plate. Secondary organisms may then invade damaged tissue causing bulbs to rot. ***Spread*** by infested soil. ***Favoured*** by warm weather, ***Avoid warm weather*** plantings where the disease is known to occur. ***Rotate crops*** with non-susceptible crops.

Soot (*Embellisia allii*) affects ***garlic***. Powdery black soot develops on outer scales, usually at the base of roots. Only causes blemishing, no yield loss or rotting. Probably ***overwinters*** in the soil Spores are ***spread*** by wind and air currents. ***Favoured*** by bulbs left in the soil after maturity. Control is rarely necessary. Harvest bulbs when mature.

White rot, sclerotium stem rot, southern blight, (*Sclerotium cepivorum*) affects garlic, onion, shallot and leek but is rarely a problem in commercial crops. ***Bulbs*** rot at the base, white fluffy mycelium and small, black sclerotia develop on diseased areas. Plants yellow and die. Plants die out in small patches which extend slowly, often only 0.5 m a season. If affected bulbs are packed extensive breakdown may occur during ***transit*** and ***storage.*** In cool weather the fungus grows through the soil invading seedlings or bulbs which it contacts. Do not plant onions or garlic in affected areas for at least 10 years. ***Biocontrol*** of white rot is being researched. Also ***Sclerotium stem rot*** (*S. rolfsii*). See Vegetables M 8.

See Fruit F 5, Vegetables M 7.

Rust (*Puccinia allii = P. porri*) affects chives, garlic, onion and shallot, eventually causing pustules on ***both leaf surfaces***. Pustules are filled with black spore masses. Leaves may ***die***. ***Favoured*** by warm moist weather. Rotate planting sites, ***volunteer plants*** should be treated with fungicide. See Annuals A 7, Herbs N 34 (Fig. 410).

Smut, onion smut (*Urocystis cepulae,* Basidiomycetes) is a ***serious disease of onions*** in some areas. It also affects leeks, shallots, chives and many other lesser known *Allium* species. Garlic is not affected as it reproduces by cloves and not by seed. Black elongated blisters form in the ***leaves*** and on ***bulbs***. These may break open to expose black powdery masses of spores. Affected leaves are usually thickened and often curve downward. Most infected seedlings die 3-5 weeks after germination. Some diseased plants survive until mid-season or harvest with new leaves becoming infected as they develop. ***Overwinters*** in infected soil, onion sets, transplants. ***Spread*** by windborne soil and surface water, soil on implements, containers, boots and plants. ***Favoured*** by temperatures of 10-29^{o}C. The fungus can invade the plant in the early seedling stage only. If the outer seedling leaf escapes infection until it is mature the plant will remain healthy even in very heavily infested land. ***Quarantine measures*** exclude import of onions from areas where the disease is believed to occur into principal commercial onion-growing districts.

Others: ***Neck rot, foliage blight*** (*Sclerotinia squamosa*). Also ***macrophomina bulb rot*** (*M. phaseolina*), ***white tip*** (*Phytophthora porri),* ***black bulb*** (*Alternaria alternata*), ***leaf blight*** (*Heterosporium allii*).

NEMATODE DISEASES

Stem and bulb nematode, bloat (*Ditylenchus dipsaci*) causes ***seedlings*** to be dwarfed, twisted and whitish with swollen areas where the skin may be split. Onion sets planted in infested soil develop stunting and yellow speckling on older plants. ***Bulbs*** become soft, ***leaves*** become spongy and twisted and die from the tips back. Infected bulbs can be decayed by secondary rotting organisms. Practise a 3 year crop rotation between onions and related plants where the soil has become infested. See Daffodil C 20.

Others: ***Root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus*), *Paratrichodorus* spp., *Radolophus* sp.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Green peach aphid (*Myzus persicae*)
Onion aphid (*Neotoxoptera formosana*)
Shallot aphid (*Myzus ascalonicus*)
Aphids may spread ***virus diseases***. They also infest garlic. See Bulbs C 3 (Fig. 65), Roses J 4, Vegetables M 11.

Bulb mite (*Rhizoplyophus echinopus*) feeds inside bulbs causing them to rot in the ***field*** and especially ***postharvest***. Injury is most likely in onions planted as ***bulbs*** for seed production, also in shallots, garlic and chives. As chives may be propagated continuously by tufts, and shallots and garlic by cloves or bulbous sections, they are most likely to be damaged year after year following the original infestation. See Bulbs C 7.

Caterpillars (Lepidoptera)

Cutworms (*Agrotis* spp.) may nip ***leaves*** off during the night if onions are planted in previously weedy land. See Seedlings N 68.
Leek moth (*Acrolepcia assea*) infests onions overseas.

See Annuals A 8, Vegetables M 13.

Onion maggot (*Delia platura,* Anthomyiidae, Diptera) infests ***vegetables***, eg onion, bean, crucifers, cucurbits, sweetcorn. Maggots are thought to feed and breed mainly on organic matter. ***Flies*** are grey-brown, slightly hairy, about ***5 mm*** long and are commonly seen flying over soil top dressed with blood and bone fertiliser. ***Maggots*** when fully grown are yellow-white, legless, tough-skinned and about ***6 mm*** long. They enter roots and stems of young ***seedlings*** below ground level, causing them to wilt, rot, die and fall over. ***Many maggots*** may be found in one seedling. One maggot may feed on several stems only partly injuring them. Plantings are thinned out, generally only a few plants in any one spot are affected. There are ***many generations*** each season. Female flies lay eggs in the soil close to the host plants and the maggots feed on organic matter and seedlings. They pupate in the soil near the infested plant; the pupae are barrel-shaped, brown and about 5 mm long. ***Spread*** by adult flying. ***Favoured*** by cool, moist conditions during spring after wet winters, sandy soil, and slow germination due to planting too early. Flies are attracted for egg laying to decomposing organic matter, animal manures, organic fertilisers, eg bone dust, blood and bone and decomposing heavy green manure crops ploughed in shortly before onions were planted. ***Do not fertilise*** spring and autumn crops with animal manures or organic fertilisers. Prepare ground early to ensure plant material is decayed before planting. Inorganic fertilisers may be applied. ***Insecticides*** are used to control the flies. There are no effective insecticide treatments for the control of maggots. Seed treatments have been used overseas but have not been considered necessary in Australia. See Beans (French) M 28. Overseas ***onion fly*** (*Hylamyia antiqua*, Agromyzidae) maggots mines in bulbs.

Onion thrips

Scientific name: Thripidae, Thysanoptera:
Onion thrips (*Thrips tabaci*)

Host range: Ornamentals, vegetables, weeds.

Description and damage: ***Adult female thrips*** are tiny, light or dark brown, about 1.3 mm long, with 2 pairs of narrow grey fringed wings. Males are smaller. ***Nymphs*** are wingless, sluggish, creamy and cluster at the bases of ***central leaves*** in the throat of plants. Adults rasp and suck foliage causing silvering seen in almost every onion bed. See Vegetables M 3 (Fig. 309). More than 30 thrips per leaf may cause yield reduction. In a heavy attack, leaves may be twisted and die back from tips, plants can be dwarfed or killed, yield is reduced, quality of onions downgraded. Leaf symptoms may vary on other hosts, eg thrips feed on leaf undersurfaces of potato and brassicas Onion thrips is a ***vector*** of tomato spotted wilt virus.

Pest cycle: Incomplete metamorphosis (egg, nymph, adult) with many generations each year, all stages are found on onions at any time. Females lay eggs, nymphs pass through 4 stages, the last two of which are spent in the soil without feeding. Although there are males, which are wingless, the females can produce without mating.

Overwintering: On host plants, in soil.

Spread: Thrips fly and are windborne; infested plant material.

Conditions favouring: Warm, dry weather in spring following a mild dry winter, unirrigated crops. When soil conditions are dry onion thrips move on to onions from other crops or weeds.

Control:
Cultural methods: Damage is reduced by cool, rainy weather and regular irrigation.
Biological control: Many predators control thrips overseas including ***predatory mites*** (*Amblyseius cucumeris, A barkeri*) and ***anthocorid bugs*** (*Anthocoris* sp., *Orius* sp.) (Sunderland 1991).
Pesticides: Apply insecticides when nymphs are seen on a periodic inspection of the throats of the plants. 3-4 treatments in the life of the crop may be needed, depending on the rainfall and temperature (undersides of the leaves must be treated). ***Monitor*** nymphs and adults at regular intervals before applying insecticides (Brough et al. 1994). See Roses J 6.

Vegetable weevil (*Listeroderes difficilis*) **larvae** cause minor damage by chewing small holes in the sides of **leaves** and in **central shoots**. Older larvae chew big holes. See Vegetables M 17.

Others: **Mole crickets** (*Gryllotalpa* spp.) cause poor seedling emergence by tunnelling just below the soil surface. **Rutherglen bug** (*Nysius vinitor*) may invade onions in spring, plants wilt, immature seed heads are destroyed. **Also European earwig** (*Forficula auricularia*), **lucerne flea** (*Sminthurus viridis*), **redlegged earth mite** (*Halotydeus destructor*), **seedharvesting ants** (*Pheidole* spp.), **vegetable leafhopper** (*Austroasca viridigrisea*), **wireworms** (Elateridae).

SNAILS AND SLUGS

Garlic snail (*Oxychilus alliarus*, Zonitidae) may infest *Allium* spp. See Seedlings N 70.

Non-parasitic

Nutrient deficiencies, toxicities: Zinc deficiency may occur **Leaf analysis standards** are available for onion (Weir and Cresswell 1993).

Others: **Uneven water supplies** may cause split or double bulbs. **Slime moulds** (Myxomycetes) may occur on bulbs in the field. See Bulbs C 3 (Fig. 69).

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State/Territory Departments of Agriculture/Primary Industry eg

A Growth Regulator for Potatoes and Onions (Vic Agnote)
Diseases of Onions (Tas Farmnote)
Diseases of Onions and Related Plants (NSW Agfact)
Fungal and Bacterial Diseases of the Onion Family (WA Farmnote)
Fusarium Rot of Onions (Vic Agnote)
Garlic Growing (NSW Agfact)
Leeks (NSW Agfact)
Mechanical Harvesting of Onions (Vic Agnote)
Onion Growing (NSW Agfact)
Onion Growing for Home and Abroad (Vic Agnote)
Onions in the Home Garden (Vic Agnote)
Onions : Cultural Notes (Tas Farmnote)
Onions : Growing the White Spanish (Vic Agnote)
Onions : Growing the Pukekohe Long Keeper (Vic Agnote)
Onion Varieties for Storage (Vic Agnote)
Onions : Pests and Disease Control (Vic Agnote)
Onions : Pink Root Rot (Vic Agnote)
Onions : Weed Control (Vic Agnote)
Pests and Diseases of Onions (SA Fact Sheet)
Shallots and Chives (NSW Agfact)
White Rot of Onions (SA Fact Sheet)

Associations, Journals etc.

Australian Garlic Industry Association
Australian Onion Association (AOA)
Australian Onion Grower
Onions Australia

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Onions are grown for processing and the fresh market. ***An overview of the industry*** is presented by Coombs (1995). ***Choose a variety*** suitable for the time of sowing. If early varieties are sown late, or late varieties are sown early, there will be little bulb formation. Cultivars vary in ***resistance*** to bacterial rots, downy mildew, and some other problems. Plant only ***disease-free*** seed, sets and clones. Hot water seed treatments reduce seedborne diseases but may also reduce germination, seed be dusted prior to planting, to prevent damping off. ***Propagated*** by seed, seedlings. ***Practise a 3-year rotation,*** onions and related plants should not be grown in the same soil more than once every 3 years. Over-rich soil will produce foliage growth at the expense of bulb formation and may encourage the formation of thick, open necks which allow easy entry of fungi. ***Pre-plant soil treatments*** may be necessary if nematodes and white rot are problems. ***Sanitation:*** Destroy all unmarketable bulbs and volunteer plants in the field. Due to the poor ground cover offered by onion plants, an efficient ***weed management program*** is required throughout crop growth. This involves a combination of mechanical weeding and pre- and post-emergence ***herbicides***. Weed control during the first 3-4 weeks after emergence is essential to prevent any check in crop growth. ***Pesticides*** are registered for controlling diseases and pests. ***Growth regulators*** improve growth and reduce sprouting. ***Postharvest diseases and pests*** include *Aspergillus*, *Penicillium*, *Botrytis* and sometimes *Rhizopus*. ***Harvest*** when 70-80% of tops have dropped to the ground. To avoid excessive shedding of skin lift before tops are fully dried. Harvest only under dry conditions and handle carefully to reduce injury. Destroy/burn diseased and damaged plants and bulbs. Do not water at harvest. Remove all bulbs from an area at harvest. ***Store*** only healthy, undamaged bulbs under cool, dry, well ventilated conditions otherwise *Aspergillus* may occur (Salvestrin 1991).

Parsnip

Pastinaca sativa
Family Apiaceae (carrot family)

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*) may cause a watery soft rot of the ***tap root*** both in the ***field and postharvest***. See Vegetables M 5.

Others: ***Crown gall*** (*Agrobacterium* sp.).

FUNGAL DISEASES

Fungal leaf spots (various species) are usually seedborne and favoured by wet weather.

Canker, parsnip canker (*Itersonilia pastinacae*) causes small ***leaf spots*** with light brown centres, ***yellow halo***. See below.
Dry rot and canker (*Phoma* spp.) causes ***leaf spots*** similar to canker but with ***tiny black fruiting bodies*** within the spots. See below.
Phleospora leaf spot (*Phleospora crescentium*) causes ***small pale leaf spots*** when temperatures are moderate and there are heavy dews.
Others: *Cercospora pastinaca, Cercosporella pastinaceae, Cylindrosporium pastinacae, Ramularia pastinacae, Phyllachora pastinacae*, *Septoria apii, S. pastinacae.*

See Annuals A 5.

Powdery mildew (*Oidium* sp.) may attack parsnips. A grey-white powdery growth develops initially on older ***leaves***. ***Favoured*** by moderate temperatures and heavy dews during late summer. ***Most serious*** during humid weather. See Annuals A 6, Vegetables M 7.

Root and stem rots, cankers

Canker, parsnip canker (*Itsersonilia* spp., Imperfect Fungi) affects parsnip, carrot, chrysanthemum, sunflower. ***Crowns*** become brown to reddish, roughened, later large black sunken cankers may develop. The whole root may later be affected and invaded by secondary bacterial soft rots. ***Leaf spots*** are irregular, ***1-3 mm*** across with light brown centres with a pale yellow halo limited by the smaller veins. Centres of older spots are often torn. Leaf spots may enlarge or join together to form large dead patches. ***Leaf stalks*** may develop elongated, sunken, dark brown spots. ***Overwinters*** in soil, infected roots of plants, crop debris and seed. Spores from leaf spots and crop debris are ***spread*** by wind and water and washed into soil to infect lateral roots. ***Favoured*** by cool, wet seasons, poor drainage (in Sydney area in autumn-grown crops). ***Control:*** Practise crop rotation, grow parsnips only once every ***3 years*** in raised beds but not near older infected crops or near land containing infected crop debris. Gradually ***hill plants*** (cover crown with soil) as crops grow to protect roots from infection by leafborne spores. Do not store roots in ground after they mature. ***Collect all diseased roots*** and destroy burn them. Plough in other crop debris promptly. Plant ***disease-free seed,*** do not save seed from infected plants. ***Fungicides*** may be applied in damp weather.
Dry rot and canker (*Phoma* spp.) attacks parsnip and potato. It causes ***leaf spots*** similar to canker. Black pinpoint ***fruiting bodies*** develop in the centres of the spots. Spores washed on to soil infect roots directly but most disease is associated with crown damage.
Rhizoctonia root canker (*Rhizoctonia solani*) causes brown shallow scurfy lesions on ***roots*** (obvious after washing). Seedborne. See Vegetables M 7.
Rhizopus soft rot (*Rhizopus stolonifer*) may develop ***postharvest***. See Fruit F 6, Vegetables M 6.
Sclerotinia rot (*Sclerotinia sclerotiorum*) may occur in the ***field*** and ***postharvest***. See Vegetables M 7.

See Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meliodogyne* spp.) causes ***roots*** to become knotted, misshapen and unsaleable. Yield is reduced. See Soil N 84 (Fig. 450), Vegetables M 10.

Others: ***Stem and bulb nematode*** (*Ditylenchus dipsaci*) causes a dry mealy rot, splitting about ***crowns***, secondary rots of the ***stems and leaf bases*** may develop. Also ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Rotylenchus* spp.), *Paratrichodorus* spp., *Paratylenchus* sp.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Carrot aphid*** (*Cavariella aegopodii*) is yellow-green and causes ***foliage*** to curl, dry up and become covered with honeydew. See Carrot M 45, Roses J 4.

Caterpillars (Lepidoptera)

Parsnip webworm (*Depressaria heracliana*, Oecophoridae) is not known to be present in Australia but ***seriously*** interferes with the production of celery and parsnip seed overseas.

Others: Cutworms (Noctuidae), ***lightbrown apple moth*** (*Epiphyas postvittana*), ***lucerne leafroller*** (*Merophyas divulsana*).

See Annuals A 8, Vegetables M 13.

Mites (Acarina)

Redlegged earth mite (*Halotydeus destructor*) is deep blue-black, about the size of a pin head, and has bright red legs. Their sucking causes ***leaves*** to look bleached. See Vegetables M 16.

Spider mites (*Tetranychus* spp.) may invade ***leaves*** causing speckling. See Beans (French) M 29, Vegetables M 16.

Parsnip seed wasp (*Systole* sp., Hymenoptera) larvae eat out the contents of ***parsnip seeds***. They pupate inside, and wasps emerge through ***tiny holes*** in ripening seed in the flower heads. Remove and burn old parsnip seed heads and crop debris, avoid growing parsnip seed in the area for at least one season. See Seeds N 74.

Vegetable leafhopper (*Austroasca viridigrisea*) is small, green and weak-flying. ***Foliage*** turns grey or yellow, due to their sap sucking. See Vegetables M 15.

Weevils (Curculionidae, Coleoptera)

Vegetable weevil (*Listroderes difficilis*) eats ***new leaves*** on crowns. Large irregular holes in ***leaves, stalks*** and ***roots*** may be eaten and roots extensively gouged and tunnelled. See Vegetables M 17.

Whitefringed weevil (*Graphognathus leucoloma*) larvae furrow in ***roots***, going into the core. Bases and stems of ***seedlings*** may be chewed causing death. See Vegetables M 17.

Others: ***Green mirid*** (*Creontiades dilutus*), ***root mealybug*** (*Rhizoecus falcifer*), ***thrips*** (Thysanoptera), ***wireworms*** (Elateridae) and ***false wireworms*** (Tenebrionidae).

SNAILS AND SLUGS

Snails and slugs may eat growing tips and leaves, shiny trails may be obvious. See Seedlings N 70.

Non-parasitic

Deformed roots: Misshapen and twisted ***roots***, forking and secondary roots may develop for a variety of reasons. Some varieties are said to be ***more susceptible*** to forking than others. See Carrots M 46.

Environment: Parsnips may ***bolt*** (run to seed prematurely). See Vegetables M 18.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for asparagus (Weir and Cresswell 1993).

Seed viability: Parsnip seed loses its germinating capacity rapidly and is unlikely to germinate if >1 year old. Even with good seed, ***germination is slow***.

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State/Territory Departments of Agriculture/Primary Industry eg

Carrots and Parsnips : Root-knot Nematodes (Vic Agnote)
Diseases of Parsnip (NSW Agfact)
Growing Parsnips for the Fresh Market (Tas Farmnote)
Parsnips in the Home Garden (Vic Agnote)
Parsnips : Weed Control (Vic Agnote)
Pests and Diseases of Carrots and Parsnips (SA Fact Sheet)
Storage Conditions for Fruit & Vegetables (NSW Agfact)

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

An industry overview has been presented by Coombs (1995). Choose varieties suited to the area and with some ***resistance*** to powdery mildew, eg White Gold, and bolting, eg slow bolting varieties. Some diseases are ***seedborne***, eg leaf spots. ***Propagate*** by direct seeding. ***Selection and preparation of site:*** Thoroughly prepare the planting site. Parsnips compete poorly with ***weeds***, which must be constantly controlled until parsnip leaves form a canopy that will smother young weeds. Wide row spacings with interrow cultivation is possible. ***Pre-emergence herbicides*** control a range of broadleaved weeds and some grasses in parsnip crops. ***Irrigate and fertilise*** appropriately. Parsnip may be ***harvested*** mechanically when roots are firm and of sufficient size but before seed is set, mature roots left or stored in the ground in warm weather may rot. Leaves are removed (slashed). If leaves are left attached, roots have a shorter storage life. Do not cut the top of roots. Roots are usually washed and placed in bulk bins, or packed into ventilated polythene bags for transport to the wholesaler. Parsnips have a soft flesh, ***avoid injury*** during harvest, washing and grading, which can lead to breakdown during storage. ***Cool*** within about 12 hours after harvest, eg at $0^{o}C$ and at very high humidity (over 95%). Estimated storage life is 2-6 months depending on storage conditions. ***Home gardeners*** can ***store*** uninjured roots for several weeks in a cool, dry place (best in a refrigerator) in perforated plastic bags to prevent them drying out. During winter, they may leave them in well drained ground, where they may keep until September when they normally go to seed.

Pea

Pisum sativum
Family Fabaceae (pea family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases:**
- **Bacterial diseases**
  - Bacterial blight
- **Fungal diseases**
  - Damping off, seed rots
  - Downy mildew
  - Fungal leaf spots
  - Powdery mildew
  - Root and stem rots, wilts
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Lucerne flea
  - Mites
  - Thrips
  - Weevils
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic
- Environment
- Genetic problems
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Pea pimple virus affects *Pisum sativum* Telephone, overseas also nasturtium. ***Leaves*** are mottled and become smaller with time, small enations develop along veins of the lower surface. Yellow spots with raised dead centres develop on uppersurfaces. ***Pods*** are small, with rounded surface enations. Few seeds, watersoaked lesions, flowers absciss, reduced crop yield. Symptoms persist. ***Spread*** by potato aphid (*Macrosiphum euphorbiaceae*), green peach aphid (*Myzus persicae*), not by seed.

Pea seedborne mosaic virus (pea leaf rolling virus) affects pea. Symptoms vary between cultivars and include veinclearing, rosetting of main stem and side branches, small dark green ***leaves*** folded upwards along rib, distorted ***flowers***, often small, distorted, sterile ***pods*** with a few misshapen ends. Plants recover soon after infection. ***Spread*** by pea aphid (*Acyrthosiphon pisum*), cowpea aphid (*Aphis craccivora*), *A. fabae, Dactynotus escalanti, Macrosiphon crataegarius,* oat or wheat aphid (*Rhophalosiphon padi*), by seed (up to 100% in *Pisum sativum*).

Subterranean clover stunt virus (top yellows) is common in certain varieties causing yellowing and stunting of the plant. ***Older leaves*** are thickened and brittle and may have yellow edges. ***Younger leaves*** are upright, uniformly yellow and smaller and narrower than normal, with shortened internodes resulting in a rosette. ***Infected crops*** seen from a distance are yellowish green. Plants remain stiff and upright instead of lying over as do healthy ones. Infects many legumes, eg clovers, medics, broad beans, cowpeas and French beans. ***Spread*** by aphids, eg cowpea aphid (*Aphis craccivora*), green peach aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiae*), which migrate mainly in September and October.

See Vegetables M 4.

Others: Alfalfa mosaic virus, beet western yellows virus, bean yellow mosaic virus, broad bean wilt virus, clover yellow vein virus, peanut mottle virus, subterranean clover red leaf virus, tomato big bud mycoplasma, tomato spotted wilt virus.

BACTERIAL DISEASES

Bacterial blight (*Pseudomonas syringae* pv. *pisi*). Do not confuse with *P. syringae* pv. *syringae* which may cause a less serious, but more widespread disease, on frosted crops. ***During cool weather***, spots on ***leaflets*** and ***stipules*** are dark brown, irregularly shaped, and become papery as tissue dries out or black. If infection occurs at the junction of the stipule and stem or between the midrib and leaflet, spots may be fan-shaped. ***During warm weather***, leaf spots are black and more discrete. ***Stem spots*** are dark brown and elliptical, sometimes extending many centimetres. ***Pod spots*** are dark green and watersoaked initially, later becoming sunken and dark brown. Most common along pod suture. ***Overwinters*** in infected crop debris and seed. ***Spread*** by rain, irrigation, drainage water, machinery, people, animals moving through the crop when it is wet with rain or dew. ***Favoured*** by cool damp weather, overhead watering. ***Sanitation:*** Harvest and handle seed to avoid contamination from field peas, unclean bags and machinery. Avoid movement of people, animals and machinery through the crop while it is wet with rain or dew. People who have been in contact with bacterial blight should disinfect hands, clothing and machinery before handling seed or moving to uninfected crops. Plant ***resistant varieties*** and ***disease-free seed***, do not save seed from infected crops. Serious losses have occurred in southern Australia especially in field peas. See Stone fruits F 124, Vegetables M 5.

Others: ***Bacterial soft rot*** (*Erwinia carotovora* subsp. *carotovora*) may rot ***seed***.

FUNGAL DISEASES

Damping off, seed rots (*Pythium* spp., *Fusarium*, *Rhizoctonia*, *Rhizopus stolonifer*), especially if seed is germinated in cold wet conditions. Treat seed with ***fungicide*** before sowing. See Seedlings N 66.

Downy mildew (*Peronospora viciae*) causes thick grey-brown growth on ***leaf undersurfaces***. Leaf uppersurfaces turn yellow. ***Pod*** infections result in disfiguring creamy coloured areas. Commonly found infecting ***seedling leaves***. Often not so severe on mature plants. See Annuals A 5.

Fungal leaf spots

Septoria blotch (*Septoria pisi*): Small yellow irregularly shaped areas develop on ***lower leaves*** which later turn brown. Small black dots ***(fruiting bodies)*** which produce spores may be seen on diseased parts. Severe infection of ***young plants*** causes shrinking, wilting and ***death***. ***Favoured*** by senescing tissue and moisture.

Others: Cladosporium spot (*Cladosporium pisicola*), ***leaf blotch*** (*Mycosphaerella tulasnei*). Also *Ascochyta*, *Mycosphaerella* (see below).

See Annuals A 5.

Powdery mildew

Powdery mildew (*Erysiphe polygoni*) is a ***common*** and ***serious disease*** of peas affecting ***leaves, stems*** and ***pods***. Severely affected leaves ***die***. Infected pods produce grey-brown seeds. Dwarfing and twisting may occur. Possibly seedborne. ***Favoured*** by warm dry days with cool moist nights, water stressed crops. Early season plantings are generally less affected than later plantings. See Annuals A 6.

Root and stem rots, wilts

Root rot disease complex

More than 20 different fungi can cause root rots of peas worldwide. In Canada about 25% of pea crops were estimated to have root rot disease (Tu 1987). Root rot diseases in Australia are ***common*** and ***widespread*** in soil and can cause rotting of lower stem and roots of peas.

Aphanomyces black root rot (*Aphanomyces euteiches*). Symptoms appear a few weeks after planting. ***Roots*** and ***lower stems*** are initially light brown, becoming dark, outer tissues become soft. Leaves wilt and shrivel from the base. A reduced crop is set, usually nearly all the crop is affected. Damage is often mistaken for drought injury. ***Favoured*** by wet conditions. Avoid poorly drained areas. See Vegetables M 7.

Ascochyta foot rot and black stem, foot rot (*A. pinodella* = *Phoma medicaginis* var. *pinodella*, Ascomycetes) is a minor disease in NSW. Similar to those of mycosphaerella blight except that ascochyta foot rot causes more damage to the ***lower stem***. A few spots may appear on ***stems, leaves*** and ***pods***. ***Overwinters*** in infected debris from previous crops.

Ascochyta leaf and pod rot (*Asochyta pisi*) is similar to mycosphaerella blight (*Mycosphaerella pinodes*) except that ***leaf*** and ***pod*** infection is the most common symptom. Rotting of lower stems is unusual. Spots caused by *A. pisi* are usually light brown with distinct darker margins, while those caused by *M. pinodes* are brownish-purple with indefinite margins. Spots range from small flecks to stem lesions up to several centimetres, depending on the weather. ***Spread*** by seed residues, spores by wind. Severe disease follows showery weather. Snow peas are very ***susceptible***. Treat seed.

Ashy stem blight, charcoal rot (*Macrophomina phaseolina*) attack many crop plants, eg cowpea, and weeds. Usually appears after flowering, as the ***crop is maturing.*** Affected plants senesce early and the ***lower stem*** and ***tap root*** show charcoal discoloured zones which eventually darken. Small black fungal bodies ***(sclerotia)*** can be seen if affected stems are split lengthwise. ***Favoured*** by hotter and drier areas in inland NSW. Infection levels up to ***30%***. ***Overwinters*** in crop residues. Sclerotia may survive in debris or in soil for many years, especially in dry soils. May be seedborne. Irrigate to avoid drying of soil, especially in the post-flowering period. See Vegetables M 7.

Fusarium wilt (*Fusarium oxysporum* f.sp. *pisi*) may be ***serious*** on crops grown on light soils during warm weather. Yellowing, wilting and ***death*** occurs. Symptoms progress from the base upwards. ***Water conducting tissues*** in roots and the lower part of the stem are reddish-brown. See Vegetables M 9.

Mycosphaerella blight and foot rot, ascochyta blight (*Mycosphaerella pinodes*, Ascomycetes) is probably the ***most serious disease*** of peas. A dark purplish rot occurs on ***lower stems***. Girdled stems cause plants to wither and ***die***. Large purplish areas may also develop on upper stems, especially where the stem and leaf stalk meet. ***Leaf spots*** are brown to purple and often have an irregular outline, in moist weather they become circular with a zonate pattern (Fig. 342). ***Pod spots*** are bluish and sunken. Spores may survive for many years in soil. Seedborne. Spores are ***spread*** by wind and air currents from infected crop debris, infected seed. ***Favoured*** by cool, damp weather, crops with a dense canopy and associated high humidity. Avoid poorly drained land.

Others: Pythium root rot (*Pythium* spp.), ***rhizoctonia stem rot*** (*Rhizoctonia solani*), ***sclerotinia rot*** (*Sclerotinia* spp.), ***thielaviopsis black root rot*** (*Thielaviopsis basicola*).

Many cultivars have tolerance to ***Ontario disease complex*** (*Aphanomyces, Aschochyta, Fusarium, Pythium, Rhizoctonia, Thielaviopsis*) overseas (Tu 1987). ***Phenoxy herbicides***, eg MCPA and MCPB, predisposed peas to root rot, ***dinitroaniline and triazine herbicides***, eg cyanazine, oryzalin, pendimethalin and trifluralin, did not. Peas grown in ***raised seedbeds*** had significantly lower root rot incidence and severity than those grown in flat seedbeds. ***Green manure crops***, eg oats, sorghum or Sudan grass, reduced root rot severity in subsequent pea crops. ***Chisel ploughing*** or ploughing in autumn and spring, reduced root rot severity. ***Soil compaction*** increased root rot incidence and severity. ***On site soil indexing*** reliably determined the level of field ***infestation*** as well as cultivar ***susceptibility***. ***Management programs*** were then developed which included planting resistant cultivars, seed treatments, avoiding MCPA/MCPB herbicides, reducing soil compaction, practising chisel ploughing or ploughing in autumn and spring, raised seedbeds, using soil indexing and planting green manure crops in the intervals between pea crops. See Vegetables M 7.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.); do not confuse with nitrogen-fixing nodules on roots. Also ***root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematode*** (*Helicotylenchus dihystera*), ***stem and bulb nematode*** (*Ditylenchus dipsaci*), *Filenchus exiguus, Helicotylenchus dihystera, Paratrichodorus* spp., *Paurodontus apiticus.* See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Cowpea aphid (*Aphis craccivora*) infests summer grass especially, also young beans, broad bean, cucurbits, pea, apple, weeds especially *Medicago* sp. in inland areas. Restricts growth of ***young plants***, especially in unirrigated crops during dry weather. ***Flowering*** and ***podding*** may be reduced or prevented. ***Adult aphids*** are ***greenish-black,*** about ***2.5 mm*** long. They infest ***new growth*** of young plants and undersurfaces of older leaves, leaf distortion may follow. They produce ***honeydew*** on which black sooty mould may develop. When pastures dry off in spring, aphids migrate to peas. Good growing conditions can offset, to some extent, the damaging effects of aphids.

Potato aphid (*Macrosiphum euphorbiae*) is ***3 mm*** long, and ***pale green.*** It clusters on the undersides of the ***older leaves*** and on younger growing tips. In severe infestation they may cause wilting and twisting of leaves and retarding growth to some extent. See Potato M 80.

Others: Green peach aphid (*Myzus persicae*) and ***pea aphid*** (*Acyrthosiphon pisum*).

Aphids also spread ***virus diseases***. See Roses J 4, Vegetables M 11.

Caterpillars (Lepidoptera)

Butterflies (Lycaenidae) are minor pests. ***Grass blue butterfly*** (*Zizina labradus*) caterpillars are about 10 mm long, green, pink or brown with a white stripe down each side of the body, and covered with small pale brown hairs and a brown head. They feed on ***small leaves, flower buds*** and ***seed pods***. ***Pea blue butterfly*** (*Lampides boeticus*) caterpillars feed on Fabaceae, eg *Kennedia prostrata*, lupin, pea. Young caterpillars tunnel into ***flowers*** and later ***pods*** to feed on developing seeds and may be accompanied by small ants (*Crotalaria* spp.). Without suitable food caterpillars attack each other. ***Overwinter*** as pupae unattached on the ground or below ground in sandy soil. Butterflies migrate (Common and Waterhouse 1981).

Corn earworm (*Helicoverpa armigera*) is a ***serious pest*** and chews young ***foliage, flowers*** and ***pods***, retarding growth. If infestation is heavy, peas are eaten out of many pods. All stages of pea crops may be attacked though they are at their most susceptible after ***flowering starts***. Spray at early podding stage. Crops ready for harvest may need to be picked heavily before spraying to allow for withholding periods. See Sweetcorn M 89.

Cutworms (*Agrotis* spp.) attack ***young plants*** at, or near ground level, during the night. Bogong moth, common cutworm (*A. infusa*) and southern armyworm, barley grub (SA) (*Persectania ewingii*). See Seedlings N 68.

Other: Lightbrown apple moth (*Epiphyas postvittana*), ***looper caterpillars*** (*Chrysodeixis* spp.), ***lucerne seed moth***, etiella (*Etiella behrii,* Pyralidae), ***bean podborer*** (*Maruca testulalis*, Pyralidae), *Capusa senilis*, Geometridae

Monitor bean pod borer and corn earworm damage prior to applying insecticides (Brough et al. 1994). See Annuals A 8, Vegetables M 13.

Lucerne flea

Lucerne flea (*Sminthurus viridis,* Collembola) is ***2-3 mm*** long (Fig. 343), jumps when disturbed, skeletonises leaves ***leaving*** only main veins and lower cuticle, leaves look transparent. Often occurs in association with redlegged earth mite. More common in clay soils. Insecticides may be applied when lucerne fleas are seen.

Mites (Acarina)

Earth mites (Penthaleidae) may destroy pea ***seedlings*** planted in weedy areas soon after they appear (Fig. 344). See Vegetables M 16.

Spider mites (Tetranychidae): ***Bryobia mite*** (*Bryobia rubrioculus*). ***Twospotted mite*** (*Tetranychus urticae*) and ***bean spider mite*** (*T. ludeni*) may be a problem in hot dry weather (Fig. 345). ***Pods*** develop a tough surface. ***Monitor*** populations. See Beans (French) M 29.

Thrips (Thripidae, Thysanoptera)

Plague thrips (*Thrips imaginis*) are tiny and dark. They attack ***flowers*** and ***young pods*** causing curling, distortion and malformation of young buds and pods. See Roses J 6, Vegetables M 17.

Onion thrips (*T. tabaci*) cause ***leaf*** silvering and retard growth. Damage to ***flowers*** may cause them to drop. Infested ***pods*** are reduced in market value, plants may be killed. Damage is only serious in dry periods after thrips migration from nearby wilting weed hosts, during spring or early summer. See Onion M 68.

Weevils (Coleoptera)

Pea weevil (*Bruchus pisorum*, Bruchinae, Chrysomelidae) attacks ***peas***, it is not a true weevil (Curculionidae) and ***cannot reproduce in stored grain***. Infestation by pea weevils occurs only ***if eggs are laid on green pods in the field*** (SA Fact Sheet: Pea Weevil). ***Adults*** are ***4-5 mm*** long (Fig. 346), brownish, flecked with white, black and grey patches. ***Larvae*** eat into green pods and peas, 50% of the pea seeds may be attacked. Damaged ***seeds*** may germinate if injury is confined to the cotyledons but seedlings are weaker and more prone to weed competition and damage by other pests. Adults ***overwinter*** in cracks in posts, under bark or in rubbish. ***Spread*** by adults flying, infested seed. ***Infestation arises*** from peas being shattered before or during harvest, volunteer peas or peas sown for grazing, pea hay, sowing infested seed. ***To minimise losses***, all growers in a district should follow recommended control procedures. If damage occurred ***last year***, then sow this season's crop far from previously used fields and seed storage areas. ***Harvest promptly*** as soon as crop is ready and treat/fumigate seed immediately to prevent larvae from developing and further loss in weight. ***Graze*** crop residues to reduce infested peas and expose larvae to sunlight which kills them. Then ***cultivate*** to bury remaining unharvested seed more than 200 mm deep to prevent beetles from emerging. ***Control self-sown peas*** especially in early cereal crops. Cut peas grown for ***hay*** before pods form to prevent weevils from breeding. ***Monitor*** beetles by sweeping with a net in flowering crops and spray before beetles lay eggs in pods. All peas ***exported*** to Tasmania must be treated. Only plant ***weevil-free seed***.

Spinetailed weevil (*Desiantha caudata,* Curculionidae) may damage peas. ***Larvae*** are pale yellow, active, thick-set, about ***6 mm*** long, and may be found in soil close to plants chewing stems of pea ***seedlings***. Sometimes furrows up to 25 mm long are made on stems, seedlings wilt and die. Larvae attack pea plants if they are sown in areas that formerly carried other hosts. Prepare ground early prior to sowing.

Bean weevil (*Acanthoscelides obtectus*) and ***cowpea weevil*** (*Callosobruchus* spp.) are both mainly ***storage pests*** which may first infest seed ***in the field***. See Beans (French) M 31.

Peas ***resistant*** to weevils which eat peas in store, are being developed. The digestion of starch in the weevils stomach is blocked so that they starve to death. See Seeds N 74.

Others: ***Bean fly*** (*Ophiomyia phaseoli*) and ***pea fly*** *(Kleinschmidtimyia pisi,* Agromyzidae). ***Crickets, grasshoppers, locusts*** (Orthoptera), ***green vegetable bug*** (*Nezara viridula*), ***vegetable leafhopper*** (*Austroasca viridigrisea*). ***Various stored pea pests***, eg confused flour weevil, (*Trilobium confusum*), granary weevil (*Sitophilus granarius*), rice weevil (*S. oryzae*), rust-red flour weevil (*T. castaneum*).

SNAILS AND SLUGS

Snails and slugs chew ***foliage*** making it ragged. See Seedlings N 70.

VERTEBRATE PESTS

Birds will attack developing ***pods***. See Fruit F 13.

Non-parasitic

Environment: ***Frosting*** of leaves causes lifting and tearing of the epidermis, dead areas may develop between the veins. Terminal growing points may die causing the development of buds lower down the stem, this is a problem for mechanically harvested crops. Young developing ***leaves*** may become distorted about 1-2 weeks later. ***Flowers*** may be killed by frost. Peas are sensitive to ***heat*** and temperatures > 30 °C will cause early maturity and lower yields.

Genetic problems: Pea seedlings were used to prove Mendel's theory of ***inheritance***. Home gardeners who repeatedly save seeds from their current crop for planting the following season, may produce seedlings with genetic problems, eg ***albinism*** (Fig. 347). Seedlings ***die*** due to lack of chlorophyll..

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for peas (Weir and Cresswell 1993). Overseas ***manganese deficiency*** (marsh spot) and ***manganese toxicity*** (purple blight) may occur on peas.

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State/Territory Departments of Agriculture/Primary Industry eg

Charcoal Rot (NSW Agfact)
Diseases of Peas (NSW Agfact)
Green Peas (NSW Agfact)
Green Peas for Processing : Cultural Notes (Tas Farmnote)
Green Peas : Seed Quality & Sowing Times (Tas Farmnote)
Growing Peas for Processing (Vic Agnote)
Growing Peas for the Fresh Market (Vic Agnote)
Peas in the Home Garden (Vic Agnote) old
Peas : Pest and Disease Control (Vic Agnote)
Peas : Weed Control (Vic Agnote)
Pea Weevil (NSW Agfact, SA Fact Sheet)
Pests and Diseases of Peas (SA Fact Sheet)
Powdery mildew of Green Peas (Tas Farmnote)
Snow Peas and Sugar Snap Peas (NSW Agfact)

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Peas are grown to eat fresh, for canning, freezing, as feed for stock, and for cut flowers. An overview of the industry is presented by Coombs (1995). Select quality cultivars which have some ***resistance*** to virus diseases and plant ***disease-tested*** seed which is free from viruses, leaf spots, root rots and pea weevil. Do not save seed from infected crops. Avoid using seed that has matured under hot dry conditions. ***Practise crop rotations*** of 2-5 years between pea crops. Sow new plantings as far away as possible from other plantings infected by disease or land carrying infected debris. ***Plant*** in well structured, well drained soils, peas will not tolerate waterlogging. Liming 3-4 weeks before sowing is essential. ***Dust seed*** before sowing (with fungicide and insecticide) to prevent infection by soilborne damping off fungi and insect pests. Sow at correct rate and distance apart, etc. Peas may need some support. Water plants sparingly until seedlings are above ground. Poor germination may occur if fertiliser is allowed to come into contact with the seed. Seed and seedling rots are encouraged by overwatering in early stages. Peas compete very poorly with ***weeds*** and so early weed control is necessary. Some pre-emergence herbicides are applied after the crop is sown but before seedlings have emerged. Care must be taken not to damage surface roots. Maintain moist surface. Some herbicides used on peas have a long residual life, so care must be taken with follow-on crops that are known to be sensitive to these herbicides. Some herbicides may damage pea plants suffering from any physical damage, downy mildew, collar or stem rot. At some stages in the development of a pea crop ***insufficient moisture*** may cause severe losses, eg when the first flowers appears. However, ***over irrigation*** before this first flowering. may lead to excessive straw growth, uneven setting and uneven maturity, and pod swell when the seed is expanding in the pod. ***Diseases and pests***, especially caterpillar pests which attack the pods, should be ***monitored***. ***Pesticides:*** Chemical controls can be difficult with peas because they have a waxy surface which sheds water and plants are usually very tangled. ***Harvest stage:*** Home gardeners should pick peas when plump and a good bright green. Pods that have a crazed pattern on the pods should be left because they are overmature and very starchy in taste. ***Maturity of commercial crops*** is determined by a maturometer test. Fast cooling is required (up to 4 hours), at $0^{o}C$ at high (90-95%) relative humidity (Salvestrin 1919). Properly harvested peas may be stored for 1-3 weeks. ***Storage and packaging procedures*** will depend on the end use for the peas. Stored peas may be damaged by storage pests, eg tropical warehouse moth (*Cadra cautella*). After harvest. ***plough in all crop debris*** or burn, as soon as possible.

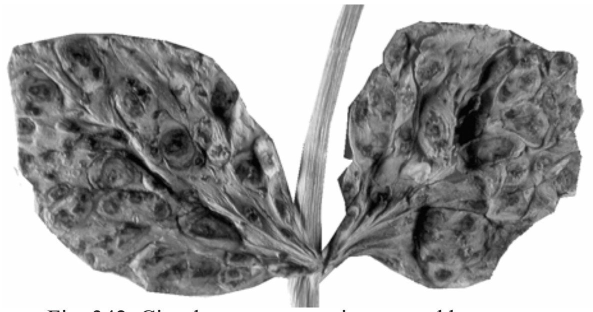

Fig. 342. Circular zonate spotting caused by mycosphaerella blight and foot rot (*Mycosphaerella pinodes*).

Fig. 343. Lucerne flea (*Sminthurus viridis*) about 2-3 mm long.

Fig. 345. Twospotted mites (*Tetranychus urticae*) crawl over webbing on a pea crop.

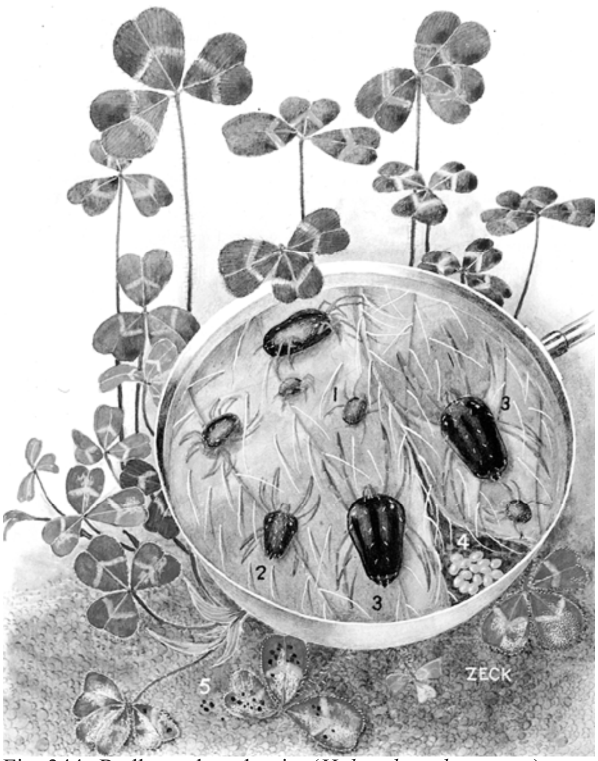

Fig. 344. Redlegged earth mite (*Halotydeus destructor*). **1.** Six-legged 1st stage nymphs. **2.** 2nd stage nymphs with 8 legs. **3.** Adult redlegged earth mites. **4.** Eggs laid on surface of soil. Enlarged about 22 times. **5.** Subterranean clover showing injury caused by the mites feeding on the leaves. Actual size. Dept. of Agric., NSW.

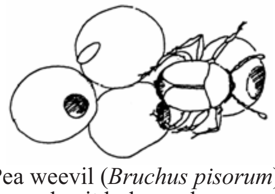

Fig. 346. Pea weevil (*Bruchus pisorum*). Pea seeds with large round exit holes and a pea weevil (4-5 mm long) that has recently emerged from one of them.

Fig. 347. If seed is continually saved from pea crops, 25% of seedlings may lack chlorophyll (albinism).

Potato

Solanum tuberosum
Family Solanaceae (nightshade family)

PESTS AND DISEASES

Parasitic

- **Virus and virus-like diseases**
- **Bacterial diseases**
  - Bacterial soft rots
  - Bacterial wilts
- **Fungal diseases**
  - Early blight, target spot
  - Late blight, Irish blight
  - Root, stem and tuber rots, wilts
  - Potato black wart
  - Scab diseases
- **Nematode diseases**
  - Potato cyst nematode (PCN)
  - Root knot nematodes
- **Insects and allied pests**
  - Aphids
  - Bugs
  - Caterpillars
  - Crickets, grasshoppers, locusts
  - Greenhouse whitefly
  - Leaf beetles, flea beetles
  - Leafhoppers
  - Mites
  - Onion thrips
  - Potato ladybirds
  - Potato moth
  - Potato wireworm
  - Scarab beetles
  - Weevils

Non-parasitic

- Environment
- Nutrient deficiencies, toxicities
- Poisonous properties
- Seedpiece breakdown

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Some virus diseases are more important than others. Some infect only potato, others potato and related plants while others have a wide host range. Symptoms vary from no visible effect (latent viruses) to mottled leaves, small tubers and reduced yields .

Potato leaf roll virus affects potato, and occasionally other Solanaceae, eg tomato, thornapple (*Datura stramonium*), apple of Peru (*Nicandra* physalodes), gooseberry (*Physalis* spp.), shepherd's purse (*Capsella bursa-pastoris*), dead nettle (*Lamium amplexicaule*). ***Seedborne infection*** causes rolling of lower leaves first, and plants have a rattling sound when shaken. ***Aphidborne infection*** causes rolling of upper leaves first. ***Stems*** may be thickened at leaf junctions. ***Tubers*** may be small with ***spindly sprouts*** and internal browning. See Vegetables M 1 (Fig. 292). Plants are often stiff, stunted and erect. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*), potato aphid (*Macrosiphum euphorbiae*), by vegetative propagation (tubers), by movement of infected tubers, not by mechanical inoculation, not by seed, not by pollen. Do not plant seed crops near table crops or older infected crops.

Potato viruses X, S and Y (PVX, PVS and ***PVY):*** ***PVY*** has a wide host range, eg potato, tomato, capsicum, tobacco, petunia, bulbs, roses, *Kennedia coccinea*, weeds. ***PVX and PVS*** individually cause mild mosaic or no visible symptoms. ***Tuberborne*** infection with ***PVX and PVY*** together in one plant cause crinkling, mottling and stunting of leaves. ***Aphidborne*** infection with ***PVY*** causes leaf spotting, blackening of leaf veins and stems (leaf drop streak). Infected plants die early. ***Spread: PVX*** by contact. ***PVX and PVY*** by aphids and contact.

Tomato big bud, purple-top wilt (tomato big bud mycoplasma) causes upward rolling and pigmentation of young leaves, erect leaf stalks. ***Leaves*** of ***white-flowered cultivars*** turn yellow, leaves of ***pigmented flowered cultivars*** turn red or purplish depending on variety, ***stems*** also become pigmented. Crops grown under high moisture develop a bunched appearance. Stems eventually yellow and collapse, lower stems show internal browning. There is no greening of flowers. ***Tubers*** of infected plant may be flabby, form spindly sprouts and be discoloured at stem end. Aerial tubers may form on stems. See Tomato M 97, Vegetables M 1 (Fig. 292).

Tomato spotted wilt virus (TSWV) causes brown dead spots or rings on potato ***leaves***, most severe on younger leaves which may be killed. The ***shoot apex*** may be blighted and killed. Old leaves may show zoned, torn brown spots. ***TSWV*** in planting material may be detected using ***ELISA*** (Enzyme Linked Immunosorbent Assays). See Tomato M 96.

Others: Alfalfa mosaic virus, beet western yellows virus, cucumber mosaic virus, lucerne (Australian) latent virus, potato A virus, potato virus M, potato aucuba mosaic virus, potato spindle tuber viroid (Glen Innes collection).

Overwinters in older infected crops, seed tubers, volunteer tubers in soil, infected hosts especially weeds near crops. All viruses are ***spread*** by use of infected tubers. Some also by aphids, mechanical inoculation, contact between infected and healthy plants, cutting tools and other implements. ***Measures to minimise losses:*** Avoid growing young crops near older infected potato crops and other hosts. Destroy weeds known to harbour insect vectors. Some new varieties have ***resistance*** to potato leaf roll virus (resistance of Omega and Spunta is probably due to resistance to aphid colonisation). Katahdin and Sebago are field-resistant to ***PVA*** and Katahdin has some resistance to ***PVY***. Plant ***certified seed potatoes***. Where disease is a problem, commercial growers may attempt to control ***aphid vectors*** by spraying field crops in spring and early summer to reduce numbers of infected plants. See Vegetables M 4.

BACTERIAL DISEASES

Bacterial soft rots

Black leg (*Erwinia carotovora* pv. *atroseptica*) causes a soft rot of potato. An inky black decay of the stem starting below ground level may progress rapidly up one or more stems. ***Leaves*** roll and yellow, plants wilt and die. The seed tuber is usually rotted. ***Tubers*** produced by affected plants may rot from the stem end, emerging stems rot. ***Favoured*** by cool weather. ***E. chrysanthemi*** causes a rapid soft rot of seed tubers and an offensive ***smell*** in hot climates.

Bacterial soft rot (*E. carotovora* pv. *carotovora*) causes a soft light rot of ***tubers*** with an offensive ***smell***. Soft depressed areas occur around lenticels. Sebago is very ***susceptible***. Soft rot in warmer weather and maturing crops, attacks many vegetables. ***Rotating potatoes*** with brassicas increases susceptibility.

Field control: Avoid damage to stems by wind, machinery, fertiliser, and mechanical injury to tubers during and after harvest, do not harvest under wet conditions. ***Store tubers*** in cool, well ventilated conditions. Allow adequate ventilation between tubers and bags/bins. Isolate affected tubers where rot is detected in seed. Never allow tubers to become wet except when dipping against other diseases. If tubers do get wet, dry rapidly. ***Freshly cut seed*** can be rapidly invaded by soft rot so cure rapidly then plant as soon as possible. Regularly clean and disinfect/sterilise seed cutting and handling equipment between different seed lots. Use only clean water to wash potatoes, do not wash potatoes before storage. Sebago is very ***susceptible***. Plant ***certified seed potatoes***. Plant whole tubers if possible. See Vegetables M 5.

Bacterial wilts

Bacterial ring rot (*Corynebacterium michiganense* pv. *sepedonicum*) is a ***serious*** vascular wilt disease of potato in North America and Europe. Leaves wilt and vascular rings in tubers are discoloured. ***Quarantine risk:*** Infected tubers are the greatest risk of introducing this disease into Australia (Com. of Aust. 1985).

Bacterial wilt, brown rot (*Pseudomonas solanacearum*) may affect plants in hot weather at any age, foliage is not discoloured, plants wilt and eventually die. When infected ***stems*** at ground level and ***tubers*** are cut across, vascular tissue is brown and ***bacteria ooze out*** (this does not occur with fungal wilts). Milky bacteria ooze from ***tuber eyes*** (milky eye), soil adheres to eyes. ***Practise crop rotations*** of 3 years. Avoid planting in infested land. Clean machinery, disinfect tools. Chlorinate water used in washing tubers, grade tubers prior to washing, minimise movement of machinery from affected areas and clean before transporting. Bring only new bags into properties. Contractors may spread diseases on machinery. Avoid very ***susceptible*** varieties, plant certified ***disease-tested seed potatoes*** which have a nil tolerance. See Vegetables M 6.

FUNGAL DISEASES

Early blight, target spot

Scientific name: Imperfect Fungi: (*Alternaria solani*) is a ***major disease*** of potato.

Host range: Potato, tomato, related plants, eg eggplant and nightshade (*Solanum nigrum*).

Symptoms: Angular, concentrically zoned dark brown spots on ***leaves***. Older, lower leaves are affected first. Spots may enlarge quickly, blighting foliage. Shallow pits occur on ***tubers***, tissue directly under pits turns brownish-black.

Overwintering: Infected plants and crop debris (for at least a year), older diseased crops and weeds, eg nightshades, by seed in tomato.

Spread: Spores spread by wind, air currents, rain, irrigation, farm machinery and insects from infected plants and crop debris. Spores from foliage infect tubers. Seedborne on tomato.

Conditions favouring: Warm, wet weather but only needs slight humidity, morning dews. Develops between flowering and maturity. Crowded tomato seedbeds. Overhead irrigation.

Control:
Cultural methods: ***Rotate crops*** so that potatoes do not follow tomatoes, to allow time for infected crop debris to break down. Prepare seedbeds properly. Avoid overhead irrigation.
Sanitation: Destroy old crops after harvest.
Resistant varieties: Some cultivars have some ***resistance***. Cultivar selection is important.
Disease-free planting material: Plant ***disease-free tubers***. Spread to healthy tubers in storage is not known, but possible in sprouting racks during rising spring temperatures.
Pesticides: Fungicides may be applied from flowering onwards.

Late blight, Irish blight

Scientific name: Eumycetes: paper
Late blight (*Phytophthora infestans*) occurs in Australia. It caused ***famine*** in the 1840s in ***Ireland*** and could now cause a famine in ***South America***. A new strain imported from Mexico has spread across Europe.

Host range: Potato, tomato, other Solanaceae.

Symptoms: Dark areas on ***leaves*** (Fig. 348), often commencing at leaf margins, leaves shrivel or rot. Delicate white fungal growth may develop on leaf undersurfaces around lesion edges. Infection can extend from leaves to stems. ***Infected tubers*** have brown to purple black metallic sunken areas on the surface. Underneath tissues are reddish brown (Fig. 348). ***Tubers*** may rot and be invaded by secondary organisms causing soft smelling rot.

Overwintering: Infected plants and tubers.

Spread: Spores are spread by wind and water on to foliage and tubers; contact of diseased foliage with tubers at harvest; planting infected tubers. In wet weather each spore produces a number of smaller spores which swim in the moisture on leaves, tubers.

Conditions favouring: Humid weather with cool nights (10-15^{o}C) and warm days (21-27^{o}C). Overhead irrigation.

Control:
Cultural methods: Allow diseased plants to die down completely before digging. Do not cover tubers with dead plants. ***Sort out*** affected tubers before bagging and storing.
Resistant varieties: Attempts to breed more resistant cultivars have only been partially susceptible. Avoid ***highly susceptible*** varieties where disease is a problem.
Disease-free planting material: Plant only ***healthy seed tubers***; ensure no infected tubers from a previous crop stay in the ground.
Pesticides: ***Fungicides*** may be necessary. Strains have emerged in the USA which show ***resistance*** to most of the fungicides used during the 1980s.

Root, stem and tuber rots, wilts

Anthracnose, black dot (*Colletotrichum coccodes*) infects Solanaceae and produces abundant black dot-like ***sclerotia*** on affected ***tubers, stolons*** and ***stems***. ***Young leaves*** may show vein death, interveinal scorching, rolled leaf margins. Plants may wilt, older leaves may yellow. See Fruit F 5.

Fusarium diseases (*Fusarium* spp.) causes many tuber rots of potato, eg *F. avenaceum, F. solani, F. sulphureum*. ***Dry rot*** (*Fusarium* spp.) is a dry sunken rot, tubers have a wrinkled appearance. Pockets in tuber rot are generally filled with ***white or pink wefts*** of fungus which may be present on the outer surface (see below). If the rot starts around the point of attachment it is known as ***stem end rot*** and may indicate the presence of ***fusarium wilt*** in the parent crop. ***Powdery dry rot*** (*F. trichothecioides*): Areas of ***tuber*** are shrivelled and brown, often with small tufts of surface fungal growth. Underlying tissue rots and develops cavities filled with fungal threads. A band of light brown to dark brown tissue surrounds the rotted area. See Vegetables M 7.

Gangrene (*Phoma exigua* f.sp. *foveata*) is a minor disease causing shallow thumb-mark depressions on ***tuber surfaces*** on which small black fruiting bodies develop during cool moist conditions in the field and postharvest in storage.

Leak (*Pythium* spp.) attacks a wide range of vegetables. Fungus invades tubers through injuries. ***Tubers*** develop a ***watery rot*** that quickly develops during ***transport*** and ***storage***. See Vegetables M 7.

Pink rot (*Phytophthora* spp., not *P. infestans* which causes late blight) infects ***tubers***. A watery rot develops in ***transit*** and ***storage***. Rotted tissue turns almost black when exposed to air, the skin of affected tubers breaks easily, releasing watery liquid. Within a few days nothing may be left except a thin papery skin. ***Favoured*** by harvesting and storage under hot dry conditions. See Vegetables M 7.

Rhizoctonia disease, black scurf (*Rhizoctonia solani*) attacks all stages of growth. The host range of the strains attacking potatoes is unknown. ***Young sprouts*** from newly planted tubers rot and may not emerge above ground, top leaves may crowd together (rosette), affected plants may die. Black resting bodies ***(sclerotia)*** up to 8 mm across form on ***tubers***, which may be pitted or cracked. ***Seed potatoes*** may be infected. ***Favoured*** by cool moist conditions in early stages of growth. See Vegetables M 7.

Sclerotinia rots, white moulds (*Sclerotinia sclerotiorum*, *S. minor*) cause watery rots of ***stems*** and ***leaves*** near ground level, foliage wilts and yellows. A white fungal growth and black ***sclerotia*** develop on rotted areas. Disease is most obvious 10-14 days after the last hilling. See Vegetables M 7.

Silver scurf (*Helminthosporium solani*) causes buff areas on ***tuber skins***. Large areas look silvery when wetted, and gradually become dark brown, often with a sooty black fungal growth on their surfaces. In severe cases the outer cells of the tuber skin may slough off causing tubers to shrink.

Stem-end hard rot (*Phomopsis tuberivora*) causes a hard, dry corky rot at the stem end of ***tubers***. Rotted areas sink and enlarge to a circular patch. Eventually whole tubers rot and may mummify. Small black dots (fruiting bodies) develop on rotted tubers. ***Favoured*** by dry soil conditions approaching harvest.

Wilts: Fusarium wilt (*F. oxysporum*) causes stunting, yellowing and wilting of foliage, death of plants. ***Stems*** are brown and rotted at and below ground level. Internal woody parts of ***stems*** above rotted areas are brown. ***Tubers*** show a ring of discoloured tissue near the veins. ***Verticillium wilt***, early dying (*Verticillium dahliae*): Plants wilt, are pale green or yellow and age early. ***Vascular tissues*** in stems and tubers are light brown (brown rings in tubers). Plant ***resistant cultivars***. Possibly ***other Verticillium spp***. may occur on potato in Australia. See Vegetables M 9.

Others: Armillaria root rot (*Armillaria* sp.), ***ashy stem blight***, charcoal rot (*Macrophomina phaseolina*), ***phoma stem spot*** (*Phoma eupyrena*), ***powdery mildew*** (*Oidium* spp.), ***rhizopus soft rot*** (*Rhizopus stolonifer*), ***sclerotium stem rot*** (*Sclerotium rolfsii*), ***tuber discolouration*** (*Plectosphaerella cucumerina*), ***violet root rot*** (*Helibasidium purpureum*). Also *Acrostalagmus cinnabarinus, Gibberella cyanogena, Gliocladium penicillioides, Trichocladium* sp.

Most of these fungi are ***soilborne*** and enter through ***wounds***. Most cultivars are ***susceptible***, there are exceptions. ***Inspect seed consignments*** on arrival and reject those affected; hot water seed treatments remove seedborne infection. ***Dip seed*** in recommended fungicide before planting. Do not harvest immature tubers, or dig or store, tubers under wet conditions. ***Prevent injury*** to tubers during harvest and ***discard*** tubers with damage. Avoid digging on hot dry days and keep tubers out of hot air and sunlight. ***Store*** under recommended conditions to toughen the skin and heal cuts and bruises. Allow tubers to dry before bagging, apply recommended fungicides to tubers before storing. See Vegetables M 7, M 9.

Potato black wart (*Synchytrium endobioticum*) is a ***serious disease*** of potatoes in NZ and other countries. It causes potatoes to produce abnormal wart-like growths in the region of the eyes of ***tubers***. ***Quarantine risks:*** Affected potatoes and soil contaminated with spores of the fungus pose the greatest damage. The fungus can also infect tomatoes and a few other Solanaceae (Com. of Aust. 1987).

Scab diseases

Common scab (*Streptomyces scabies*, an Actinomycete, not a fungus) affects potatoes, turnips, beets. Scabs on ***tubers*** vary from deep pits 5-8 mm across to less commonly corky raised areas, depending on cultivar, district and season. Spots may coalesce to cover most of the tuber surface. Infection occurs through ***lenticels*** when tubers are young. ***Favoured*** by dry seasons, alkaline soils. Practise ***long rotations*** using grass or cereal crops. Do not lime soil. Keep soil moist for at least 4 weeks after tubers begin to form. Irrigate plants as recommended.

Powdery scab (*Spongospora subterranea,* Plasmodiophoromycetes) affects potato, tomato, nightshade, other Solanaceae. Wart-like swellings up to 10 mm across form on ***tubers***. These break open to form a scab, releasing brown powdery spore balls. Swellings form on roots or stolons only. Disease may develop in storage (a dry rot). Secondary organisms may invade lesions. ***Favoured*** by cool moist conditions, especially in wet areas or where crops have been heavily watered to reduce frost injury. Soil temperatures < 18°C and high soil moisture in early stages infection. Crop rotation is not an effective control. ***Do not lime*** before growing a winter potato crop in light acid soils. Plant ***resistant varieties.***

Both scab diseases ***overwinter*** in contaminated seed tubers and soil and are ***spread*** by planting infected tubers, movement of infested soil on machinery, footwear and equipment, water. Only plant ***pathogen-tested seed*** in ***disease-free soil.*** Seed and soil treatments may be necessary.

Others: ***Septoria leaf spot*** (*Septoria lycopersici*).

NEMATODE DISEASES

Potato cyst nematode ***(PCN)*** (*Globodera rostochiensis*) attacks potato, other Solanaceae, eg capsicum, eggplant, tomato, nightshade. Low populations of the nematodes may not be noticed. Growth may slow, yellow, wilt and dieback early. High populations may reduce crop yield by up to ***90%*** as a result of ***smaller tubers*** (tuber quality and quantity are not affected). One life cycle is completed with each crop. Eggs in cysts remain dormant in soil for years. When potato plants grow, substances exuded by roots stimulate eggs to hatch into larvae which move into the soil and penetrate host roots just behind the root tips. They establish a permanent feeding site and develop into adults. Males leave the root but females remain attached by the head and neck only (Fig. 349). Females produce 300-500 eggs which are retained in the body. Females die with the root and the skin hardens and tans, forming a protective cyst for the eggs. ***PCN*** is spread in the same way as root knot nematodes. Currently, ***PCN*** is present on properties near Perth and Melbourne (1994). ***Contact*** local Departments of Agriculture if ***PCN*** is suspected to obtain information on quarantine regulations to prevent spread (Com. of Aust. 1991, 1993).

Root knot nematodes (*Meloidogyne* spp.) may be ***important pests*** of potato in light sandy soils. Rounded raised lumps develop on tubers, occasionally lumps occur on roots (Fig 350). Do not plant infected tubers. Plant ***certified nematode-free tubers*** in nematode-free soil. Maximum residue limits (MRLs) exceeding the ***legal limit*** for a nematicide (fenamiphos) is sometimes found in spot market checks. See Vegetables M 10.

Others: ***Root lesion nematodes*** (*Pratylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus dihystera, Rotylenchus* spp.), ***stem and bulb nematodes*** (*Ditylenchus* spp.), also *Paralongidorus* spp., *Scutellonema brachyurum*, *Tylenchorhynchus capitatus*.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Green peach aphid (*Myzus persicae*) ***(GPA)*** is about ***2 mm*** long and smaller than potato aphid. Wingless adults are green, pale yellow or pink, winged adults are green with darker markings. Aphids are active and tend to infest undersurfaces of ***lower leaves*** as well as new shoots. See Stone fruits F 129.

Potato aphid (*Macrosiphum euphorbiae*) is ***green***, slow moving, about ***3 mm*** long with long slender cornicles. Winged and wingless forms occur together, infesting potato, many crops and weeds.

Others: ***Rice root aphid*** (*Rhopalosiphum rufiabdominalis*) sucks sap from roots causing wilting, may be a ***serious pest***. Also ***bulb and potato aphid*** (*Rhopalosiphoninus latysiphon*).

Both species suck sap from leaf ***undersurfaces*** of older leaves, causing leaf curling and wilting. They produce honeydew, but more seriously ***transmit virus diseases***, eg potato leaf roll. ***GPA*** is the more important insect vector. Leaf hairs on potato are tipped by tiny sacs filled with a substance that sticks to any insect that alights on the leaf. Small insects starve, larger ones that ingest the glue develop severe constipation. Crossbreeding of wild ***resistant varieties*** with hairy leaves with commercial high-yielding varieties may be used to combat aphids. Usually seed potatoes are green-sprouted before planting; infestation and infection can occur at that stage if the green sprouting is done outdoors. Regular spraying to control aphids may be necessary if potatoes are grown for seed. ***Monitor*** aphid populations after emergence before applying an insecticide (Brough et al. 1994). See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)

Green mirid bug (*Creontiades dilutus*) is a minor pest of potato, it is ***6 mm*** long and moves rapidly among potato blossoms. Infested ***buds*** when sucked dry turn yellow, dry out and fall. Blossom production may be suppressed but tuber production is not affected. See Vegetables M 12

Green potato bug (*Cuspicona simplex*, Pentatomidae) is related to the spined citrus bug (*Biprorulus bibax*) and is a pest of a range of crops. See Citrus F 36.

Green vegetable bug (*Nezara viridula*) is green, shield-shaped, about ***15 mm*** long and may suck sap from ***growing tips*** causing wilting of terminal growth in spring. ***Monitor*** wilted tips up to flowering before applying an insecticide (Brough et al. 1994). See Vegetables M 12.

Rutherglen bug (*Nysius vinitor*) is a grey-brown bug about ***5 mm*** long. It often swarms on potato crops in spring feeding on ***shoots and foliage***; plants wilt and may die. Considerable damage may occur in a short time. See Vegetables M 12.

Others: ***Potato bug***, potato capsid (*Calocoris norvegicus*, Miridae). ***Trilaccus***, Miridae may feed on potato and Cape gooseberry

See Vegetables M 12.

Caterpillars (Lepidoptera)

Corn earworm (*Helicoverpa armigera*) caterpillars may cause minor damage to leaves. ***Monitor*** damage. See Sweetcorn M 89.

Cutworms (*Agrotis* spp.) may cut off growing stalks of potato ***seedlings*** at ground level at night. They may also chew holes in lower leaves. Injury may be important in the early stages of establishment. See Seedlings N 68.

Loopers (*Chrysodeixis* spp.) may attack potato crops in some seasons and may do extensive damage in a short time. They are most troublesome in spring-grown potatoes. Control is difficult. See Vegetables M 13.

Others: Overseas tomato and tobacco hornworms (*Protoparce* spp. Sphingidae).

See Annuals A 8, Vegetables M 13.

Crickets, grasshoppers, locusts
(Orthoptera): ***Black field cricket*** (*Teleogryllus commodus*) feed on exposed tubers in the field and ***mole crickets*** (Gryllotalpidae) may burrow in maturing tubers. Also ***spur-throated locust*** (*Nomadacris guttulosa*), ***wingless grasshopper*** (*Phaulacridium vittatum*). See Vegetables M 13.

Greenhouse whitefly
(*Trialeurodes vaporariorum*) and *Bemisia* sp. frequently infests potatoes, suck sap from ***leaves*** and produce honeydew. ***Monitor*** populations prior to spraying (Brough et al. 1994). See Greenhouses N 24.

Leaf beetles, flea beetles
(Chrysomelidae, Coleoptera)

Colorado potato beetle (*Leptinotarsa decemlineata*) and its larvae feed on the ***foliage*** of potato and other Solanaceae in Europe and North America causing severe crop losses. ***Quarantine risks:*** Beetles may be transported on vehicles, containers, ships, aircraft and more commonly associated with vegetables, seeds, grains and nursery stock (Com. of Aust. 1984).

Potato flea beetle (*Xenidea picticornis*) damage Solanaceae, eg potato, rhubarb, bean tomato, weeds. ***Adults*** are metallic-blue stout beetles about ***3 mm*** long with a smooth, finely pitted surface. They jump when disturbed and lay eggs on ***stems***. They chew small irregular holes in leaves (shot-holed). ***Larvae*** are cream, about ***12 mm*** long, bore in ***stems*** which may wilt. Yield is not usually reduced. ***Favoured*** by dry weather in spring. See Hibiscus K 82.

Others: ***Pumpkin beetle*** (*Aulacophora hilaris*), ***tobacco flea beetle*** (*Epitrix hirtipennis,* ***threelined potato beetle*** (*Lema trivittata*) larvae feed on Cape gooseberry, potato, other Solanaceae.

See Trees K 15.

Leafhoppers (Cicadellidae, Hemiptera)
Common brown leafhopper (*Orosius argentatus*) is about ***3-4 mm*** long and brownish and spreads purple top wilt (tomato big bud mycoplasma). ***Vegetable leafhopper*** (*Austroasca viridigrisea*) is yellow-green about ***4 mm*** long. Crops may be stunted. ***Both species*** are small, mobile insects which suck sap from ***stems*** and ***leaf undersurfaces*** causing greyish white stippling on ***leaves***. Large numbers may affect vigour. They feed on native species and invade crops when their usual hosts dry off in warm dry conditions. ***Monitor*** leafhoppers before applying insecticides (Brough et al. 1994). ***Potato leafhopper*** (*Empoasca fabae*) occurs overseas. See Vegetables M 15.

Mites (Acarina)
Broad mite (*Polyphagotarsonemus latus*) is an occasional ***major pest*** of potato. ***Leaf under surfaces*** become bronzed or russetted, followed by in-rolling of leaves, often resembling hormone herbicide injury. Growth is stunted. ***Monitor*** damage (Brough et al. 1994). See Greenhouses N 26.

Spider mites (*Tetranychus* spp.) including ***twospotted mite*** (*T. urticae*). ***Leaves*** may turn yellow and fall. Leaf undersurfaces are covered with fine grey webbing among which the tiny mites, and their round colourless eggs are visible. Control is rarely necessary. See Beans (French) M 29.

Others Blue oat mite (*Penthaleus major*), ***bryobia mite*** (*Bryobia rubrioculus*).

Onion thrips
(*Thrips tabaci*) may stunt plants by feeding on ***leaf undersurfaces*** which become dull silvery or bronzed. Injury is generally not important. Thrips are ***vectors*** of tomato spotted wilt virus which can infect potatoes and many other plants. See Onions M 68.

Potato ladybirds
Leafeating ladybirds
Scientific name/Host range: Coccinellidae, Coleoptera:
Twentyeight-spotted potato ladybird (*Epilachna vigintisexpunctata vigintisexpunctata*) is primarily a pest of potatoes and other Solanaceae. ***Twentysix-spotted potato ladybird*** (*Epilachna vigintioctopunctata pardalis*) commonly feeds on cucurbits. ***Both species*** feed on beans, weeds, eg nightshade, thornapple, paddymelon, false castor oil.

Description and damage: ***Beetles*** are oval, strongly convex, about ***6 mm*** long with chewing mouthparts. They are mainly yellow-orange with 26 or 28 black spots. Do not confuse with aphid-eating ladybirds which have only 18 spots or fewer on its wing covers. ***Larvae*** are yellow-green, about ***6 mm*** long and covered with long, black spines. ***Adults*** feed on ***leaf uppersurfaces,*** while the ***larvae*** generally feed on ***undersurfaces.*** Leaves are skeletonised, but adults may also chew holes. Leaves wither, plants look scorched. Young crops may be severely injured, reduced tuber yield. See Cucurbits M 54, M 57 (Fig. 330).

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with many overlapping generations during spring, summer/autumn. Female beetles lay eggs in spring on leaf undersurfaces. Larvae pupate on the food-plant, or nearby litter. All stages may be found on the plant at once.

Overwintering: As inactive adults.

Spread: Beetles do not fly readily but are assisted by wind. Infested seedlings.

Conditions favouring: High humidity as in coastal or irrigated areas. October to April.

Control:

Sanitation: ***Destruction*** of infested crops as soon as possible after harvest may assist control.

Biological control: Little information is available on their natural enemies, but the furry larvae may deter some known parasites and predators.

Pesticides: Apply foliage sprays or dusts at the first sign of infestation. ***Monitor*** damage at regular intervals before making a decision to apply an insecticide (Brough et al. 1994).

Potato moth
This is the ***most destructive pest*** of potatoes.

Scientific name: Gelechiidae, Lepidoptera:
Potato moth (*Phthorimaea operculella*)

Host range: Solanaceae, ***vegetables***, eg potato, tomato, ***field crops***, eg tobacco, ***weeds***, eg thornapple, nightshade.

Description and damage: ***Moths*** are brown-grey, with a wingspan of about 12 mm. They hide among the plants during the day. ***Caterpillars*** are up to ***12 mm*** long, with a dark head, grey-pink if it feeds in tubers or dark green if it feeds on foliage.

Caterpillars mine in ***leaves***, later they tunnel into ***stems***, terminal sections may die. Plants die prematurely. More seriously, caterpillars also tunnel in ***tubers*** in the ***field*** and in ***store***, 80% of tubers may be infested. Heavy infestations in bags may reduce contents to a decaying mass.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with several generations each year. Moths lay eggs on leaf undersurfaces and around eyes or surface scars on tubers. Caterpillars feed in leaves, stalks and tubers. When fully-fed they pupate in plant debris on the ground or between tubers in contact or in folds of bags.

Overwintering: In cooler areas as pupae.

Spread: By moths flying, assisted by wind. Introduction of infested tubers, bags, other containers.

Conditions favouring: Warm to hot, dry weather in cooler areas. Ground cracks which remain open due to lack of rain or irrigation allow moths and larvae from top growth to reach tubers. Unirrigated plants are attractive to moths for egg laying. Delay in bagging and removal from field.

Control:

Cultural methods: Practise ***crop rotation*** (3-5 years). Protect tubers from attack by providing adequate humus in soil and irrigation. ***Hill tubers*** with soil during formation to protect them from attack. After harvest, tubers should be bagged, sewn up and removed from the field as soon as possible, especially in warm sunny weather.

Sanitation: ***Destroy*** crop debris, volunteer potato plants, related plants and weeds promptly after harvest. ***Clean*** storage area of debris. ***Dust*** sound tubers and cool store to protect against the moth.

Biological control: Several ***wasp parasites*** (*Pantiles subacidness*, *Copidosoma koehleri, Orgilus lepidus*) have been introduced as possible biological control agents.

Resistant varieties: Egg laying is significantly less on leaves with pubescence (hairy leaves).

Disease-free planting material: Only plant ***certified caterpillar-free*** tubers/seed.

Physical and mechanical methods: Cold store prevents caterpillar development.

Pesticides: ***Monitor*** moths by pheromone traps and mines/leaf, and parasites at regular intervals before applying insecticides (Brough et al. 1994). Otherwise spray as soon as leaf damage appears when caterpillars are small. ***Protect*** stored tubers to prevent further infestation; insecticides do not kill caterpillars feeding in potatoes.

Potato wireworm (*Hapatesus hirtus*), other ***wireworms*** (Elateridae) and ***false wireworms*** (Tenebrionidae) may bore into ***tubers***, leaving narrow round holes. See Seedlings N 69.

Scarab beetles (Scarabaeidae)

African black beetle (*Heteronychus arator*) is shiny, black, about ***12 mm*** long and chews at ***stem bases*** which wilt and collapse, ***eyes of setts*** in the ground and may bore into ***new tubers*** that may lead to rotting. See Turfgrasses L 7, Vegetables M 16.

Large pasture scarab (*Rhopaea magnicornis*) larvae that have been feeding on grass roots turn to potatoes planted in newly cultivated pasture. Potato ***stems*** may be severed below ground or round deep holes gouged in ***tubers***. No control measures can be recommended once attack has appeared. A long fallow is required between ploughing and planting a potato crop. See Turfgrasses L 11, Vegetables M 16..

Weevils (Curculionidae, Coleoptera):

Vegetable weevil (*Listroderes difficilis*) is grey-brown, about ***9 mm*** long and can quickly strip potato plants. During winter, light green, legless ***larvae*** up to ***12 mm*** long may feed on ***lower leaves*** and ***stems***, but damage is not serious, plants grow away from it. See Vegetables M 17.

Whitefringed weevil (*Graphognathus leucoloma*) is greyish with a short broad snout, ***10-13 mm*** long, and in late summer may migrate to potato crops from nearby weeds to strip leaves. ***Larvae*** are legless, white-grey with brown heads and may damage ***young plants*** and gnaw furrows and pits in maturing ***tubers***. In Tasmania prescribed procedures limit its spread. See Vegetables M 17.

Others: ***Potato stalkborer*** (*Trichobaris trinotata*). Overseas ***Andre potato weevil*** (*Premnotrypotes* sp.).

Others: ***Termites*** (Isoptera) may tunnel inside ***stems*** and ***tubers*** of potatoes planted in freshly-cleared land near bushland. Infestations start from a dead tree stump or log in the crop or on adjoining land. Potatoes are reached through underground galleries. Outside rows are more likely to be attacked than others. Also ***lucerne flea*** (*Sminthurus viridis*).

Non-parasitic

Environment: ***Black heart*** (oxygen deficiency of internal tuber tissue) occurs in storage and transit due to suffocation of tissue (high temperatures and poor ventilation). Dark brown to black areas in the centre of the tuber (Fig. 351). All cultivars seem to be susceptible. ***Brown fleck*** (tubers with irregular brown spots through the flesh, usually towards the centre, especially in large tubers) (Fig. 352). Favoured by light, acid, dry soils. Do not plant badly flecked tubers. ***Hollow heart*** (cavities in the tuber centre) is caused by excessively rapid tuber enlargement due to rapid flushes of growth following uneven growing conditions, eg watering or fertilising (Fig. 353). Avoid wide hill spacing, irrigate to ensure even growth, mix fertiliser evenly into soil. Kill vines if necessary to prevent oversized tubers. Sequoia is susceptible. ***Lenticels*** enlarge to form corky areas during excessive soil moisture before harvest. These dry out to form evenly distributed common scab-like lesions over the tuber surface. ***Severe frost*** will kill potatoes.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for potato (Weir and Cresswell 1993).

Poisonous properties: All parts of the potato plant contain toxic alkaloids, eg ***solanines***. They are also present in the tuber but normally in negligible amounts. Under certain conditions, eg after incorrect (excessive action of daylight) or overlong storage, the ***alkaloid content*** can reach concentrations which are critical for humans. When potatoes sprout and become green, intensive production of alkaloids is initiated especially in the skin and eyes. The biosynthesis of the alkaloids is not necessarily connected with an increase in chlorophyll, so that potatoes which have ***not changed colour*** may already be toxic. It is important not to develop varieties which contain higher levels in the tubers. The way in which potatoes are ***prepared*** greatly affects their palatability. Well peeled and boiled potatoes are very much less dangerous (removal of the solanines with the peelings and in the water used for boiling) than unpeeled, baked ones as the alkaloids are largely heat stable (Frohne and Pfander 1983).

Seedpiece breakdown is rotting of the ***seed piece*** and ***lower stem*** and ***roots***. Plants may fail to emerge, or produce weak shoots. It is a physiological disorder caused by the growing conditions of the seed crop, storage conditions, length of storage and handling. ***Susceptible consignments*** cannot withstand cutting injury and are then easily rotted by soft rot bacteria and fungal tuber rots, eg *Fusarium*, *Rhizoctonia*.

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Potatoes : Root-knot Nematodes
Potatoes : Weed Control
Rhizoctonia or Black Scurf Disease of Potatoes
Seed Potato Certification Scheme
Target Spot (Early Blight) of Potatoes (Vic Agnote, SA Fact Sheet)
The Potato Moth
Potato Varieties
Potato Variety : Tarago
The Victorian Seed Potato Certification Scheme Based on Pathogen-tested Stock
Weed Control Programs for Potatoes
Wireworms in Potatoes

WA Farmnotes
Bacterial Soft Rot or Brown Rot of Potato
Fungal Diseases of Potatoes
Fungal Diseases of Potatoes
Potato Cyst Nematode
Powdery Scab of Potatoes (NSW Agfact, Vic Agnote)

Associations, Journals etc.
Atherton Potato Growers Association
Australian Potato Industry Council (APIC)
Australian Vegetable & Potato Growers Federation (AUSVEG)
NSW (Crookwell) Potato Growers Association
Potato Australia
Queensland Fruit & Vegetables Growers Association (formerly COD)
Seed Potato Certification Scheme (DARA)

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Different varieties are grown for boiling, canning and chips. An overview of the industry is presented by Coombs (1995). Where possible plant varieties with some ***resistance*** to local problems. Plant ***certified pathogen-tested*** ***(PT)*** seed potatoes from Seed Potato Certification Schemes which have a nil or prescribed tolerances for the many diseases which are tuberborne. In some areas certified seed potatoes should be planted every year or every 2nd year. Miniature potato seed tubers can now be grown in a factory environment so that new seed potatoes can be produced in 2 years rather than at the present 8-10 years (Stackhouse 1995). Tubers may be ***green-sprouted*** before planting so that any tubers with weak spindly sprouts caused by virus or other diseases can be destroyed. ***Disinfect*** all tubers used for seed to ensure against losses from seedborne rhizoctonia and scab diseases. Tubers can be treated at any time before the beginning of sprouting, but seed treated before storing is less subject to decay than untreated stock. Also ***propagated*** by tissue culture. ***Cultural methods:*** Temperatures must be suitable for growing potatoes. Practise ***crop rotations*** of 4-5 years to reduce diseases which survive for several years in soil in crop refuse and decaying soil organic matter in the absence of hosts. Lime is needed for a crop used in rotation with potatoes. ***Lime*** should be applied early, leaving as much time as possible between liming and planting the next potato crop. This discourages the common scab organisms. Do not plant in infested land. Plant in well drained soil, dug deeply, in an open sunny site; fertilise and irrigate appropriately. ***Sanitation:*** Do not plant crops near diseased potato refuse. ***Crops for seed tubers*** are ***regulated***, eg seed plants need to be planted in tuber-units to allow more accurate roguing and fewer sources of infection to establish throughout the plot. ***Control weeds*** between rows and on headlands to discourage build up of virus-carrying insects. ***Plant quarantine:*** The introduction of potatoes ***into Australia*** is strictly controlled as is the movement between some states/regions ***within Australia***. ***Pesticides:*** Fungicides, insecticides and herbicides are registered for use on potatoes. ***Harvest*** when tubers are mature and an acceptable size. In the absence of vine-killing frosts ***defoliants*** may be used. Do not dig tubers in wet soil or leave tubers lying on the ground longer than necessary. Discard tubers obviously damaged or diseased. ***Avoid injuring tubers*** during grading, bagging, transport and storage to reduce losses from ***postharvest*** bacterial and fungal diseases, eg soft rot (*Erwinia* spp.), alternaria rot (*Alternaria alternata*), rhizopus soft rot (*Rhizopus stolonifer*). ***Store*** in a cool, dark, place with good ventilation; prevent sprouting. Make sure tubers are free from soil. Tubers may be cured to promote ***rapid healing*** of cut or injured tissue. Do not allow tubers to dry out as they will shrivel and the protective corky covering formed will crack. Tubers for fresh market or seed can be ***stored*** under recommended conditions, eg 3-4^{o}C and 90-95% relative humidity. Between each growing season clean out and destroy all refuse in storage rooms, shelves and racks.

Fig. 348. Late blight, Irish blight (*Phytophthora infestans*). ***Left :*** Tuber cut across.
Right : Watersoaked areas with mouldy margins on leaves. NSW Dept. of Agric.

Fig. 349. Cysts on potato roots caused by potato cyst nematode(*Globodera rostochiensis*).

Fig. 350. Rounded lumps on tubers caused by root knot nematodes (*Meloidogyne* spp.).

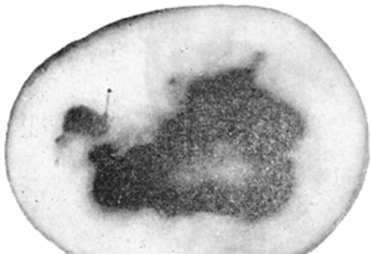

Fig. 351. Black heart (oxygen deficiency). NSW Dept. of Agric.

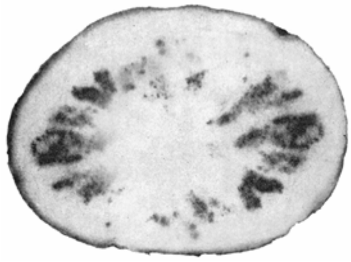

Fig. 352. Brown fleck (light, acid, dry soil). NSW Dept. of Agric.

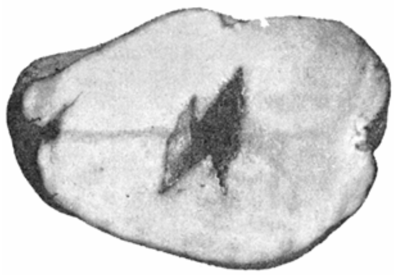

Fig. 353. Hollow heart. (rapid growth flushes). NSW Dept. of Agric.

Rhubarb

Rheum rhabarbarum
Family Polygonaceae

PESTS AND DISEASES
Parasitic

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*). See Vegetables M 5.
Crown gall (*Agrobacterium tumefaciens*) may form ***galls*** up to 300 mm across on rhubarb. See Stone fruits F 125.

FUNGAL DISEASES

Downy mildew (*Peronospora jaapiana*) is the ***most important disease*** of rhubarb. Light brown areas develop on ***leaves***. Initially the discolouration is more conspicuous on leaf uppersurfaces and spots are limited by the larger veins but eventually large sections of the leaf become brown. Under moist conditions a ***downy fungal growth*** is seen on the undersurface of the spots. As disease advances, dead areas become torn giving leaves a ragged appearance. Severe defoliation can occur under wet conditions. See Annuals A 5.

Fungal leaf spots, eg ***black spot*** (*Ascochyta rhei*). Small, circular, brown spots develop on ***leaves*** initially and enlarge, still maintaining their circular shape and develop reddish brown borders. Numerous tiny ***pycnidia*** (black spore-producing bodies) develop in the spots. Eventually parts of the dead tissue drop out and if conditions favour disease development, plants may lose most of their leaves. Small, oval to oblong reddish-brown spots that lengthen with age and extend 10 mm or more along ***leaf stalks***. Pycnidia also develop in these spots. See Annuals A 5, Vegetables M 1 (Fig. 294).

Root, stem and crown rots

Phytophthora root and crown rot (*Phytophthora nicotianae* pv. *parasiticae*) causes a firm brown to black rot of the ***root and stem tissue***. Sunken, watery, greenish-brown lesions rapidly form at the base of leaf stalks and the rot can progress rapidly causing the whole leaf to collapse suddenly. ***Secondary bacterial infections*** usually occur causing affected stalks to decay rapidly. See Trees K 6, Vegetables M 7.
Others: Grey mould, stem rot (*Botrytis cinerea*), ***rhizoctonia root rot*** (*Rhizoctonia solani*), ***sclerotinia rot*** (*Sclerotinia minor*, *S. sclerotiorum*), ***sclerotium crown rot*** (*Sclerotium rolfsii*).

Plant ***disease-free crowns*** in well drained ***disease-free soil***, remove and burn any diseased plants. Crowns being grown from seed should be raised in pasteurised soil to ensure freedom from *Phytophthora* and other diseases. See Vegetables M 7.

Rust *(Puccinia rhei-undulati,* Uredinales, Basidiomycete) may attack rhubarb during warm humid weather. Raised orange-red pustules containing orange-red spores develop on ***leaf undersurfaces*** and ***leaf stalks***, sometimes in a circular pattern. Severe infection can kill leaves. Brownish spots develop on the uppersurface. See Annuals A 7.

NEMATODE DISEASES

Beet nematode (*Heterodera schachtii*), ***root knot nematodes*** (*Meloidogyne* spp.), ***root lesion nematode*** (*Pratylenchus penetrans*), ***spiral nematode*** (*Helicotylenchus, Rotylenchus*), also *Coslenchus, Criconemoides, Hemicycliophora, Paratrichodorus, Paratylenchus, Nanidorus min*or, *Scutellonema brachyurus*, *Tylenchus* (McLeod et al. 1994). See Vegetables M 10.

INSECTS AND ALLIED PESTS

There are no really serious insect pests of rhubarb.

Aphids (Aphididae, Hemiptera)
Green peach aphid (*Myzus persicae*)
Potato aphid (*Macrosiphum euphorbiae*)
Aphids may swarm on rhubarb causing wilting and producing unsightly ***honeydew*** during spring and late autumn. See Roses J 4, Vegetables M 11.

Bugs (Hemiptera)

A mirid bug (*Creontiades* sp.) may ***severely damage*** rhubarb plants around Sydney. It is active, slender, rectangular, pale green with long legs and antennae. It sucks sap from ***growing points*** causing serious distortion or stunting of growth. This bug may be the green mirid *C. dilutus* but this is unconfirmed. See Vegetables M 12.
Others: Green stink bug (*Plautia affinis*), ***green vegetable bug*** (*Nezara viridula*), ***harlequin bug*** (*Dindymus versicolor*), ***Rutherglen bug*** (*Nysius vinitor*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Cluster caterpillar (*Spodoptera litura*): Young caterpillars feed in clusters and graze patches of surface tissue, usually on ***leaf undersurfaces***. When large, they chew big holes in the leaves. Late summer and autumn. See Brassicas M 40.
Oriental cornborer (*Ostrinia furnacalis*, Pyralidae) caterpillars tunnel in the ***leaf petioles*** and burrow in the ***stems*** of rhubarb, pale knotweed, spiny emex, inkweed, and on one occasion, in north NSW, commercially grown *Populus deltoides*. A minor pest of rhubarb.
Others: Cutworms (*Agrotis* spp.), ***grapevine hawk moth*** (*Hippotion celerio*).

See Annuals A 8, Vegetables M 13.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) causes ***leaves and stalks*** to become rusty or silvery, distorted, the injury is sometimes similar to that of 2,4-D herbicide. Younger inner leaves are most affected. There may be a considerable reduction in vigour. See Greenhouses N 26.
Rust mite (Eriophyidae) infests leaf undersurfaces of rhubarb during summer and autumn. ***Leaves*** develop a brown or bronze colouration and slightly shiny look and may curl downwards at the edges, later withering and drying out.
Twospotted mite (*Tetranychus* urticae) during hot dry weather, may attack rhubarb, especially if it is planted near old beds of beans or cucumbers infested previously. ***Foliage*** is speckled and grey, with grey webbing on leaf undersurfaces. Plants lose vigour. See Beans (French) M 29.

Weevils (Curculionidae)

Fuller's rose weevil (*Asynonychus cervinus*) nibble pieces out from ***leaf edges***, producing a saw-tooth appearance in late summer and autumn. See Roses J 6, Vegetables M 17.
Vegetable weevil (*Listroderes difficilis*) larvae may feed on rhubarb. See Vegetables M 17.

See Vegetables M 17.

Others: ***African black beetle*** (*Heteronychus arator*) chews the fleshy bases of rhubarb crowns at ground level, if planted in old pasture, or when beetles move in from adjoining breeding areas. ***Crickets, grasshoppers, locusts*** (Orthoptera), eg ***black field cricket*** (*Teleogryllus commodus*), ***mole crickets*** (Gryllotalpidae), ***wingless grasshopper*** (*Phaulacridium vittatum*). ***Flea beetles*** (Galerucinae) jump readily, they make small holes in the foliage. ***Passionvine hopper*** (*Scolypopa australis*) may suck sap from stems and leaves.

SNAILS AND SLUGS

Snails and slugs are likely to be a considerable nuisance, especially after prolonged wet weather. See Seedlings N 70.

Non-parasitic

Bolting: Pinch out any ***flower heads*** that appear. See Vegetables M 18.

Environmental: ***Hail*** can rip the large leaves. Leaves may wilt in ***hot weather*** but recover;water well in hot weather, soil must be well drained. Leaves may be ***sunscorched***, but do not confuse this damage with that caused by downy mildew.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for rhubarb (Weir and Cresswell 1993). Soil must be acidic and large quantities of organic m atter are necessary for optimum growth. ***Excessive nitrogen*** fertiliser results in very leafy plants.

Poisonous leaves: Leaves contain ***oxalic acid*** but poisoning is considered to be due to the presence of reduced anthracene glucosides rather than oxalic acid poisoning (Frohne and Pfander 1983). Do not eat leaves or feed to poultry or other stock.

SELECTED REFERENCES

Coombs, B. (ed.). 1995. *Horticulture Australia.* Morescope Pub., Hawthorn East, Vic.
Frohne, D. and Pfander, H. J. 1983. *A Colour Atlas of Poisonous Plants*. A Wolfe Science Book, London.
McLeod, R., Reay, F. and Smyth, J. 1994. *Plant Nematodes of Australia : Listed by Plant and Genus.* NSW Agric./Rural Industries Research and Development Corporation, Sydney.
Persley, D. (ed.). 1993. *Diseases of Fruit Crops*. Qld Dept. of Primary Industries, Brisbane.
Salvestrin, J (ed.) 1991. *Australian Vegetable Growing Handbook*. 4th edn. CSIRO/NSW Agric., Melbourne.
Weir, R. G. and Cresswell, G. C. 1993. *Plant Nutrient Disorders 3 : Vegetable Crops.* Inkata Press, Melbourne.
State/Territory Departments of Agriculture/Primary Industry eg
Diseases of Rhubarb (NSW Agfact)
Growing Rhubarb (Vic Agnote)
Home Vegetable Garden Books (Most States/Territories)
See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Rhubarb is one of the few perennial vegetables and is grown for the fresh market, canning and freezing. An overview of the industry is presented by Coombs (1995). Choose varieties with some ***resistance*** to disease, eg downy mildew. Transplant only ***disease and pest-free crowns*** and plant in disease-free soil. Dip seed and crowns in fungicide before planting. ***Propagated*** by seed or preferably by division or setts taken from established plants. ***Replant crowns*** every 3-4 years. Extensive bed preparation is necessary for successful growth, plant crowns in well drained friable soil, and keep ***weed-free***. On rhubarb, no herbicides are listed for use and many pesticides have to be 'approved'. ***Harvest*** stalks with a downwards and sideways action, remove all leaves from the cut stalks. Rhubarb is ethylene sensitive. Cool quickly. ***Store and transport*** at $0^{o}C$ at very high relative humidity (> 95%) for 2-3 weeks (Salvestrin 1991).

Sweetcorn

Zea mays var. *saccharata*
Family Poaceae (grass family)

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Sugarcane mosaic virus (Johnson grass strain) may damage sweetcorn, maize, sorghum, Johnson grass (*Sorghum halepense*), various grasses. Mosaic or ringspot patterns of light and dark green in ***leaves***. Leaves yellow in very susceptible cultivars. Plants infected early in the season may be stunted. On some hybrids, husks gape, increasing grain rot. Early infection reduces grain yields. ***Overwinters*** in host plants. ***Spread*** by aphids, eg corn aphid (*Rhopalosiphum maidis*), which is the main vector. ***Favoured*** by Johnson grass and other hosts near sweetcorn crops, seasons favourable for aphid vectors during summer (spring plantings may avoid high disease levels). Control host grasses close to crops. Grow ***resistant*** cultivars.

Others: Barley yellow dwarf virus, cereal chlorotic mottle virus, chloris striate mosaic virus, maize mosaic virus, maize sterile stunt virus, maize stripe virus.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial soft rot, top rot (*Erwinia carotovora* subsp. *carotovora*). Overseas ***Stewart's wilt*** (*E. stewartii*) is a ***major disease*** in parts of the USA. In Australia, also ***bacterial streak*** (*Xanthomonas campestris* pv. *holcicola*).

FUNGAL DISEASES

Damping off (*Fusarium* spp., *Pythium* spp., other species) can cause seed or seedling rots before or after emergence, especially in early plantings when conditions are cold and wet, and germination and growth slow. ***Resowing*** may be necessary. Plant good quality undamaged treated seed when soil is reasonably warm. Use in well drained soil, do not overwater. See Seedlings N 66.

Downy mildews (Eumycetes)

Crazy top downy mildew (*Sclerophthora macrospora*) is a minor disease of grasses and cereals but may cause significant losses in some sweetcorn crops. Plants are stunted, yellowed with thickened leathery leaves and may not tassel. If tassels develop they resemble a mass of leafy structures ***(crazy top)***. ***Overwinters*** in soil for many years. Seedborne transmission can occur but may not be important. ***Favoured*** by saturated soil, low lying areas, cool temperatures, crops watered or subject to heavy rain after sowing. Sow into prepared moist seedbeds.

Downy mildew, Java downy mildew (*Peronosclerospora maydis*) is probably endemic in northern Australia on plume sorghum (*S. plumosum*) and may cause ***severe losses*** in sweetcorn and maize. Plants are systemically infected soon after emergence and become resistant with age. Leaves develop pale yellow stripes (resembling virus infection). Spores are produced on yellow areas of younger plants but not on older plants which become severely distorted. Multiple cobbing, deformed or leaf-like tassels and cobs, elongated or shortened stems. Ensure that seed is treated before planting. (Persley 1994). ***Sorghum down mildew*** (*P. sorghi*) is a serious disease of maize and sorghum overseas (Com. of Aust. 1990).

See Annuals A 5.

Ear rots (*Diplodia* sp., *Fusarium spp., Khuskia oryzae, Nigrospora sphaerica, Phaeotrichoconis crotalariae, Trichoderma viride*) may cause severe losses on sweetcorn and maize ***grown for seed*** especially if harvesting is delayed by wet weather. Except for *Diplodia,* most can infect other cereals and grasses. They may reduce ***yield, quality, seed vigour*** and ***establishment of seed*** from diseased ears if sown for subsequent crops. Damage may be restricted to scattered individual kernels on the cob or the whole ear may progressively rot. Kernels are usually discoloured and shrivelled. Fungal growth is formed by *F. moniliforme*, and if extensive, husk tissues are bound together and may shred from the tip. ***Overwinters*** on diseased crop debris. Most fungi causing ear rots are also associated with stalk rots. ***Spread*** from diseased crop debris by spores during wet, windy weather. Secondary spread from spores released from newly infected ears also occurs. Seedborne. ***Favoured*** by above average rainfall during cob filling, insect and bird damage. ***Practise crop rotation*** to reduce the carry-over of fungi on diseased debris. Harvest crops as soon as possible and destroy crop debris immediately after harvest. Hybrids with poor husk cover or thin seedcoats are often very ***susceptible***. Sow only ***disease-free seed*** of high vigour for new sowings. Ear-damaging insects should be controlled. ***Penicillium moulds*** (*Penicillium* spp.) and ***grey mould*** (*Botrytis cinerea*) may be ***postharvest diseases***.

Fungal leaf spots

Turcicum leaf blight, northern blight (*Exserohilum turcicum,* Ascomycetes) affects sweetcorn, maize and probably grasses. Strains are probably host specific. Elongated greenish-grey spots restricted by the larger leaf veins develop initially on the ***lower leaves***. Spots may join together, leaves wither and ***die***. As spots dry out they become black (fungal spores) in the centre. Cobs may be small. Disease is common on sweetcorn in Qld. ***Severe blight*** may occur before or during tasselling reducing cob fill and yield. ***Favoured*** by warm, wet weather, humid coastal regions, late sown crops. Avoid late sowings of ***susceptible hybrids*** and ***rotate crops***. Destroy volunteers before sowing. Grow recommended ***resistant or tolerant*** hybrids.

Others eg *Cochliobolus* spp., *Colletotrichum graminicola, Curvularia brachyspora.*

See Annuals A 5.

Root and stalk rots include ***fusarium rots*** (*Fusarium* spp.) which are the most common, also ***ashy stem blight***, charcoal rot (*Macrophomina phaseolina*), ***diplodia stalks rot*** (*Diplodia* sp.) and ***sclerotium stem rot*** (*Sclerotium rolfsii*). Stalk rots are ***probably responsible for more damage than any other diseases***. Plants are infected early in their growth, but symptoms do not usually appear until after flowering. As plants mature, they senesce early and many may be blown over. Affected tissues are discoloured, usually ***red*** with *Fusarium* infections and ***grey-black*** with *Diplodia* and *Macrophomina*. Minute fruiting bodies of the fungi may be present, especially on the nodes. ***Stalk rot*** can extend for some distance above ground and into roots. Seed and grain from affected plants may be small and of poor quality. ***Favoured*** by prolonged wet, warm weather. Moisture stress post-flowering can accentuate losses from stalk rots. ***Control:*** Sow at correct times to avoid extreme hot weather during and after flowering. Avoid ***moisture stress*** from overcrowding and post-flowering. Apply a balanced fertiliser. Grow hybrids ***tolerant*** to stalk rots. See Vegetables M 7.

Rusts (Uredinales, Basidiomycetes)

Rust (*Puccinia sorghi*) is a ***common*** but minor disease. Reddish-brown pustules up to 2 mm long develop on ***leaf upper and undersurfaces***, leaves wither and die. Build-up of rust in new sowings can be rapid. and often appears just after tasselling. Yield may be reduced. ***Favoured*** by warm wet weather, in higher rainfall coastal districts in late plantings. Early plantings avoid high disease levels. Destroy ***volunteer*** maize and sweetcorn plants before sowing. Currently recommended hybrids usually do not become severely affected provided they are sown early in the season. Some super-sweet hybrids are highly ***susceptible***. If disease is likely to be serious and planting is to be late in the season, use ***resistant cultivars.*** Sow at correct density and fertilise to maintain vigorous growth.

Tropical (polysora) rust (*Puccinia polysora*) may attack sweetcorn and maize in North Qld during warm wet weather. Small round reddish brown pustules develop on ***leaf uppersurfaces***, severely affected leaves die early. Pustules produced on midveins and leaf sheaths are larger than those on the leaf and irregular in shape. Plant ***resistant cultivars*** where the disease occurs (Persley 1994).

See Annuals A 7.

Smuts (Ustilaginales, Basidiomycetes)

Common smut, boil smut (*Ustilago zeae*) is a ***serious, world-wide disease*** of maize, sweetcorn and the related grass *Euchlaena mexicana,* causing significant yield losses. It is a minor, sporadic disease occurring on the north coast of NSW and in neighbouring areas of southern Qld. Swellings ***(boils, blisters, galls)*** up to 200 mm across form on ***cobs, stems, tassels*** and ***leaves***. Young galls are pale green, later brown-black masses of spores are released and are ***spread*** by wind, with seed or stock food and in soil adhering to vehicles, clothes, machinery and animals. Spores may ***overwinter*** in soil for years and under favourable conditions germinate to produce aerial spores (sporidia) which are spread by air currents and rain splash to infect young host tissues and stimulate them to form galls. Specific control measures are not warranted, most hybrids have at least a reasonable level of ***resistance*** to boil smut. Departments of Agriculture should be advised of suspected outbreaks.

Head smut (*Sphacelotheca reiliana*) is a minor disease of maize and sorghum. Specific strains occur on each host. Although plants are infected as seedlings, symptoms are not seen until ***tasselling***. Flowering parts are replaced by a mass of black smut spores. Entire tassels may be affected or, more commonly, only individual spikelets. Ears may abort or be replaced entirely by black smut spores. Affected tassels and ears are distorted and leafy structures may replace some of the normal floral structures. ***Overwinters*** in seed, and may survive in soil for many years. The most important source of infection is from the soil. ***Fungicide seed treatment*** will not prevent infection from soilborne spores. Spores germinate with the maize seed and infect the young seedlings. The fungus grows within the plants and produces smut symptoms at flowering. During harvest, spores in smutted heads are ***spread*** on to healthy seed or fall into the soil to become sources of infection for later crops. Infected seed. Seedling infection is ***favoured*** by soil temperatures of 18-20^{o}C and moderate to low soil moisture. ***Rotate crops*** to avoid buildup of soil-borne inoculum. Grow ***resistant*** hybrids. Sow only treated seed.

Others: ***Brown spot*** (*Physoderma maydis*), ***cob, ear, leaf and stalk rots*** (*Gibberella* spp.), ***ear rot, leaf spot*** (*Setosphaeria* sp.), ***rhizopus grain rot*** (*Rhizopus stolonifer,* ***root and stalk rots*** (various species).

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.), ***root lesion nematodes*** (*Pratylenchus* spp.), ***burrowing nematode*** (*Radopholus similis*), ***citrus nematode*** (*Tylenchus exiguus*), ***spiral nematodes*** (*Helicotylenchus dihystera, Rotylenchus parvus*), *Criconema mutabile, Ditylenchus* sp., *Filenchus* spp., *Gracilacus mutabilis, Hemicycliophora* sp., *Hexatylus* sp., *Neopsilenchus magnidens, Paratrichodorus* spp. See Vegetables M 10.

INSECTS AND ALLIED PESTS

African black beetle (*Heteronychus arator*) is about ***12 mm*** long and shiny black. It may attack establishing sweetcorn and maize crops, resowing may be necessary. ***Beetles*** chew large, ragged holes in the ***stems*** of ***young plants***, just below the soil surface, killing the growing point so that the central roll of leaves withers and plants become ***'dead-hearted'*** (Fig. 354). Damaged young plants usually produce suckers. Older, established plants may survive attack but remain weakened and prone to falling over. ***Maturing plants*** may be attacked by large numbers of beetles feeding at their bases. Beetles may then attack ***ripening cobs***. See Turfgrasses L 7, Vegetables M 16.

Black field earwig (*Nala lividipes*) is about ***10 mm*** long, narrow bodied and shiny black with prominent curved 'forceps' at the rear of the body. They feed on decaying stubble, ***germinating seeds*** and ***roots of young plants***, killing or weakening them. Feeding on the prop roots may cause ***plants to fall over*** as they get larger. ***Favoured*** by heavy soils with high organic matter content and are usually most numerous in stubble mulched paddocks. Losses can be reduced by using a press-wheel at planting. ***Monitor*** earwigs by baiting or shaking out soil samples onto white sheets before applying an insecticide (Brough et al. 1994). See Vegetables M 14.

Bugs (Hemiptera):

Green vegetable bug (*Nezera viridula*) may suck sap from the base of ***young cobs*** stunting or deforming them. They may also pierce husks and puncture ***grains***. Damaged grains do not develop or may become dry and shrivelled. See Vegetables M 12.

Rutherglen bug (*Nysius vinitor*) may cause ***serious damage*** under hot dry conditions by sucking sap from the ***foliage***. Adults are ***5 mm*** long, brown and have silvery wings folded over the body. ***Insecticides*** may be applied when observed. See Vegetables M 12.

Caterpillars (Lepidoptera):

Armyworms and cutworms (many species) chew through stems of ***seedlings*** at or below ground level and may eat top growth. They may climb older plants, chew leaves and feed like corn earworm (*Helicoverpa armigera*) on ***tassels, silks*** and ***tops of cobs***. Defoliation at silking reduces seed yield. ***Monitor*** caterpillars and damage at regular intervals before spot spraying infested areas (Brough et al. 1994). See Seedlings N 68.

Corn earworm (*Helicoverpa armigera*) is the ***most serious pest*** of sweetcorn. See below.

European corn borer (*Ostrinia nubilalis*, Pyralidae) is considered to be one of the ***most serious insect pests*** affecting maize overseas. If introduced to Australia it could cause serious damage to maize and other crops. Caterpillars feed in spaces between husks, between the ears and the stalk and when larger they tunnel in tassel stems causing them to break. ***Genetically engineered maize*** is being developed which contains a gene from *Bacillus thuringiensis* which makes a toxin lethal to the corn borer and other agricultural pests. Insects feeding on such plants ***die***. It is not known whether insects will develop resistance. ***Quarantine risks:*** The most likely means of entry would be as larvae or pupae infesting plants or plant parts, eg as dried floral arrangements, straw of plant debris, eg maize. ***Quarantine prohibits*** the entry of maize and sorghum stalks. Any straw articles allowed entry are treated with heat. Imported farm machinery which could be contaminated with infested crop debris is treated as required. Imported broom millet also requires special attention (Com. of Aust. 1990).

Sugarcane and maize stemborer, large cane moth borer (*Bathytricha truncata,* Noctuidae). ***Caterpillars*** are up to ***40 mm*** long and pink on their upper surfaces. They damage ***stems*** of young plants and leave stems through holes bored near ground level. ***Central leaves*** of damaged plants wither, turn brown and the plants may sucker. Usually only scattered plants around the perimeter of crops are affected. Control measures are seldom warranted.

Yellow peach moth (*Conogethes punctiferalis*) caterpillars tunnel in ***stem nodes*** weakening plants, which may fall over later when cobs are heavy. Holes where caterpillars have entered stalks are usually covered with frass. Caterpillars may also feed in ***kernels*** especially at the distal end. Control is not usually required. Plough in infested crops as soon as possible after harvest. See Stone fruits F 133.

Others: ***Grass caterpillar*** (*Herpetogramma licarsisalis*).

See Annuals A 8, Vegetables M 13.

Corn aphid (*Rhopalosiphum maidis,* Aphididae) about ***1.5-3 mm*** long, winged or wingless, green and black. ***Nymphs*** resemble adults but are wingless. Large colonies may form on ***leaf undersurfaces***, in funnels or throats of plants, on tassels, silks or ears of sweetcorn (Fig. 355). During dry weather heavily infested leaves may bleach, redden and shrivel. Aphids also cause ***poor kernel set*** and ***unattractive cobs***. Corn aphid is a minor pest, but can transmit virus diseases and there is nil tolerance for some markets, eg Japan. ***Natural controls***, eg weather, ladybird beetles, parasitic wasps and larvae of hover flies, normally control infestations. Aphids are difficult to control chemically in ears. See Roses J 4, Vegetables M 11.

Corn earworm

Scientific name: Noctuidae, Lepidoptera:
Corn earworm, cotton bollworm, tomato grub, tobacco budworm (*Helicoverpa armigera*) is a ***major and frequent pest***. ***Native budworm*** (*H. punctigera*) also atttacks sweetcorn.
Other earworms attack other plants, eg
Cape gooseberry budworm (*H. assulta)*
Indian weed caterpillar (*Heliothis rubrescens*)

Host range: ***Ornamentals***, eg calendula, carnation, everlasting, hollyhock, snapdragon, ***fruit***, eg young apple, peach, strawberries, ***vegetables***, eg tomato, bean, maize, sweetcorn, ***field crops***, eg cotton, corn, clover, medic, ***weeds***.

Description and damage: ***Moths*** are stout with a wingspan of about ***40 mm***. They are generally buff to reddish-brown with darker markings on the forewings and a black area at the outer margin of pale hindwings. The darker markings on the forewings are more distinct in *H. armigera* than in *H. punctigera*. There is a distinct light patch in the dark area of the outer margin of the hindwings of *H. armigera* which is rarely present in *H. punctigera*. Moths hide among foliage during the day and fly at dusk feeding on nectar and laying eggs on young growth. ***Caterpillars, budworms or earworms*** grow to about ***40 mm.*** Initially pale green or cream they change to shades of green, fawn, yellow, buff or red-brown depending on the host. Brown or black stripes run along the body (Fig. 356). Younger stages have conspicuous bristle-like hairs, but fully-fed caterpillars appear smooth. They have a coarse appearance, fairly long prolegs. Caterpillars feed on ***unfolding leaves*** in throats of young plants, plants look ragged. If early infestation is mild, plant growth is unaffected. Caterpillars feed on ***tassels, silks*** and ***developing seeds on tops of cobs.*** Damage to tassels is not important but feeding on silks and tops of cobs produces cobs with poorly filled-out tops and encourages moulds. Caterpillars bore through husks and enter middle or lower parts of developing cobs.

Pest cycle: Complete metamorphosis (egg, caterpillar, pupa, adult) with several generations each year. ***Moths*** live for about 2 weeks and each female lays about 1,000 white dome-shaped eggs singly on tips of young growth, sepals, petals and young fruits and flower buds. ***Caterpillars*** may feed on young foliage or flowers but soon move to buds, flowers or young fruit and eat their way in. Small caterpillars make a small, entry hole but larger caterpillars may move from one pod or fruit to another making obvious entry holes. They pupate in soil.

Overwintering: As pupa in soil.

Spread: Moths can only fly for short distances up to 50 m but can still cover very long distances from where they emerged to new hosts in bloom. They are attracted to lights. Moths of the ***native budworm*** (*H. punctigera*) seem to be migratory and may move long distances from areas where caterpillars developed.

Conditions favouring: Warm, moist weather. Emergence of moths from pupae is stimulated by rainfall or irrigation and delayed by long dry spells. *H. armigera* is more common in coastal and subtropical areas and northern areas. *H. puntigera* is widely distributed throughout the inland and southern states. Usually there are 2 main periods of infestation, spring-early summer and autumn.

Control:

Cultural methods: Plough to destroy pupae in soil.

Biological control/Resistant varieties: ***Natural enemies***, eg parasitic wasps (*Trichogramma*) which may be purchased, predacious insects, diseases and birds. Hot wet conditions favour ***disease development*** in caterpillars and may reduce numbers. Natural controls are of limited effectiveness in vegetable crops. ***Virus diseases*** occur during humid weather and affected caterpillars hang in an inverted position from the plant, skin is fragile and ruptures readily releasing liquefied body contents. ***Genetically engineered plants*** are being researched so that virus particles can be synthesised in the leaves (O'Neill 1994/95). Genetic engineering may develop plants which contain a gene from *Bacillus thuringiensis* which makes a toxin lethal to certain insects feeding on such plants. The development of such plants reduces the need for spraying. It is not known whether the insects will develop resistance.

Physical and mechanical: Cut off tops of ears after harvest and before marketing.

Pesticides: *H. armigera* has developed ***resistance*** to many insecticides. In some areas certain ones may only be used at certain times of the year. To ***confirm*** that *H. armigera* is present and not *H. punctigera* (which is easily controlled with insecticides), CSIRO has developed a test which involves squashing eggs and larvae on to Lepton™ membranes, a purple stain indicates *H. armigera.* ***Monitor*** moths and eggs regularly during tasselling and silking before applying insecticides (Brough et al. 1994). Number and frequency of sprays depends on duration and intensity of egg laying and weather particularly temperature.

Crickets, locusts (Orthoptera)

Australian plague locust (*Chortoicetes terminifera*)
Black field cricket (*Teleogryllus commodus*)
Migratory locust (*Locusta migratoria*)
Spur-throated locust (*Nomadacris guttulosa*)
Yellow-winged locust (*Gastrimargus rotundipennis*)
See Vegetables M 13.

Maize leafhopper (*Cicadulina bimaculata*, Cicadellidae) sucks sap commonly from sweetcorn, maize and grasses during which they are thought to inject a toxin which is considered to cause ***wallaby ear***, ie leaves are dark green, short, stiff with enlarged veins on leaf undersurfaces. Plants affected when young are stunted. The possibility of virus involvement cannot be ruled out. Most sweetcorn hybrids are ***fairly resistant*** to damage. ***Monitor*** leafhoppers and incidence of wallaby ear before applying an insecticide (Brough et al. 1994). See Trees K 15, Vegetables M 15.

Redshouldered leaf beetle

(*Monolepta australis*) may swarm into crops in summer and autumn and feed on ***foliage, tassels, silks*** and ***husk*** at the top of cobs. Damage to foliage and tassels is unimportant but injury to silks may impair seed set. Cobs exposed at the tips may be susceptible to attack by other insects and moulds. ***Monitor*** infested plants and % flag eaten at regular intervals before applying insecticides (Brough et al. 1994). See Fruit F 11, Trees K 15.

Wireworms (Elateridae), *false wireworms*

(Tenebrionidae) bore into ***underground stems*** killing the growing point of seedlings, causing 'dead-hearted' plants. Wireworms may attack germinating seed if germination is slow in cold, wet soil. See Seedlings N 69.

Others:

Cockroaches (Blattodea), ***driedfruit beetles*** (*Carpophilus* spp.). ***Maize thrips*** (*Frankliniella williamsii*) may infest whorls and slow growth of young plants especially under stress, eg drought, waterlogging. Several sprays may be needed for control. ***Stored insect pests***, eg ***maize weevil*** (*Sitophilus zeamais*). Overseas, ***stemborers*** (*Chilo* spp.) may be ***serious pests*** of sugarcane, sorghum, rice, maize, millet and various grasses (Com. of Aust. 1996).

VERTEBRATE PESTS

Birds and ***mice*** may damage ***seed*** in the field. See Fruit F 13.

Non-parasitic

Environment: Sweetcorn may be damaged by ***frost*** at any stage of growth. Leafrolling is a sign of ***water stress***.

Faulty tasselling: Genes which produce this phenotype include 2 dominant and 3 recessive in hybrid corn. Some ***recessive genes*** are only expressed and triggered by certain conditions, eg in this instance, by cool and cloudy weather during summer plantings which could be a chance event or a regular problem (Fig. 357). If such problems are recurrent, breeders should be notified.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for (Weir and Cresswell 1993). ***Deficiencies*** of manganese and zinc may occur.

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State/Territory Departments of Agriculture/Primary Industry eg
A Guide to the Identification and Control of Insect Pests in Maize Crops in the Ord River Irrigation Area (WA Dept of Agric)
Boil Smut of Maize (NSW Agfact)
Commercial Vegetables Kit (Vic Agnote)
Diseases of Maize (NSW Agfact)
Growing Maize in the Northern Territory (NT Agnote)
Heliothis Caterpillars (NSW Agfact)
Insect Pests of Maize (NSW Agfact)
Pests and Diseases of Sorghum (NT Agnote)
Pests and Diseases of Sweetcorn (SA Fact Sheet)
Sweetcorn Growing (SA Fact Sheet)
Sweetcorn : Pest and Disease Control (Vic Agnote)
Sweetcorn Processing : Cultural Notes (Tas Farmnote)
Sweetcorn Production (Vic Agnote)
Sweetcorn : Weed Control (Vic Agnote)

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Sweetcorn is grown for the fresh, frozen and canned market and for popcorn. Many new varieties are extra-sweet. ***An overview of the industry*** is presented by Coombs (1995). Sweetcorn is a warm season crop (10-35^{o}C). Warm temperatures are essential during growth, but cooler temperatures are essential when maturity is reached to delay overmaturity and the associated rapid deterioration in quality. Areas should be frost-free. ***Propagated*** by seed which is usually treated. ***Resistant varieties:*** Cultivars Kulara and Mapee are ***resistant*** to Johnson grass mosaic virus, turcicum leaf blight, common and tropical rust, and are recommended for situations where risk of these diseases is high. The development of ***disease-resistant hybrids*** is the best method of control. ***Disease-free planting material:*** Plant certified disease-free seed. ***During establishment***, sweetcorn crops are susceptible to damping off diseases and serious soilborne insect pests, eg African black beetle, cutworms and wireworms; resowing may be necessary. Dust seed with fungicide and insecticide prior to planting. ***From tasselling-silking until harvest*** the worst pests are armyworms, budworms and redshouldered leaf beetles which often facilitate entry of other chewing insects such as driedfruit beetles and promote mould development. ***Maturing cobs*** may also be infested by maize weevil (coastal districts) and Angoumois grain moth. ***Cultural methods:*** Plant in well-drained soils high inorganic matter. Keep crop actively growing with appropriate fertilisers. Water stress must be avoided during early growing period, and at harvest. Leafrolling is a symptom of water stress and may occur during the heat of day even though enough soil moisture is present. Leaves lose moisture from their leaf surfaces faster than they can take it up. This is normal and does not mean that it is time to irrigate. If wilting is noticed in the morning, however, and the soil is obviously drying out then irrigation is required. ***Reduce weed infestation*** with cultivation during the off season. Control weeds in the growing crop by shallow interrow cultivation, throw some soil around base of plants to support them and reduce the effects of strong winds. For extended weed control use post-emergence and pre-emergence herbicides but there may be problems with some herbicides. ***Harvest of fresh cobs:*** Examine samples of cobs to determine maturity. Cobs must not be left in hot sunlight as the temperature of the corn will rise rapidly. Pick sweetcorn early in the morning, sort and fast cool (up to 4 hours) at 0^{o}C. Transport and store at 0^{o}C at very high humidity (> 95%) for 4-8 days (Salvestrin 1991). Popular varieties retain their sweetness if cooked immediately, but sweetness is quickly lost (sugar in the kernels rapidly transforms to starch after harvest). The rate of this transformation is reduced by refrigeration at temperatures of 0-2^{o}C but shelf life is still limited. In the new extra sweet varieties breakdown still occurs but some sweetness remains even after considerable shelf life. ***To maintain grain quality in storage*** moisture content must be < 12% and grain must be insect-free. Overseas customers impose a ***nil tolerance*** of insects in grain being imported.

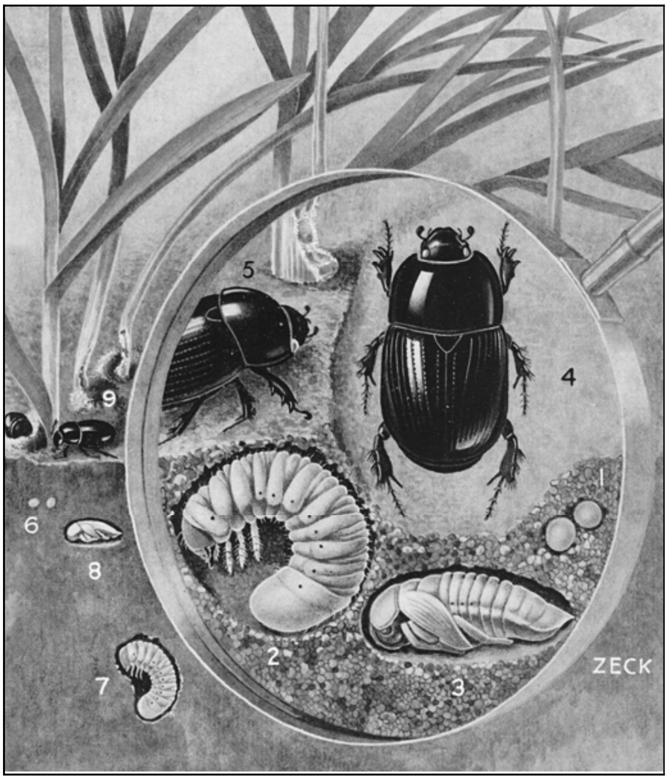

Fig. 354. African black beetle (*Heteronychus arator*).
1. Eggs in soil. **2.** Larva. **3.** Pupa. **4.** Female beetle. **5.** Male beetle. All enlarged 3½ times. **6.** Eggs. **7.** Larva. **8.** Pupa. **9.** Beetle attacking young maize plants. Actual size. Dept. of Agric., NSW.

Fig. 355. Whitish nymph skins of aphids on leaves of sweetcorn.

Fig. 356. Corn earworms (*Helicoverpa armigera*) up to 40 mm long, feeding on the cob tips.

Fig. 357. Faulty tasselling.

Sweet potato

Ipomoea batatas
Family Convolvulaceae (morning glory family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Fungal leaf spots
  - Stem and foliage scab
  - Root and tuber rots
- **Nematode diseases**
- **Insects and allied pests**
  - Aphids
  - Caterpillars
  - Crickets, grasshoppers
  - Leaf beetles, flea beetles
  - Spider mites
  - Sweetpotato leafminer
  - Sweetpotato weevil

Non-parasitic
- Environment
- Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Symptoms of virus diseases in sweet potato are not uncommon but their effect is minor, providing virus-tested cuttings are planted and plants with symptoms are rogued.

Sweetpotato feathery mottle virus affects sweet potato, other *Ipomoea* spp., eg morning glory and probably other Convolvulaceae. Symptoms vary with cultivar, age of plant, rate of growth, weather. Sometimes veinclearing, veinfeathering and yellow or purple spotting of ***leaves***. The russet crack strain of the feathery mottle complex causes brown corky lesions on ***storage roots***. ***Spread*** by aphids, eg cotton aphid (*Aphis gossypii*), cowpea aphid (*A. craccivora*), green peach aphid (*Myzus persicae*), turnip aphid (*Lipaphis erysimi*), by infected planting material, by grafting, by mechanical inoculation, not by contact between plants, not by seed, not by pollen.

Others: Virus infection probably causes a range of other symptoms, eg mosaic, dwarfing of plants and failure to produce normal runners in the cultivar Maltese. ***Tomato big bud mycoplasma*** which is spread by the common brown leafhopper (*Orosius argentatus*), may cause small yellow leaves, stunted plants often with many small thin shoots, and reduced yields if infection occurs early in the life of the plant. Also ***Potato Y virus***.

See Vegetables M 4.

FUNGAL DISEASES

Fungal leaf spots (*Phyllosticta batatas*) may cause spotting of leaves. See Annuals A 5.

Stem and foliage scab (*Sphaceloma batatas*): ***Stems and leaf veins*** are covered with small sunken brown scabs which cause distortion of ***foliage***. Severely affected ***terminals*** are brittle and growing points may die. Infected patches are visible from a distance due to the erect growth habit of infected terminals. Crop vigour may be reduced and if infection develops early in the season, yields are severely reduced. ***Overwinters*** in infected regrowth, debris from infected crops. ***Spread*** by the introduction of infected propagation material to new crops. ***Favoured*** by mild humid weather, drizzly rain. ***Control: Destroy regrowth*** from infected crops. The cultivars Centennial Gold and Beerwah Gold have some ***resistance***. Plant ***scab-free planting*** roots and stems produced in a nursery established from healthy tubers. See Violet A 56.

Root and tuber rots

Rhizopus soft rot (*Rhizopus stolonifer*) may be a ***serious postharvest storage disease*** but can invade ***roots and cuttings***. *Rhizopus* causes a soft watery rot of ***fleshy roots*** which become covered with a greyish white fungal growth and in which many small black stalked fruiting bodies appear. ***Spread*** from root to root by contact with infected roots and cuttings. ***Favoured*** by injury to roots and relative humidities of 75-85%. Drier atmospheres inhibit mould development. ***Do not harvest*** in wet weather. Dip planting material in ***fungicide*** before planting and dip harvested roots before packing. See Fruit F 6, Vegetables M 6.

Scurf (*Monilochaetes infuscans*) commonly affects sweet potato causing a greying or blackening of ***roots***. No internal breakdown occurs and only the appearance is affected. ***Overwinters*** in infested crop debris. ***Spread*** by infected propagation material. ***Favoured*** by wet areas. Rotate sweet potatoes with other crops. White Maltese is the most ***tolerant*** and Centennial the most ***susceptible***. Plant ***scurf-free planting material.*** Dip infected planting material in ***fungicide***.

Others: Ashy stem blight, charcoal rot (*Macrophomina phaseolina*), ***fusarium surface rot*** (*Fusarium oxysporum*), ***phytophthora vascular tuber necrosis*** (*Phytophthora* sp.), ***pythium tuber soft rot*** (*Pythium ultimum*), ***rhizoctonia stem canker*** (*Rhizoctonia* sp.), ***tuber rot*** (*Diaporthe phaseolorum*), *Phoma batatae*.

See Vegetables M 7.

NEMATODE DISEASES

Root knot (*Meloidogyne* spp.) causes galls or swelling on small roots. On ***fleshy roots***, swollen areas, scab-like abrasions or cracks appear. Small brown spots are visible in the underlying tissues. Also ***Haplolaimus spp***. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae), eg ***green peach aphid*** (*Myzus persicae*), transmit virus diseases of sweet potato. See Roses J 4, Vegetables M 11.

Caterpillars (Lepidoptera)

Convolvulus hawk moth (*Agrius convolvuli, Sphingidae*) caterpillars chew ***foliage*** of sweet potato and related plants, ragged. Young caterpillars feed on leaf undersurfaces. Control is only warranted if >50% foliage is eaten before vines completely cover the ground (Hely et al. 1982). ***Other hawk moths***, eg grapevine hawk moth (*Hippotion celerio*) (Fig. 358), scrofa hawk moth (*H. scrofa*), vine hawk moth (*Theretra oldenlandiae*), *Gnathothlibus eriotus* sp. may also infest sweet potato.

Sweetpotato stemborer (*Omphisa anastomosalis*, Pyraustidae) caterpillars tunnel into ***stems and roots*** overseas.

Other caterpillars are usually minor pests and most can infest a range of other plants.
Common armyworm (*Leucania convecta*)
Corn earworm (*Helicoverpa armigera*)
Cluster caterpillars (*Spodoptera litura*)
Cutworms (*Agrotis* spp., *Pseudaletia* spp.)
Loopers (*Chrysodeixis* spp.)
Yellow peach moth (*Conogethes punctiferalis*)

See Annuals A 8, Vegetables M 13.

Crickets, grasshoppers (Orthoptera): ***Black field cricket*** (*Teleogryllus commodus*) feeds on exposed stem ends of maturing tubers. ***Field crickets*** (Gryllidae) cut off the tops of cuttings at night. Provide sufficient irrigation to prevent soil cracking and apply baits as soon as infestation is observed. ***Mole crickets*** (*Gryllotalpa* spp.) may burrow into tubers. Harvest as soon as mature. ***Wingless grasshopper*** (*Phaulacridium vittatum*) strips leaves off plants. See Vegetables M 13.

Leaf beetles, flea beetles (Chrysomelidae, Coleoptera): ***Sweetpotato leaf beetle*** (*Colasposoma sellatum*), ***sweetpotato tortoise beetles*** (*Aspidomorpha* spp.) and their larvae feed on leaves. ***Flea beetles*** (Galerucinae) may feed in great numbers, eating small holes in the leaves. ***Overseas***: Argus tortoise beetle (*Chelymorpha cassidea*), striped tortoise beetle (*Cassida bivittata*), sweetpotato flea beetle (*Chaetocnema confinis*) and other species. See Hibiscus K 82, Trees K 15.

Spider mites (*Tetranychus* spp.): ***Bean spider mite*** (*T. ludeni*) during hot dry weather feed on ***leaf undersurfaces*** which become mottled, grey, wither and fall. See Beans (French) M 29.

Sweetpotato leafminer (*Bedellia somnulentella,* Lyonetiidae, Lepidoptera) infest sweet potato. ***Moths*** are greyish with narrow fringed wings and a wingspan of about 9 mm. ***Caterpillars*** are yellow-grey, about 6 mm long with red and white tubercles on their sides. Caterpillars mine in ***leaves*** of newly planted crops. ***Complete metamorphosis*** (egg, caterpillar, pupa, adult) with many generations each year. Eggs are laid on leaves, caterpillars bore into leaves. Initially there is a serpentine tunnel which later becomes a large blistered area. Caterpillars pupate on leaf undersurfaces. Moths emerge later. ***Spread*** by moths flying, ***Favoured*** by warm weather. ***Insecticides*** are registered for use. ***Potato moth*** (*Phthorimaea operculella*) may damage sweet potato. See Potato M 81.

Sweetpotato weevil (*Cylas formicarius,* (Curculionidae, Coleoptera) is the ***most serious pest*** of sweet potato in the ***field***, and ***postharvest***, it also damages other Convolvulaceae, eg morning glory. ***Weevils*** are ant-like, shiny blue/black and red/orange, about 6 mm long (Fig. 359). They cause minor damage to ***leaves***. ***Larvae*** are white, legless, brown headed and up to 9 mm long. They tunnel in ***stems and tubers*** causing major damage. Stems wilt in dry weather and tubers are honeycombed. Weevils breed in tubers in ***storage***. Damaged tubers have a bitter taste. There is a ***complete metamorphosis*** (egg, larva, pupa, adult) with many generations each year. Female weevils lay eggs in cavities on tubers, larvae hatch and tunnel in stems or tubers. Larvae pupate in the end of the feeding tunnel. ***Spread*** by introduction of infested planting material. Weevils only fly when food runs out but they can fly at least 5 km. ***Control:*** Practise ***crop rotation.*** Keep tubers covered with soil. ***Destroy crop residues*** after harvest and remove all roots from soil. Eliminate volunteer plants before planting. Various wasps ***parasitise larvae.*** Centennial is very ***susceptible***. Only plant ***weevil-free cuttings***. ***Whitefringed weevil*** (*Graphognathus leucoloma*) larvae may also chew furrows in ***tubers***. See Vegetables M 17.

Others: ***Scarab beetles***, eg African black beetle (*Heteronychus arator*), black beetle (*Metanastes vulgivagus*), ***maize leafhopper*** (*Cicadulina bimaculata*), ***greenhouse whitefly*** (*Trialeurodes vaporariorum*), ***wireworms*** (Elateridae).

Non-parasitic

Environment: A 4-6 month frost-free growing period is necessary for successful growth.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for sweet potato (Weir and Cresswell 1993).

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State/Territory Departments of Agriculture/Primary Industry eg

Insect Pests of Sweet Potato (NSW Agfact)
Sweet Potato Growing (NSW Agfact)
Sweet Potatoes : Growing Recommendations (Qld Farmnote)
Sweet Potatoes : Pests & Diseases (Qld Farmnote)

Associations. Journals etc.

Heavy Produce Committee of the Qld Fruit & Vegetables Growers
Tweed Fruit & Vegetable Growers Assoc. in NSW

See Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Sweet potato is a subtropical plant requiring a daily mean temperature of 23^{o}C for adequate growth. An ***industry overview*** has been presented by Coombs (1995). Choose varieties with some ***resistance*** to scab and scurf and only plant ***disease and pest-free planting material***, eg weevil-free tubers, cuttings and plants. ***Propagated*** by vine cuttings, preferably tip cuttings in frost-free areas, in temperate regions by sprouting storage roots. ***Practise crop rotation.*** Plant in frost-free areas, use fertiliser, deep well drained soil and irrigate during establishment and to prevent checks in growth which contribute to cracking and skin blemishes. ***Destroy old plants and tubers*** left in the ground, volunteer plants and any discarded plants and tubers and old seedbeds as much as possible by cultivation or other means. Weevils can breed continuously in this material and may then infest new plantings. ***Pre-plant treat soil*** for root knot nematodes. ***Monitor*** insect pests and disease development while plants are small as spraying is more likely to be effective at that stage; spraying becomes impractical and difficult in vigorously growing densely foliaged beds. ***Weed control*** is critical during ***establishment*** until there is sufficient vine and leaf growth to cover the ground. Hillers can be run through the crop during this period to control weeds. ***Pre-emergence herbicides*** are an effective method of controlling weeds. ***Growth regulators*** are used to promote sprouting. ***Harvest timing*** is not critical, they can be harvested when an acceptable economic yield has been achieved, and may be left in the ground provided top growth is healthy and conditions are suitable. If harvesting is delayed too long, excessive cracking and breakdown of tubers can occur, cessation of growth can lead to sprouting of storage roots. Washing improves the appearance but injury makes them susceptible to soft rot. Tubers are ***ethylene sensitive***. ***After harvest*** cure tubers and roots at high temperatures before cooling over 1 day. ***Store*** at 13^{o}C at a moderate humidity (85-90% relative humidity). Estimated storage life is 4-6 months, but depends on the conditions of storage. Tubers and roots ***are chilling sensitive*** and will be damaged if stored at lower temperatures. They lose their ability to ripen, skin becomes pitted and darkened and is increasingly susceptible to fungal diseases.

Fig. 358. Grapevine hawk moth (*Hippotion celerio*) caterpillars are grey-green and 60-80 mm long. There is a prominent spine projecting obliquely upward at the tail end of the body.

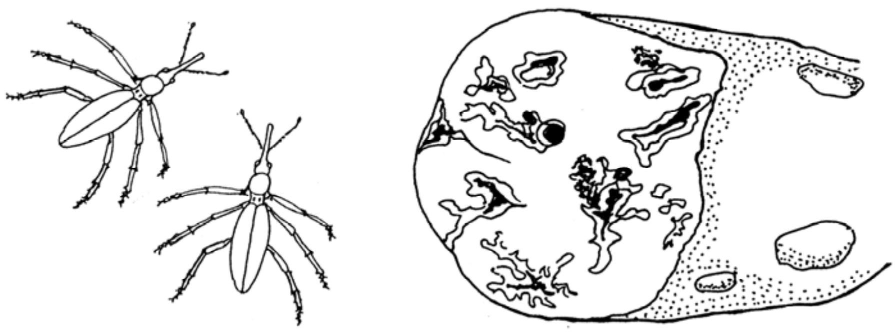

Fig. 359. Sweetpotato weevil (*Cylas formicarius*).
Left : Adult weevils are ant-like (about 6 mm long).
Right : Larvae (up to 9 mm long) tunnel in tubers creating a honeycomb effect.

Tomato

Lycopersicon esculentum
Family Solanaceae (nightshade family)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Tomato spotted wilt virus
- **Bacterial diseases**
  - Bacterial canker
  - Bacterial speck
  - Bacterial leaf spot
  - Bacterial wilt
- **Fungal diseases**
  - Early blight, target spot
  - Fruit rots
  - Fungal leaf spots
  - Grey mould, *Botrytis*, ghost spot
  - Late blight, Irish blight
  - Powdery mildew
  - Root and stem rots, damping off
  - Wilts
- **Nematode diseases**
  - Root knot nematodes
- **Insects and allied pests**
  - African black beetle
  - Aphids
  - Bugs
  - Caterpillars
  - Crickets, grasshoppers, locusts
  - Flies
  - Greenhouse whitefly
  - Leafhoppers
  - Mites
  - Potato ladybirds
  - Thrips
  - Weevils
  - Wireworms, false wireworms
- **Snails and slugs**

Non-parasitic
  - Environment
  - Nutrient deficiencies, toxicities

PESTS AND DISEASES
Parasitic

Tomato (and some stone fruits) are the most difficult plants on which to ***diagnose*** *problems.*

VIRUS AND VIRUS-LIKE DISEASES

Tomato spotted wilt

Scientific name: Tomato spotted wilt virus ***(TSWV).*** Impatiens necrotic spot virus ***(INSV)*** is closely related to ***TSWV***, but has not been detected in Australia (Hill 1994). The recently introduced western flower thrips (*Frankliniella occidentalis*) ***(WFT)*** is the major vector of both viruses. ***WFT*** is the only thrips that can spread ***INSW***. As ***WFT*** spreads in Australia, both these viruses may cause increased crop losses and damage.

Host range: Over 500 species of annual and herbaceous plants, eg ***ornamentals***, eg aster, begonia, calendula, chrysanthemum, cyclamen, dahlia, Dutch iris, gloxinia, Iceland poppy, impatiens, nasturtium, petunia, ranunculus, zinnia, ***vegetables***, eg broad bean, capsicum, celery, eggplant, lettuce, peas, potato, spinach, tomato, ***weeds***, eg dandelion, lamb's tongue, nightshades, thornapple, stinking Roger.

Symptoms: Symptoms usually appear on leaves 14-21 days after infection but vary according to the host species attacked. ***Tomato:*** Small areas of bronzing develop on the upper side of ***young leaves***. ***Older leaves*** develop dark spots or rings between the veins. These spots may extend and join up and affected tissues blacken and shrivel until shoots look as though they have been scorched by flame. Dark streaks may also appear on ***leaf stalks*** and ***stems***. Young vigorously growing plants may be ***killed*** in a few days but older plants may take several weeks to develop symptoms. ***Fruits*** develop irregular or circular blotches as they ripen (Fig. 360) but taste is not affected. Young fruits may shrivel and fall. Symptoms vary with temperature, nutritional levels of the host and age of plants. The most efficient way of detecting the virus is by enzyme-linked immuno sorbent assay ***(ELISA)*** techniques. ***ELISA*** should be used in conjunction with one of the other techniques, eg indicator plants or electron microscopy, to ensure an accurate diagnosis.

Overwintering: Infected weeds, and other hosts, tubers (dahlia, potato). It is not seedborne (except for broad bean).

Spread: By onion thrips (*Thrips tabaci*), melon thrips (*T. palmi*), *Frankliniella* spp., eg tomato thrips (*F. schultzei*), ***WFT*** (*F. occidentalis*), by mechanical inoculation, by grafting and by vegetative propagation from infected plants, not by contact between plants, not by seed (except for broad bean), not by pollen.

Conditions favouring: Spring, summer, occasionally autumn. Proximity to large weedy areas and perennial flower crops. Thrips are likely to migrate on to crops when weed hosts, on which they have been breeding and feeding, have matured and are drying out after hot, dry weather.

Control: Once a plant is infected nothing can be done. Measures to ***minimise losses*** include:

Cultural methods: Do not locate seedbeds or grow tomatoes, potatoes or lettuce ***near susceptible*** vegetable crops and ornamentals, especially spring flower crops or weeds, which act as alternative hosts for the virus. Plant excess plants to allow for loss due to ***TSWV*** (up to 50% can be lost). Early plantings are affected more seriously than later plantings.

Sanitation: Remove and destroy infected plants and weeds known to harbour ***vectors*** in and near crops.

Biological control: Thrips vectors are biologically controlled overseas. See Annuals A 9, Onion M 68.

Resistant varieties: All tomato varieties are ***susceptible***.

Disease-free planting material: For plants propagated vegetatively, purchase ***virus-tested planting material*** (cuttings, tubers). Do not propagate vegetatively from infected plants. Otherwise select propagation material only from symptom-free plants.

Pesticides: Because the disease is more serious in ***young plants***, insecticides may be applied to commercial seedbeds to control thrips. Regular insecticide applications to field crops in spring and early summer will at the most only reduce the number of infected plants. Where the disease is prevalent, commercial growers may spray seedbeds and/or field crops in spring and early summer to control the vector, which may reduce the number of infected plants.

Others

Cucumber mosaic virus, fern leaf: The first symptom is a thickening and rolling of ***leaf*** edges (Persley 1994). Later, terminal shoots become a mass of very narrow distorted leaflets, all with thickened and curled edges, fruit from affected plants may be malformed. Wide host range, eg crops and weeds, ***spread*** by aphids. A minor disease but regularly occurs in some districts. See Cucurbits M 50.

Potato virus Y, leaf shrivel: Leaflets and petioles curl downwards giving the plant a ***clawed appearance. Leaves*** may also be mottled and leaf area of the plant reduced (Persley 1994). Older leaves may show a dark grey to brown spotting on the underside and eventually shrivel and die. Fruit shows no symptoms, though actual yield is reduced. ***Spread*** by aphids. The main source of infection is old infected tomato, capsicum and tobacco crops and weeds, eg gooseberry (*Physalis* spp.), nightshade and apple of Peru. Leaf shrivel is widespread and is often ***very severe*** especially late in the season. See Potato M 77.

Tobacco mosaic virus (TMV): Many different ***strains***. This virus has probably been studied more than any other virus. Hosts throughout the world include > 150 genera of mostly herbaceous, dicotyledonous plants including many vegetables, flowers and weeds. Found in ***greenhouse crops***. Symptoms vary according to the strain of virus and host. Usually causes mosaic and chlorosis of ***leaves***, ***flowers*** and ***fruit*** and stunting of the plant. It almost never kills the plant. ***Tomato: TMV*** may occur in association with other viruses, different strains produce different diseases, eg drop head wilt, tomato streak, etc. ***Overwinters*** in debris from infected plants in the soil, on the surface of seeds, in natural leaf of manufactured tobacco, including cigarettes, cigars and snuff. Infected perennial host plants. ***TMV*** is one of the most infectious of plant viruses. There is no vector. It is ***spread*** by mechanical inoculation, by sap adhering to fingers and tools during the handling of plants, by grafting and vegetative propagation, contact between plants, seed, introduction of infected seedlings, plant material and debris from infected plants, not by a vector. Infection by ***TMV*** is inhibited by milk. Overseas authorities recommend spraying seedlings with ***milk*** before transplanting or handling them. Dipping hands in milk during transplanting and handling greatly reduces spread of ***TMV***. Seed may be treated.

Tomato big bud mycoplasma, greening, rosette, virescence is an ***important disease*** in inland areas. It affects a wide range of annual and herbaceous plants and weeds similar to tomato spotted wilt. Symptoms different from those on other hosts develop on tomato and potato. ***Ornamentals:*** Greening of the floral parts is a constant feature of this disease. There is no bud enlargement. ***Tomato***: Symptoms may not develop for 6 weeks or longer after infection. ***Stems*** thicken and become stiff and upright (Fig. 361). Plants branch prolifically producing many stiff shoots with shortened internodes. Root initials may develop high on the stem, splitting may occur. ***Flower buds*** are greatly enlarged and imperfectly developed (often infertile). Sepals often fail to separate and whole buds are green. Abnormal flowers do not set fruit. ***Fruit***, immature at the time of infection, become distorted and woody. ***Potato (purple top wilt):*** Rolling and pigmentation of upper leaves, erect leaf stalks. Leaves of white flowered varieties turn yellow, leaves of pigmented varieties turn red or purplish depending on variety. ***Overwinters*** in infected host plants, eg weeds, perennial ornamental plants and field crops, near the crop. ***Spread*** by common brown leafhopper (*Orosius argentatus*), a brown insect about ***3 mm*** long, by vegetative propagation from infected host plants. Not by seed except for broad bean. At certain times of the year, eg after hot weather, leafhoppers migrate from drying weeds where they breed and feed to host plants. Migration mostly occurs in spring. ***Control:*** As for tomato spotted wilt.

Tomato mosaic virus, internal browning, streak (many strains), has a wide host range including Cape gooseberry, blackberry nightshade, tobacco, tomato and weeds. It is important in ***greenhouse crops*** but can also be severe in the field. Symptoms depend on the strain. ***Leaves*** and ***stems*** develop mosaics, mottle and streaks. Fern leaf symptoms may appear in cold conditions. Affected plants may be lighter in colour than healthy plants. ***Fruit*** formed before infection develops internal browning. Brown and sunken markings appear on fruit surface and in the flesh of the outer wall. ***Overwinters*** in infected seed, hosts, undecomposed crop debris. The virus can remain infective in dead plant material for many years. Infective root debris may be found several metres deep where a diseased crop has been grown. ***Spread*** by mechanical inoculation (sap transmission) on hands, implements, pruning knives, by direct contact between plants, old trellis material and contaminated hands and clothing, by grafting, by contact between plants, by seed (but occasionally through the testa and not through the embryo), not by a vector. Disease can spread from a few infected seedlings (produced from infected seed) during transplanting. All cultivars are ***susceptible***. Direct seeding can reduce the spread of the virus, as it eliminates handling young seedlings.

Tomato yellow top virus affects tomato, other hosts, eg potato and ***weeds***, eg thornapple, apple of Peru, nightshades and shepherd's-purse (Persley 1994). Infected plants are stunted and have a stiff upright appearance. From a distance plants look yellow. Symptoms include reduced leaf size, rounding and marginal yellowing of leaflets and down curling of leaflet margins. Flowers often fail to set fruit and flower buds can be killed following infection. ***Yield can be reduced drastically*** if plants are infected at an early stage. Late infection has progressively less effect. No symptoms on the fruit. ***Spread*** by aphids, eg green peach aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiae*).

Others: Alfalfa mosaic virus, potato virus X, sunflower ringspot virus, tobacco necrosis virus, tobacco yellow dwarf virus, tomato (Australian) leaf curl virus, tomato shatter virus.

See Vegetables M 4.

BACTERIAL DISEASES

Bacterial canker (*Corynebacterium michiganense* pv. *michiganense*) affects tomato, capsicum, nightshade, especially black nightshade. Infected ***seedlings*** may be killed or stunted and malformed in the seedbed or may show no symptoms until transplanted into the field. ***Leaflets*** of older plants may wilt on one side only, later they turn brown and shrivel, giving the leaf a one-sided appearance. Wilting progresses until the whole plant is affected. ***Stems*** and ***leaf stalks*** may develop yellow to brown streaks which crack open to form cankers. When a diseased stem is cut across, the ***water-conducting tissue is brown***. With time the tissues in the centre of the stem turn brown, appear mealy and eventually the stem is hollowed for several centimetres. The internal browning and cavities can be seen by snapping off a leaf where the leaf joins the stem. Sometimes the roots and lower stems show little evidence of the disease. ***Young fruits*** may be stunted and distorted. Fruits approaching maturity at the time of infection, ripen normally and often have no external symptoms. During wet weather, fruit may develop circular spots with raised brown central areas that are surrounded by a white halo (bird's eye spot). In heavy infections, the spots form crusty patches. Bacterial canker can be ***distinguished*** from *Fusarium* and *Verticillium* wilts by the wilting of the leaflets on one side of the affected leaves, the formation of cankers on the stems and leaf stalks, and cavities in the stem. ***Overwinters*** in infected seed. ***Favoured*** by wet weather, 16-28^{O}C. ***Direct seeding*** largely prevents infection, if a trace of infection (as little as 1%) is present in a seed sample the disease will spread from plant to plant in the seedbed. Healthy plants should be ***handled*** before diseased plants. ***Wash hands*** and tools with a bactericide before touching healthy tomato plants, and after pruning each plant, disinfect pruning knives with a bactericide. Clean stakes and trellises before re-use. Check for infected plants during trellising and pruning and remove any infected. All tomato cultivars are ***susceptible***. See Vegetables M 6.

Bacterial speck (*Pseudomonas syringae* pv. *tomato*) infects tomato and is a similar disease to bacterial leaf spot. Lesions on ***leaves, stems*** and ***fruit*** are similar but smaller; lesions often coalesce and appear scabby. ***Favoured*** by cool moist weather. Control as for bacterial leaf spot (see below).

Bacterial leaf spot, bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*) affects tomato, Cape gooseberry and other *Physalis* spp., capsicum, nightshades, thornapple. ***Leaves*** develop small irregular areas with a greasy appearance. These areas dry out and form slightly raised dry spots which are greyish-brown in the centre. Bacteria often ooze from these spots which when dry form raised greyish-brown spots. When infection is severe, the spots coalesce and leaves yellow and fall. Marginal and tip burns on leaves have often been noted. ***Stems*** are occasionally attacked and develop elongated scab-like spots. ***Flowers*** and ***young fruit*** may also wither and fall. Small watersoaked areas form on green fruit, these dry out and form scab-like lesions rendering the fruit unmarketable and susceptible to secondary rots. All tomato cultivars are ***susceptible***. See Vegetables M 5.

Bacterial wilt (*Pseudomonas solanacearum*) affects Solanaceae including ***vegetables***, eg tomato, potato, eggplant, capsicum, ***fruit***, eg custard apple, ***ornamentals***, eg nasturtium, ***field crops***, eg tobacco, ***weeds***, eg nightshade, Cape gooseberry, wild tobacco tree, nightshade, thornapple. There are strains of *P. solanacearum*. ***Bacteria enter plants through roots*** and multiply in the water-conducting tissues which become blocked, causing wilting. Affected plants wilt rapidly and ***die*** without any spotting or yellowing of the leaves. Plants do not recover despite watering. If the stem of a wilted plant is cut across near ground level, the ***vascular tissue is dark*** and watersoaked, and a greyish, slimy bacterial ooze can be pressed out of it. When placed in water a milky ooze from affected stems causes the water to cloud. The rapid onset of wilting ***distinguishes*** this disease from bacterial canker and from fungal wilts. ***Favoured*** by hot weather, 21-32^{O}C. Very moist soil seems to favour initial infection, but soil type and pH have little effect. It may cause losses on newly cleared land or may attack crops on previously used land. Widespread in tropical and subtropical areas. All tomato cultivars are ***susceptible*** except Scorpic, which is resistant at temperatures < 32^{O}C. Graft ***susceptible*** commercial varieties on to ***resistant rootstock***. Currant tomato (*L. pimpinellifolium*) is used as a resistant rootstock in Hawaii. See Vegetables M 6.

Others: ***Bacterial soft rot*** (*Erwinia carotovora* subsp. *carotovora*), ***crown gall*** (*Agrobacterium* sp.), also *Pseudomonas cepacia, Pseudomonas marginalis* pv. *marginalis.*

FUNGAL DISEASES

Early blight, target spot (*Alternaria solani*): ***Leaves*** develop brown spots often surrounded by a yellow halo (Fig. 362). Spots enlarge and may join together to form large irregular dead areas. Individual spots are oval, from 6-13 mm across and develop a series of concentric rings ***(target spots)***. The oldest leaves show the largest lesions and die rapidly. They may fall giving the basal part of the plant a dead, drooping appearance which extends upwards as the disease progresses. Similar lesions develop on ***stems***, but are more elongated and the target effect is more pronounced. The fungus cannot penetrate the unbroken skin of ***fruit***, so fruit lesions are confined to around the fruit stalk scar or around growth cracks (star cracks) Other fungi can also invade star-cracked fruit. ***Seedlings*** may develop a collar rot at soil level, often only on one side, which rapidly girdles the stem, seedlings die. Sometimes lesions appear higher on seedling stems. Affected seedlings never thrive after being transplanted. All tomato cultivars are ***susceptible***. Plant ***disease-free seed*** or seedlings, into well prepared seedbed or soil-less mixes. ***Fungicides*** are registered for application to seedlings and field crops. See Potato M 78.

Fruit rots

Alternaria rot, alternaria stem canker (*Alternaria alternata*) causes dark brown to mouldy sunken spots on ***fruit*** which enlarge as the fruit matures. Spots occur generally on fruit shoulders, around the edges of the stem scars and growth cracks, or on other small injuries to the skin. ***Latent infections*** develop on fruit which have been cool stored for prolonged periods. Symptoms on fruit are similar to grey leaf spot (*Stemphylium*). ***Serious*** in varieties with fruit prone to growth cracks which allow entry of secondary pathogens. Store at correct temperature and apply recommended fungicides.

Anthracnose, ripe fruit rot (*Colletotrichum* spp.) can cause losses in ***ripe tomatoes*** but is not important if green fruit is harvested. It is more important in crops on the ground than in staked or trellised crops. Affected ***fruit*** first show small slightly sunken, watersoaked, circular spots that become darker than the surrounding tissue. These spots become depressed, are about 10-12 mm wide and develop concentric markings. The centres become tan coloured and develops dark specks which are the fruiting bodies of the fungus. Spots become ***pink*** due to production of masses of pink-orange spores. Under favourable conditions, extensive fruit rot can occur. ***Favoured*** by warm, humid conditions with temperatures around $26^{o}C$ and relative humidities > 93%. All tomato cultivars are ***susceptible***. See Fruit F 5.

Early blight (*Alternaria solani*) and ***late blight*** (*Phytophthora infestans*) may affect ***fruit***. See Tomato M 98, M 100.

Penicillium moulds (*Penicillium* spp.) usually only affects poor quality and over-ripe ***fruit***. Dark olive-green or blue spores develop on wounds. See Fruit F 6.

Fusarium fruit rots (*Fusarium* spp.) cause scattered spots on fruit skin. A white to pink fungal growth develops. Fruit breakdown during ***transit*** and ***storage***. *Fusarium* also causes ***root rots***.

Phoma rot (*Phoma destructiva*) attacks tomato and capsicum. Small irregular spots develop on ***leaves***. Seedlings may be infected before transplanting. Slightly sunken brown spots develop on the ***fruit*** near the stem scar. As the fruit ripens during ***transport***, the spots may enlarge rapidly and reach over 25 mm across. Affected areas become brown and leathery and dotted with minute, black, fungal fruiting bodies. A black rot develops in the underlying tissue. Spores are ***spread*** by rain, irrigation water, cultural operations, picking and transport, on to fruit. Infection takes place through ***injuries***. All tomato cultivars are ***susceptible***.

Phytophthora buckeye and root rot (*Phytophthora* sp.) affects ***fruit*** near the soil. Fruit develop greyish-green or brown watersoaked spots without definite margins. Spots can enlarge rapidly. If development is slow, spots develop dark zonate markings. Green fruits do not become soft when infected, although the rot may progress well into the flesh. Fruit showing small spots are often overlooked at packing and develop extensive decay ***postharvest***. ***Roots*** may be attacked. All tomato cultivars are ***susceptible***. See Trees K 6, Tomato M 100, Vegetables M 7.

Rhizoctonia fruit rot (*Rhizoctonia solani*): Small round brown spots with definite concentric markings develop on ***green fruit***. As it ripens and areas enlarge the ring markings may disappear. Spots become dark brown and a brown mould often develops on the surface of the spots. *Rhizoctonia* affects only fruit on or close to the soil during warm wet weather. It can cause extensive ***postharvest*** breakdown of affected fruit especially if fruit is not cool stored. Do not pack fruit with signs of infection, cool fruit promptly. It also causes ***damping off*** and ***stem rots***. See Tomato M 100, Vegetables M 7.

Rhizopus soft rot (*Rhizopus stolonifer*) causes slightly watersoaked spots with little discolouration, to develop rapidly over the entire ***fruit***, skin may remain intact. When the fruit splits and collapses into a soft mass it is quickly covered with black fruiting bodies in a fungal growth. Discard fruit with serious growth cracks. See Fruit F 6, Vegetables M 6.

Sour rot, yeasty rot (*Geotrichum candidum*) causes watersoaked areas often starting at cracks or injuries to the skin or at the stem scar. In ***green fruit*** affected areas remain firm until decay is well advanced. In ***ripening fruit*** decay progresses rapidly. Cracks in the skin over infected areas become filled with a whitish fungus. Yeasty rot often occurs in association with bacterial soft rot. The fungus is common on decaying plant matter in the soil. ***Spread*** to fruit by wind and water splash and insects. ***Favoured*** by hot weather, although most infection originates in the field, spread may occur during ***harvesting*** and ***packing***, especially if heavy rains has increased fruit cracking. See Citrus F 34, Pineapple F 103.

Others: *Gibberella, Phomopsis*.

See Fruit F 6, Tomato M 100, Vegetables M 6.

Fungal leaf spots

Grey leaf spot (*Stemphylium* sp.) infects tomato, possibly other plants. Lower ***leaves*** are affected first. Small, dark brown spots (about 3 mm in diameter) develop on leaves. As spots enlarge, they look greyish brown and glazed, centres may crack and tear. Badly affected leaves yellow, wither and drop. All leaves except the youngest may be killed. ***Stems*** are only occasionally attacked. ***Fruit*** production may be severely reduced. Use ***resistant varieties***.

Leaf mould (*Fulvia fulva*) is a ***serious foliage disease*** of ***greenhouse tomatoes*** but can also cause losses in the field. Small, yellow areas develop on ***leaf uppersurfaces***, a white downy growth appears on the undersurfaces of the yellow areas. The white downy growth may enlarge rapidly, and change to light brown. At this stage the growth is velvety and each area has a downy white margin. Leaves die and the fungal growth turns purple. Occasionally ***flowers*** and ***young stems*** are affected. Infected flowers fail to set fruit. Yield losses depend on the stage at which plants are infected; more mature plants withstand the disease better than young ones. ***Favoured*** by warm humid weather. All tomato cultivars are ***susceptible***.

Septoria leaf spot (*Septoria lycopersici*) causes tomato ***leaves*** to develop small circular spots about 3 mm across, which have brown margins and light grey centres studded with small black pin-point fruiting bodies (pycnidia) which produce the fungal spores. Severely affected leaves yellow and fall. Older leaves are affected first so that finally only a tuft of small green leaves is left at the top of the plant. ***Stems*** and ***fruit*** may develop spots. Reduced leaf area may mean that exposed fruit is liable to ***sunscald***. All tomato cultivars are ***susceptible***.

Others: ***Early blight*** (*Alternaria alternata*), ***late blight*** (*Phytophthora infestans*), ***phoma rot*** (*Phoma destructiva*), ***zonate leaf spot*** (*Alternaria* sp.), *Cercospora fuligena*.

See Annuals A 5.

Grey mould, *Botrytis*, ghost spot (*Botrytis cinerea*) of ***fruit, leaves*** and ***stems*** occurs mainly in ***greenhouse crops***, although it can occur in the field. Infection usually occurs at a point of contact, eg where old blossoms or leaves fall on to leaves, stems or fruit. Rotted areas are soon covered with a typical grey furry mould. Infection sites are usually associated with old flowers or injury from leaf scars, insect or pruning, growth cracks. On ***fruit***, a second type of infection ***(ghost spot)*** may also occur. In humid weather spores produced on previously infected areas on tomato or other hosts, may fall on to fruit. Where each spore germinates a white, circular, superficial ring spot develops, about 3-6 mm across. The fungus penetrates the skin of the fruit in very humid weather but dies without becoming established and without further damage. ***Favoured*** by long period of high humidity. ***Minimise injuries*** to crops especially during trellising. Do not slash plant tops during cool wet weather. Avoid sequential plantings close together. All tomato cultivars are ***susceptible***. See Fruit F 5, Greenhouses N 22, Vegetables M 7.

Late blight, Irish blight (*Phytophthora infestans*) affects tomato at any stage of growth. Serious losses may occur in ***seedbeds***. Dark areas develop on stems at or near ground level. These areas shrivel and the whole plant may fall over and wither. ***Stems*** of well developed plants may develop dark diseased areas which girdle the stem. In older plants, dark, watersoaked areas develop on ***leaves*** (usually on the margins), and enlarge rapidly until the whole leaf is affected. The leaves may blacken and shrivel, or, if the weather stays humid, may rot. In the early stages, the delicate downy outgrowth of the fungus can be seen next to the healthy tissue, particularly on the underside of the leaf. Blackened, elongated areas may then develop on the leaf stalks. Developing ***fruit*** may be affected, dark green watersoaked areas appear on the surface of the fruit generally at the stem scar, this may rapidly spread to produce mottled brown areas with indefinite margins. A white downy fungal growth may develop during humid conditions or during ***transit***. Fruit not showing symptoms at harvest may develop extensive breakdown during ***transit*** and ***storage***. Sometimes the damage is not apparent until the fruit reaches market. See Potato M 78.

Powdery mildew (*Oidium* sp.) may be ***severe*** in some areas on leaves during warm dry weather. See Annuals A 6, Vegetables M 7.

Root and stem rots, damping off

Ashy stem blight, charcoal rot (*Macrophomina phaseolina*) causes a pale ashy dry ***stem rot***, black dots develop on these areas. See Vegetables M 7.

Damping off (*Fusarium solani, Pythium* spp., *Phytophthora* spp., *Rhizoctonia solani, Phytophthora erythroseptica*) causes ***seedlings*** to topple over and the stems at ground level to be soft and withered. Damping off can spread rapidly. See Seedlings N 66.

Fusarium root rot (*Fusarium solani*) causes leaves to yellow and die. Plants are stunted. A brown dry rot of the ***crown roots*** may develop. Also causes ***fruit*** rots. See Vegetables M 7.

Phytophthora fruit and foot rots, buckeye rot and foot rot (*Phytophthora* spp.) may occur in low lying poorly drained soil. ***Foot rot*** may cause losses of young plants particularly in early-planted coastal crops. Plants develop a brown discolouration of the stem tissues at, or just below, ground level. These tissues shrivel, the stem collapses and the plant dies. The primary root system is destroyed. Young plants can be killed by foot rot, older plants often form adventitious root above the point of infection and recover. Also attacks ***fruit***. See Trees K 6, Vegetables M 7.

Rhizoctonia stem and fruit rots (*Rhizoctonia* sp.): Large plants in the ***greenhouse*** or in the ***field*** may be attacked. Dark brown, sometimes sunken areas occur on ***stems*** near soil level. Affected plants are often smaller than healthy ones and fail to survive long enough to mature the upper hands of fruit. ***Fruit*** near soil surface, when green, develop small circular spots with concentric ring markings. Do not pack fruit showing signs of infection. All tomato cultivars are ***susceptible***. See Vegetables M 7.

Sclerotinia rot (*Sclerotinia sclerotiorum*): A rapidly spreading, light brown ***watery rot*** develops on the ***stem*** either at ground level or on the branches. Parts of the plant above affected areas wilt and eventually die. Under humid conditions, the rotted areas become covered with white, fluffy fungal growth in which black ***sclerotia*** develop (usually 5-10 mm long but may be larger). Sclerotia are also formed ***inside*** affected areas. All tomato cultivars are ***susceptible***. See Vegetables M 7.

Sclerotium stem rot, southern blight (*Sclerotium rolfsii*) attacks ***stems*** at ground level, producing a conspicuous white threadlike growth which radiates out into the surrounding soil. Plants wilt and ***die*** rapidly. Small, brown, spherical ***sclerotia*** about the size of cabbage seed, develop on the fungal growth. See Vegetables M 8.

See Vegetables M 7.

Wilts are important in ***field*** and ***greenhouse crops***. Infection of young plants can ***completely destroy*** a crop.

Fusarium wilt (*Fusarium oxysporum* f.sp. *lycopersici*) causes yellowing of ***leaves*** near base of plant followed by wilting especially in hot weather. Often only 1 branch shows symptoms. Diseased leaves easily break from the stem, if bark is scraped from the plant just above ground level, the ***vascular system*** is brown. Plants eventually ***die***. There may be several races of *Fusarium* in some districts.

Verticillium wilt (*Verticillium dahliae*) causes similar symptoms to *Fusarium* and bacterial wilts with wilting, yellowing and death of leaves. If the stem is cut lengthwise a brown discolouration of the ***vascular tissue*** is seen.

Fusarium is ***favoured*** by acid soil below pH 6.5 and *Verticillium* by alkaline soils > pH 7.0. The best method of control is to plant ***resistant*** cultivars or plants grafted on to ***resistant rootstocks***. See Vegetables M 9.

NEMATODE DISEASES

Root knot nematodes (*Meloidogyne* spp.) may cause ***economic losses*** in tomato. Affected plants are stunted often paler green than normal and wilt readily in hot weather. In severe cases, plants are killed. Besides interfering with normal movement of water and food materials through the plant, root knot makes the plants more susceptible to root rots and vascular wilts. ***Young roots*** are invaded by nematodes and form ***galls*** (Fig. 363). Galls may be quite small or may grow up to 25 mm in diameter. Hybrids Red Supreme and Rich Reward are ***tolerant*** to root knot. See Vegetables M 10.

Others: ***Burrowing nematode*** (*Radopholus similis*), ***dagger nematode*** (*Xiphinema* sp.), ***foliar nematode*** (*Aphelenchoides avenae*), ***root lesion nematode*** (*Pratylenchus* spp.), ***stem and bulb nematodes*** (*Ditylenchus* spp.), ***spiral nematodes*** (*Helicotylenchus* spp.), *Filenchus* spp., *Hemicycliophora truncata, Macroposthonia ornata, Paraphelenchus* sp., *Paratrichodorus* spp., *Paurodontus apitica, Scutellonema brachyurum, Tylenchorhynchus* spp.,

INSECTS AND ALLIED PESTS

African black beetle (*Heteronychus arator*) is 12 mm long, oval and shining black. It chews ***stems*** at ground level causing sudden wilting and death. Injured stems of seedlings usually have a ragged teased out look. Newly planted tomatoes in coastal districts are often attacked in spring or autumn. ***Larvae*** are typical white curl grubs about 25 mm long. ***Other species*** may also attack tomato. See Turfgrasses L 7, Vegetables M 16.

Aphids (Aphididae, Hemiptera) may become sufficiently numerous to directly damage tomatoes by sucking plant sap. Heavy infestations result in ***leaf curl*** and the production of abundant ***honeydew***. But they are more important as ***vectors*** of virus diseases, yellow top, leaf shrivel and fern leaf.

Cowpea aphid (*Aphis craccivora*) is ***greenish-black*** winged, and about ***2.5 mm*** long. Colonies of wingless forms are produced. Infestation can cause stunting of ***young plants***. Many other crops may be infested as well as weeds. See Pea M 74.

Green peach aphid (*Myzus persicae*) is about ***2.5 mm*** long, and more active than potato aphid. Wingless adults are ***green*** to ***pale yellow*** or ***pink*** in colour, winged adults are ***green*** with darker markings. See Stone fruits F 129.

Potato aphid (*Macrosiphum euphorbiae*) is ***pale green*** to ***green*** and about ***3 mm*** long with rather long legs and slender prominent cornicles. See Potato M 80.

Favoured by cool, dry weather during spring and autumn. ***Natural enemies*** attack aphid colonies in spring and may reduce or eliminate infestation. Prevent weed growth around seedbeds and crops. ***Monitor*** aphid populations, aphids may be controlled with insecticides, regular spraying may be necessary. See Roses J 4, Vegetables M 11.

Bugs (Hemiptera) may suck sap from tomato ***fruit*** creating pale dry areas of tissue.

Green vegetable bug (*Nezara viridula*) is green shield-shaped and about ***13 mm*** long (Fig. 364). Ripening tomato ***fruit*** has tiny pale areas and is commonly hard. See Vegetables M 12.

Harlequin bug (*Dindymus versicolor*) is ***12 mm*** long and occasionally very destructive on tomato, feeding on the surface of ***fruit*** and creating pale dry areas of tissue. See Vegetables M 12.

Leptocoris bug (*Leptocoris mitellata*) sometimes leaves its native hosts and attacks cultivated plants and fruit trees, as well as tomatoes and other vegetables. ***Adults*** are narrow-bodied, winged, about ***12 mm*** long and are generally reddish-brown with light and dark markings. Underneath, the body is dull red with a dark green area in the middle of the abdomen. The legs and antennae are black. See Vegetables M 12.

Rutherglen bug (*Nysius vinitor*) is ***5 mm*** long and grey-brown. Adults may swarm on to ***terminal shoots, stems*** and ***fruit*** of tomatoes and quickly cause much damage. See Vegetables M 12.

Others: Green mirid (*Creontiades dilutus*), ***grey cluster bug*** (*Nysius clevelandensis*), ***tomato mirids*** (*Engytatus nicotianae, Nesidiocoris tenuis*).

See Vegetables M 12.

Caterpillars (Lepidoptera)

Corn earworm, tomato grub (*Helicoverpa armigera*) and ***native budworm*** (*H. punctigera*) are the ***most important pests*** of tomatoes. ***Caterpillars*** attack tomatoes from the time when the first flowers appear until the last fruits are forming. Caterpillars are variable in colour, ***40-50 mm*** long with a contrasting stripes along the side. They chew ***buds*** and ***blossoms*** and may cause them to fall. When very young caterpillars enter ***fruit***, usually near the stem end, they make small pinholes that are not easy to see. Larger caterpillars move from one fruit to another and entry holes may be ***3 mm*** or more across (Fig. 365). Feeding inside the fruit generally results in extensive breakdown and obvious damage. See Sweetcorn M 89.

Cluster caterpillar (*Spodoptera litura*) congregate in groups while feeding on ***leaf undersurfaces***. Later they disperse and feed singly on foliage or fruit. Mature caterpillars are ***40-50 mm*** long and usually brownish-purple with a series of dark triangular markings on each side of the body. Caterpillars mostly feed on leaf tissue but can also damage ***fruit***. See Brassicas M 40.

Cutworms (*Agrotis* spp.), Tasmanian cutworm (*Dasygaster padockina*), etc, are ***major pests*** of ***seedlings***. If tomato seedlings are planted out on land that has recently carried a crop of weeds, heavy losses requiring extensive replanting may occur in a few nights. Plants are cut off at ground level and the top section is left lying on the soil. Smooth dark or pinkish caterpillars that curls themselves into a small circle are found in nearby soil. See Seedlings N 68.

Egg-fruit caterpillar (*Sceliodes cordalis,* Pyralidae) infests eggplant, also tomato, capsicum, thornapple, and some native species of *Solanum*. ***Moths*** have a wingspan of about 25 mm, the wing colour is yellowish brown with lighter transverse markings. Prominent golden marks on the tips of the forewings edged with black. The wings are carried at an angle of about 45^{o} to the body, and the abdomen is bent up in a scorpion-like attitude. Moths are active at night and sluggish by day. ***Caterpillars*** are up to ***25 mm*** long, pink with a small brown head and a smooth glistening appearance. When young they have colourless bodies. Newly hatched caterpillars bore into the ***fruit***, usually at the stem end. Injury is difficult to see so infested fruit may be packed and the damage detected only when it arrives at the market. Damaged fruit breaks down and rots. Some caterpillars bore into ***stems***, causing plants to wilt. After emerging from the fruit, they spin a whitish silken cocoon about 15 mm long which is anchored by silken thread. There are ***many generations*** each season. Eggs are laid at night on fruit. ***Crop sanitation*** should be practised by removing susceptible weeds and old plants where successive plantings are proposed. ***Pesticides:*** If required, regular applications during the fruiting period should protect the plant satisfactorily.

Looper caterpillars (*Chrysodeixis* spp.) may be ***pests*** in spring and autumn in ***field*** and ***greenhouse crops***. Damage is usually only severe on ***maturing crops*** in autumn when spraying for budworms may have ceased. The pale green loopers are difficult to see as they feed on ***leaf undersurfaces***. They can be detected from the dark green and barrel-shaped pellets of excreta on leaves under the ones on which they are feeding. Caterpillars damage plants by eating large rounded holes in leaves and fruits. House sparrows eat loopers and may enter greenhouses to do so. See Vegetables M 13.

Potato moth (*Phthorimaea operculella*) may damage tomato. Caterpillars mine in ***leaf blades*** or enter the leaf stalks and bore down into ***stems*** producing brown blistered patches. The brown tissue withers and the leaf dies. Caterpillars also bore into ***fruit*** at the stem end. They may also enter where two fruits or a leaf and a fruit are in contact, feeding just under the skin. Such fruit may be invaded by rot organisms that cause the contents to break down and become watery. These grey 'water-bags' are usually characteristic of potato moth attack on tomatoes. See Potato M 81.

Tomato stem-borer (*Symmetrischema tangolias,* Gelechiidae). ***Moths*** are 12 mm long, greyish-brown with dark brown markings in the centre of the forewings. They lay their white eggs singly on foliage or stems after seedlings have been transplanted. If plants are young, caterpillars burrow straight into the ***stems*** but if plants are older, they enter ***leaves*** and tunnel through the leaf stalks until they reach the stems. ***Caterpillars*** are about ***12 mm*** long and greyish green or pink. Usually there are 3-6 caterpillars per plant. There are ***many generations*** each season. Caterpillars pupate inside stems. ***Favoured*** by warm coastal climates.

Others include ***lightbrown apple moth*** (*Epiphyas postvittana*).

See Annals A 8, Vegetables M 13.

Crickets, grasshoppers, locusts
(Orthoptera)

Australian plague locust (*Chortoicetes terminfera*)
Black field cricket (*Teleogryllus commodus*)
Migratory locust (*Locusta migratoria*)
Mole crickets (*Gryllotalpa* spp.)
Spur-throated locust (*Nomadacris guttulosa*)
Wingless grasshopper (*Phaulacridium vittatum*)

Tomato plants are sometimes attacked shortly after planting out by black field crickets that chew ***foliage and stalks***. Tomato crops in the tablelands of NSW may be invaded in late summer by wingless grasshoppers which strip tomatoes of foliage. See Vegetables M 13.

Flies (Diptera)

Atherigona, tomato fly (*Atherigona orientalis*) breeds in rotting plant and animal matter. It invades tomato ***fruits*** usually only after they are already damaged or rotting. ***Presence*** of atherigona above the prescribed level causes rejection by NZ (Fullelove 1992).

Ferment flies (*Drosophila* spp.) are attracted to fruit which is grown for ***processing*** and which remains on bushes until fully coloured. If the weather is unsuitable, cracking will be common. ***Flies*** are small, soft-bodied and about ***3 mm*** long. They lay their eggs in any injured ripening fruit and the white ***maggots*** grow up to ***4 mm*** long and mature in a week. See Fruit F 8.

Fruit flies (Tephritidae, Diptera), eg Mediterranean (*Ceratitis capitata*), Queensland fruit fly (*Bactrocera tryoni*) and cucumber fly (*B. cucumis*), are ***rarely important in commercial tomato crops***. Fruit fly ***maggots*** are commonly found in ***home garden*** tomatoes and capsicums after mid-summer when populations of flies have built up rapidly in early stone fruit. When the fruit are 'stung', maggot development proceeds normally, but firm fruit does not breakdown rapidly and quite large maggots may be found in fruits that seem sound. Once breakdown starts, it is usually rapid. A fruit fly sting is seen as a tiny pinhole, usually on the ripest section of the skin and it often exudes a ***drop of juice***. See Fruit F 9.

Metallic-green tomato fly (*Lamprolonchaea brouniana*) only attacks injured or split ***fruit***, eg if fruit is allowed to hang on the bush until it is ripe. ***Flies*** are stout, bright green and ***6 mm*** long. ***Maggots*** are sometimes mistaken for fruit fly larvae. Like true fruit fly maggots and their many relatives, they are capable of ***skipping*** for a distance of several centimetres. Avoid infestation by removing and destroying ripe and damaged fruit from bushes. Good control of other tomato pests reduces the infestation.

Greenhouse whitefly (*Trialeurodes vaporariorum*) when numerous may injure tomatoes. They appear as swarms of tiny (1.5 mm long) delicate white 4-winged insects that fly out from plants when disturbed, and settle back again after a short time. They feed by sucking sap mainly from the ***leaf undersurfaces*** of soft succulent leaves. See Greenhouses N 24, Vegetables M 15.

Leafhoppers, jassids (Cicadellidae, Hemiptera)

Vegetable leafhopper, tomato leafhopper (*Austroasca viridigrisea*) is small, torpedo-shaped, green or greenish yellow, about ***4 mm*** long with 2 pairs of wings. They suck sap from leaves and fruit. Punctures on ***leaves*** show up as small dots of white tissue. Numerous dots may run together, leaves may curl up at the edges and die. Heavily infested plants become stunted and grey. ***Fruit*** may be attacked, faint whitish spots and small specks of excreta are scattered on the surface. See Vegetables M 15.

Common brown leafhopper (*Orosius argentatus*) transmits tomato big bud mycoplasma from weeds and other plants to tomatoes. See Vegetables M 15.

Others: Delphacid planthoppers (Delphacidae) may also infest tomato.

Mites (Acarina)

Eriophyid mites (Eriophyidae) are ***microscopic*** and are ***< 0.25 mm*** long, torpedo-shaped and cream with 4 legs at the front end of the body. They breed very rapidly and can complete their life cycle in 6 days. ***Tomato erineum mite*** (*Eriophyes lycopersici*) damage Solanaceae, eg tomato, eggplant, during summer and autumn. Eggs are laid on leaves. Damage causes excessive hairlike growths which look like white mould, on leaves and stems. ***Favoured*** by dry seasons. ***Tomato russet mite,*** bronze surface mite (*Aculops lycopersici*) may be a ***major pest*** of tomatoes. It also attacks other solanaceae, eg Cape gooseberry, petunia, potato, tobacco, pepper, wild gooseberry, nightshade. ***Leaves*** become silvery, then bronzed underneath, later curled downwards and dry. Leaves die progressively from the bottom of the plant until only top growth remains green. ***Stems*** and ***leaf***

stalks become brown and smooth. ***Blossoms*** may fall. ***Fruit*** may be rusty and corky. When symptoms are obvious, mites will have moved up to fresh green tissue and will not be found on bronzed areas. Further bronzing will appear even after mites have been killed by spraying, the result of feeding before treatment. ***Overwinters*** on weeds in sheltered sites. ***Spread*** by mechanical transfer on visiting insects, birds or workers, and by wind transport on their own or on shrivelled leaves. ***Favoured*** by warm dry weather during summer and autumn. Commence treatment in seedbeds at the first sign of infestation which should be remote from old tomato beds and host weeds. See Grapevine F 62.

Spider mites (Tetranychidae)

Brown almond mite, bryobia mite (*Bryobia rubrioculus*)
European red mite (*Panonychus ulmi*)
Bean spider mite (*Tetranychus ludeni*)
Twospotted mite (*T. urticae*)

Twospotted and ***bean spider mites*** suck plant sap from ***leaf undersurfaces,*** but in heavy infestations leaf uppersurfaces are also infested and webbing may be present. Leaves become mottled or speckled, and may fall. ***Do not confuse*** twospotted injury to leaves with damage caused by leafhoppers, whiteflies, thrips or deficiencies. See Beans (French) M 29, Trees K 24 (Table 3), Vegetables M 16.

Others: Occasionally other mites, eg ***earth mites*** (Penthaleidae), may infest tomato.

Potato ladybirds (*Epilachna* spp.) attack tomatoes growing near infested potato crops or solanaceous weeds, eg thornapple. ***Larvae*** are oval, spiny and brown and yellow. ***Beetles*** are orange with dark spots. ***Insecticides*** are registered for control. See Potato M 81.

Thrips (Thripidae, Hemiptera) may transit tomato spotted wilt virus ***(TSWV).*** Thrips are brownish, tiny, elongate, 1-2 mm long and have 2 pairs of delicate fringed wings.

Onion thrips (*Thrips tabaci*) does little damage to tomatoes but it is a ***vector*** for ***TSWV.*** They breed on weeds or garden plants and migrate to tomatoes, carrying the virus with them, especially when weeds die off. See Onion M 68.

Plague thrips (*Thrips imaginis*) is a minor pest. It looks like onion thrips but feeds mostly in the ***flowers***. See Roses J 6.

Western flower thrips (*F. occidentalis*) may also ***transmit TSWV***. After eggs hatch, nymphs feed on infected plants and become infected throughout their life cycle which is about 30-45 days. They move from plant to plant feeding. See Annuals A 9.

Others: Melon thrips, eastern yellow thrips (*Thrips palmi*), ***tomato thrips*** (*Frankliniella schultzei*).

Weevils (Curculionidae)

Vegetable weevil (*Listroderes difficilis*) and its larva may damage tomatoes at night by chewing ***leaves*** and leaving only bare stalks. ***Larvae*** are about ***13 mm*** long, legless, pale green or creamy, and are found in ***soil*** and in centres of ***shoots***. See Vegetables M 17.

Whitefringed weevil (*Graphognathus leucoloma*) is slaty-grey, about ***12 mm long***, and may invade the crop from adjoining weed growth or pasture and strip plants. Larvae are legless, thick-set, white or grey, they gouge out furrows in ***roots*** and are usually found in the ***soil*** nearby. See Vegetables M 17.

Wireworms (Elateridae) and ***false wireworms*** (Tenebrionidae) may attack tomatoes planted out in land recently under pasture, chewing the roots and sometimes boring up into the stems from just below the soil surface. ***Northern false wireworm*** (*Gonocephalum carpentariae*) and its adult beetles may be sporadic pests of tomato and capsicum seedlings. See Seedlings N 69.

Others: ***Ants*** (Formicidae), ***earwigs*** (Dermaptera), ***mealybugs*** (Pseudococcidae), ***pumpkin beetles*** (*Aulocophora* spp.), ***slaters*** (*Porcellio* spp.).

SNAILS AND SLUGS

Various species especially ***slugs*** may feed on fruit. See Seedlings N 70.

Non-parasitic

Environment: Tomato are sensitive to ***frost***. Field temperatures < $4^{o}C$ may lead to freezing of ***foliage*** and ***fruit*** in the field. ***Temperature control*** in growing, marketing and handling (storage and transport) is ***very important.*** To achieve good quality tomatoes, tomatoes should be ripened at $18\text{-}22^{o}C$ and transported and stored at $10\text{-}18^{o}C$. ***Fruit cracking, star cracking*** is caused by rapid growth following favourable weather conditions of high temperatures and good soil moisture. Developing fruit may show star cracks at the stem end, or circular cracks around the upper part of the fruit (Fig. 366). Cracks can be deep or shallow and may form slowly or quickly. Infection by fruit-rotting fungi may occur. Avoid irrigation just before harvest. ***Upward leaf rolling*** is due to high soil moisture or excessive pruning. In severe cases the rolled surfaces completely overlap. Up to ***75%*** of leaves may be affected. Rolling occurs first on the older leaves. Rolled leaves are firm, leathery and thickened and plants appear to be affected by a viral disease. Do not confuse this condition with potato leafroll virus which does not affect tomatoes. Avoid excessive irrigation and provide adequate drainage. Prune only according to the cultivar's requirements. ***Puffiness (hollow fruit):*** Affected fruit are soft, light in weight, walls may be flattened. Internally, there is little or no seed, a slimy gel and some hollowness. Usually caused by lack of pollination due to ***very hot or very cold*** weather, or excess ***nitrogen***. Cultivars vary in susceptibility. ***Sunscald*** is common in hot areas on sparsely foliated varieties. The sun burns the ***fruit*** causing a white to yellow hard patch on the exposed side, usually towards the stem end or shoulder (Fig. 367). It is most common on immature green fruit but may affect fruit at later stages. As affected fruit ripen, the scalded areas form large flattened, greyish-white spots with a dry paper-like surface. Sometimes superficial moulds develop on the scald and produce internal rotting. Sunscald is usually associated with ***diseases***, eg target spot, and ***pests***, eg tomato mite, which ***prematurely defoliate plants*** and expose fruit to direct sunlight. Control defoliating diseases and pests. ***Blossom drop*** is a common problem caused by ***unsatisfactory pollination*** or ***stress*** from very high or low temperatures, low soil moisture and hot drying winds, sudden cold weather and driving rain, excessive applications of nitrogenous fertilisers or animal manures, or diseases. ***Catface*** is caused by faulty pollination or injury to flowers resulting in malformation and scarring of the blossom end of fruit. Affected fruit may ripen unevenly and are unfit for market. ***Favoured*** by continued cool weather during blossoming, and injuries which cause flower parts to develop abnormally. Varieties vary in ***susceptibility***. ***Other physiological diseases*** are described by Fullelove (1992) and in various State or Territory leaflets.

Nutrient deficiencies, toxicities: ***Leaf analysis standards*** are available for tomatoes (Weir and Cresswell 1993). Common deficiencies on to tomato are described by Fullelove (1992). ***Blossom-end rot (BER)*** is caused by a ***calcium deficiency*** in the blossom end of the developing fruit. It may occur on tomato and watermelon. A watersoaked area develops on the blossom end of the fruit, which turns black or deep brown and becomes leathery and sunken (Fig. 368). ***Secondary fungal growth*** may develop. Sometimes the dead tissue is not visible from the outside but as an ***internal dark brown***, corky mass up to 25 mm from the blossom end. Disease is most common when fruit is about half-grown. ***BER*** occurs when water loss from the leaves is high and soil moisture levels are low (dry conditions preceded by periods of high soil moisture). Water and calcium are withdrawn from the fruit. To minimise ***BER*** provide an even supply of moisture throughout growth, avoid excess nitrogen that produces large leafy plants with high water demand, avoid acidifying fertilisers. In commercial crops, when conditions favour ***BER***, calcium nitrate may be applied at appropriate times.

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Glasshouse Tomato Production (SA Agric Market Development Paper No. 12.)
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Tomato : Yellow Top Virus (NSW Agfact, WA Farmnote)

NSW Agfacts

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A Rapid Nitrate Field Test for Vegetable Crops
Bacterial Canker of Tomato
Bacterial Wilt of Brown Rot of Tomato
Blossom-end Rot of Tomatoes
Capsicum Growing
Capsicums in the Home Garden
Diseases of Tomato
Early Tomatoes in the Home Garden
Eggplant Growing
Growing Tomatoes for the Fresh Market
Pests of Tomato
Ripening Tomatoes with Ethylene using the Trickle System
Target Spot of Tomato
Temperatures for Tomatoes
Tomato Big Bud
Tomato Mosaic Complex
Tomato Ripening Guide
Tomato Spotted Wilt

Vic Agnotes

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Arcadia : A New Fresh Market Tomato for Early Harvest
Early Tomato Production in the Mallee
Goulburn : A New Fresh Market Tomato
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Pruning, Tying and Support of Tomatoes
Tomatoes for Processing : Machine Harvested
Tomatoes for the Fresh Market
Tomatoes for Fresh Market : Control of Diseases
Tomatoes for Fresh Market : Control of Pests
Tomatoes for Processing : Pest and Disease Control
Tomatoes : Root Knot Nematode
Tomatoes : Weed Control
Tomato Processing Industry Legislation

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Tomato Pests and Their Control
Tomato Wilt : Causes and Control

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TomCHECK

See Hydroponic systems N 43, Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Most States/Territories have management programs for commercial tomato crops (Fullelove 1992). An ***overview of the industry*** is presented by Coombs (1995). New initiatives to develop more sustainable production systems for tomatoes and to introduce a benchmarking system (TomCHECK) for improving crop management practices is being developed (Coombs 1995). Control of pests and diseases is necessary to produce a vigorous, high yielding crop that will grow and mature uniformly. A few pests are ***serious regular threats*** and others may cause losses from time to time depending on the area, eg on coastal crops. In most areas damage by ***corn earworm*** (*Helicoverpa armigera*) and ***native budworm*** (*H. punctigera*) is likely from the start of flowering onwards, other caterpillars will also attack tomatoes but measures used to control *Helicoverpa* spp. will usually control these. ***Thrips*** spread ***TSWV***, ***aphids*** spread other viruses. ***Resistance*** by some important pests, eg *Helicoverpa*, tomato russet mite, and green peach aphid, to some insecticides now complicates the application of insecticides.

Selection

Tomatoes are grown for the fresh market, processing for canning, drying. ***Cultivars should be selected*** according to a particular district and season, field or greenhouse crop, hydroponic or organic system. Select cultivars or rootstocks with ***some resistance*** to local problems, eg wilts, virus, nematodes, etc. Only plant ***disease-free planting material***, eg certified seed, or save seed from selected healthy plants. ***Treat seed*** for seedborne viruses, bacterial and fungal diseases. ***Before sowing***, treat/dust all seed to reduce losses from damping off in seedbeds, especially hot water treated seed, which is prone to attack by soilborne fungi after planting, eg damping off .

Establishment and Maintenance

Propagated by seeds, grafting on to ***rootstock*** to prove increased ***vigour and resistance*** to specified diseases. Multi-celled polystyrene trays for nursery production, reduce root damage, susceptibility to soilborne diseases, eliminates transplant shock and produces even-sized plants. Diseases and disease control methods ***depend on how and where the crop is grown***, eg greenhouse or field grown, and locality, eg coastal, inland, NSW or WA. Most plants are transplanted from seedlings raised in a nursery. To prevent damping off and infection of seedlings by fungi, bacteria and nematodes seedlings should be raised in sterilised soil, seedbeds should be well drained and for early crops, and should be covered against cold and saturation. ***Cultural methods:*** A frost-free period of at least 120 days is needed to grow tomatoes without frost protection. A mean temperature of ***21-24^{o}C*** is optimum for growth and good fruit quality. Practise ***crop rotations*** of 4-5 years. There is little danger of infection from soilborne diseases on virgin land. It is unwise to use the same land year after year for seedbeds or cropping. ***Prepare land*** for tomatoes early. Preferably cover crop with plants, eg cowpeas, which are unsuitable for African black beetle and vegetable weevil development. If this is not done then keep land clear of weeds for several weeks prior to planting tomatoes. These practices reduce the incidence of soilborne pests. ***Pre-plant soil treatments:*** Soil fumigation or nematicides are used to control soilborne diseases, eg *Fusarium* and *Verticillium* wilts, and root knot nematodes that buildup in areas where tomatoes are grown continuously in greenhouses and in the field. Soil solarisation gives variable results. Scarab grubs and wireworms may also be problems. Tomatoes must be planted in suitable soil and have an effective root depth of 200 mm, to benefit from fertilising and irrigation. Space plants appropriately, tomatoes have a high demand for nutrients. Plants may require staking and training ***Sanitation:*** ***Roguing*** involves removing disease-affected or undesirable plants and is particularly important when diseases such as mosaic, streak or bacterial canker develop. These diseases are readily carried from plant to plant, especially by pruning, so any plants affected by these diseases should be pulled out and burnt. If you suspect, but are not certain, that any of these diseases are present, prune healthy plants first. Burn/deeply bury all plants as soon as harvest is complete. ***Weed control*** in tomatoes is based on cultivation, mulching and herbicides. Cultivation may damage surface roots, and regular cultivation also destroys the soil structure increasing the risk of soil erosion. Herbicides may be applied at transplanting. ***Effective weed control*** increases yields, reduces fluctuations in moisture and allows the roots to develop throughout the bed. Solanaceous weeds enable diseases to persist in uncropped soil. ***Pesticides:*** Fungicides, insecticides and herbicides are registered for use in tomato crops. ***Growth regulators*** are used for advancing maturity, improving growth, yield, set, increasing size for ripening.

Postharvest

Harvest at the correct stage. ***Quality standards*** are available for tomatoes (OECD cur. end). A tomato is considered to be mature when it begins to develop a white star and a pinkish tinge on the blossom-end of the fruit. Fruit to be transported a long distance is often harvested at this stage. Mature fruit can be ***ripened uniformly*** using ethylene, a natural gas, which causes fruit to ripen. Crops may be mechanically harvested. After harvest tomatoes should be ***cooled in about 12 hours*** to the required temperature. Tomatoes may be ***stored and transported*** at 13^{o}C at a moderate relative humidity (85-90%) for an estimated storage life of 2-3 weeks (Salvestrin 1991).

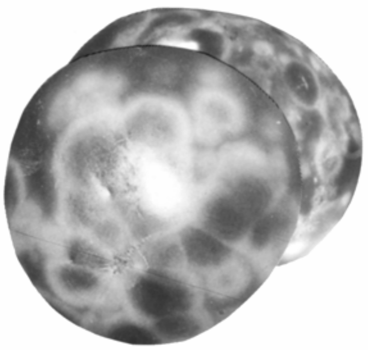

Fig. 360. Tomato spotted wilt virus. Circular blotching on fruit.

Fig. 361. Tomato big bud mycoplasma. ***Left :*** Stiff upright shoots. ***Centre :*** Stem splitting, root initials. ***Right :*** Small, hard, green fruit.

Fig. 362. Early blight, target spot (*Alternaria solani*), spots on leaves. Dept. of Agric., NSW.

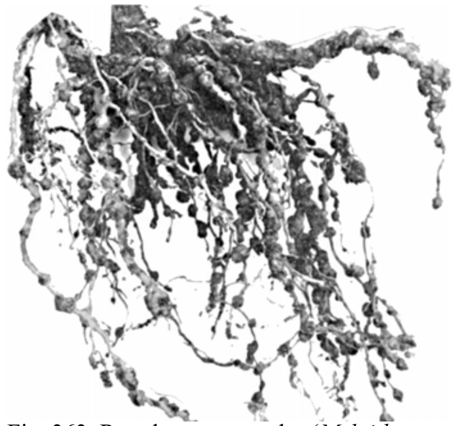

Fig. 363. Root knot nematodes (*Meloidogyne* spp.) cause small galls on roots. Dept. of Agric., NSW.

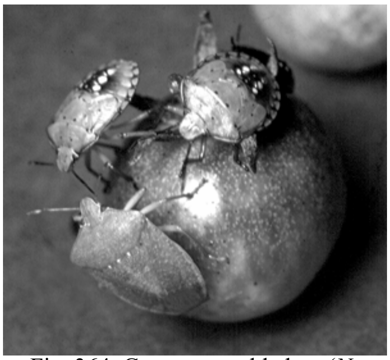

Fig. 364. Green vegetable bug (*Nezara viridula*). Adult and nymphs sucking sap from fruit.

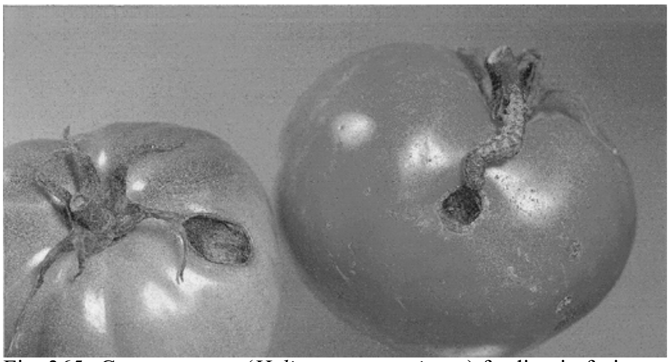

Fig. 365. Corn earworm (*Helicoverpa armigera*) feeding in fruit.

Fig. 366. Fruit cracking. Dept. of Agric., NSW.

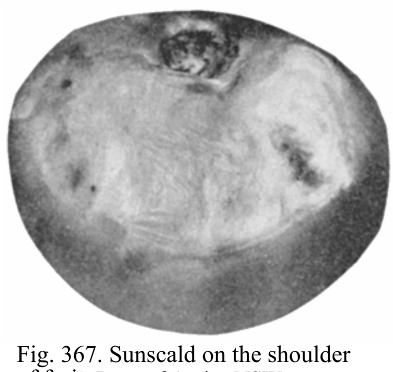

Fig. 367. Sunscald on the shoulder of fruit. Dept. of Agric., NSW.

Fig. 368. Blossom-end rot. Dept. of Agric., NSW.

Other Plantings

Fig. 369. Kennedya yellow mosaic virus on *Kennedia* sp.

Fig. 370. Canker (*Cytospora eucalypticola*) on eucalypt. D. G. Parbery.

Fig. 371. Corky leaf spot (*Aulographina eucalypti*) on *Eucalyptus resinifera*. B. A Fuhrer.

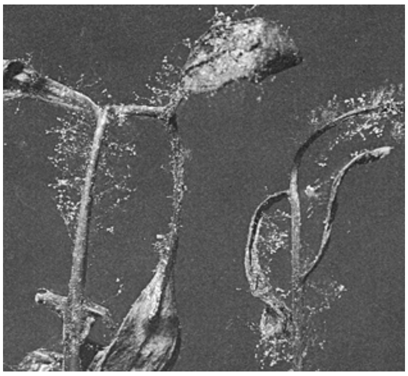

Fig. 372. Grey mould (*Botrytis cinerea*) on *Callistemon* shoots. B. A. Fuhrer.

Fig. 373. Armillaria root rot (*Armillaria luteobubalina*). Fresh white rhizomorphs under bark of *E. fastigata.* G. C. Marks.

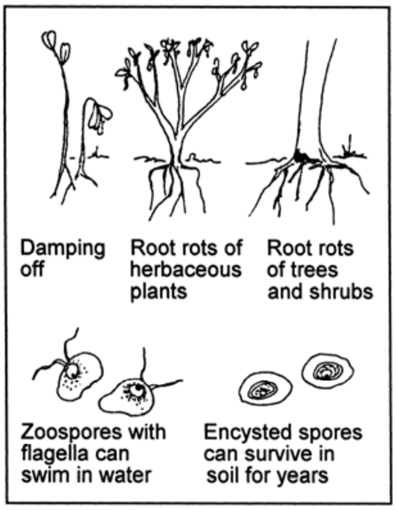

Fig. 374. Phytophthora root rot (*Phytophthora* spp.).

OTHER PLANTINGS N 1

Australian Native Plants

PESTS AND DISEASES
Parasitic
- Virus and virus-like diseases
- Bacterial diseases
- Fungal diseases
  - Cankers
  - Damping off
  - Fungal leaf spots
  - Grey mould
  - Powdery mildews
  - Root, crown and collar rots
  - Rusts
  - Smuts
  - Wilts
  - Wood rots
- Parasitic plants
- Nematode diseases
- Insects and allied pests
  - Aphids
  - Borers
  - Bugs
  - Caterpillars
  - European earwig
  - Froghoppers, spittle bugs, leafhoppers, planthoppers, treehoppers (*Summary*)
  - Gall insects
  - Grasshoppers, katydids, locusts
  - Leafeating beetles
  - Leafminers
  - Lerps, psyllids
  - Mealybugs
  - Mites
  - Sawflies
  - Scales
  - Seed insects
  - Stick insects, leaf insects
  - Termites
  - Thrips
  - Tip borers
  - Weevils
  - Whiteflies
- Snails and slugs
- Vertebrate pests

Non-parasitic
  - Environment
  - Fire adaptation
  - Genetic problems
  - Humans
  - Medicinal uses, fodder and food
  - Nutrient deficiencies, toxicities
  - Sooty mould

WEEDS

Probably the most important problems are the ***soil-borne fungal diseases*** (*Phytophthora cinnamomi* and *Armillaria luteobubalina*), ***foliage-feeding insect pests*** and ***destruction of native habitat by humans*** due to clearing of forest areas for agriculture, horticulture, mining, forestry and wildflower cutting. Individually, Australian native plants are susceptible to particular diseases and pests in the same way that introduced plants are.

Introduced diseases and pests may attack ***Australian native plants***.

Diseases: ***Phytophthora root rot*** (*Phytophthora cinnamomi*) is considered to be an introduced disease which can attack a wide range of both introduced and native plants. See Trees K 6.

Pests: ***Corn earworms*** (*Helicoverpa* spp.) may feed in flowers and buds. ***Cineraria leafminer*** (*Chromatomyia syngenesiae*) maggots may mine in the leaves of *Helichrysum*. ***White wax scale*** (*Gascardia destructor*), a pest of introduced citrus and other plants, also infests *Boronia* and *Senecio*.

Australian native diseases and pests may attack ***introduced plants***.

Diseases: ***Rust*** (*Puccinia lagenophorae*), which can severely damage native *Lagenophora*, *Senecio* and other Asteraceae, also attacks introduced calendula and English daisy (*Bellis perennis*).

Pests: ***Painted apple moth***, painted wattle moth (*Teia anartoides*) caterpillars originally fed mainly on wattles now also feed on a wide range of introduced plants. ***Native budworm*** (*Helicoverpa punctigera*) caterpillars, in addition to their native hosts, feed in the buds and flowers of many introduced plants including cotton.

Australian native plants grown ***overseas*** may be attacked in these countries by diseases or pests which are not presently in Australia, eg ***rust*** (*Puccinia psidii*) may attack ***eucalypts*** overseas. There is then the possibility of introducing these diseases or pests into Australia if these plants re-enter Australia.

The increased cultivation of ***intensively managed*** native species as monocultures is likely to result in an increase in diseases and pests.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Compared with introduced plants, Australian native plants suffer from relatively few virus diseases. This may be due to the fact that relatively few have been tested for viruses, that virus diseases are mostly researched on plants of economic importance and that most species of fruit, nut, vegetables and field crops have been imported. Also, most virus diseases of annual and herbaceous perennial plants are spread by sucking insects (aphids, thrips, leafhoppers) which are generally scarce in Australia on native plants.

Viruses present in ***introduced species*** where there are also ***native species***.

Cassia (Fabaceae): Bean yellow mosaic virus, cassia yellow blotch virus, clover yellow vein virus, passion fruit woodiness virus, tomato spotted wilt virus.
Cymbidium (Orchidaceae): Cymbidium mosaic virus, odontoglossum ringspot virus, orchid fleck virus, tomato spotted wilt virus.
Ranunculus (Ranunculaceae): Tomato spotted wilt virus.
Rubus (Rosaceae): Raspberry bushy dwarf virus, tobacco streak virus.
Senecio (Asteraceae): Cucumber mosaic virus, beet western yellows virus, tomato spotted wilt virus.
Vanda (Orchidaceae): Cymbidium mosaic virus, odontoglossum ringspot virus.
Viola (Violaceae): Cucumber mosaic virus, tomato spotted wilt virus.

Virus diseases recorded in ***native plants***.

Cunjevoi (*Alocasia macrorrhizos*, Araceae): Dasheen mosaic virus.
Crassula sp. (Crassulaceae): Cucumber mosaic virus.
Duboisia (Solanaceae): Tomato spotted wilt virus
Glycine (Fabaceae): Alfalfa mosaic virus, glycine mosaic virus, glycine mottle virus. Lucerne (Australian) latent virus, passionfruit woodiness virus, peanut mottle virus, potato Y virus, soybean mosaic virus, sunflower ringspot virus and others occur in the introduced soybean (*Glycine max*).
Indigofera australis: Kennedya yellow mosaic virus.
Kennedia coccinea (Fabaceae): Potato Y virus
K. rubicunda: Kennedya Y virus, Kennedya yellow mosaic virus (Fig. 369).
Phaius, Orchidaceae: Cymbidium mosaic virus, odontoglossum ringspot virus, tobacco mosaic virus.
Sturt pea (*Clianthus formosus*), Fabaceae: Bean yellow mosaic virus. Also tomato spotted wilt in *Clianthus* sp.

Do not propagate vegetatively from virus-infected plants. See Annuals A 4, Trees K 4.

BACTERIAL DISEASES

Australian native plants suffer from relatively few known bacterial diseases. Examples include ***crown gall*** (*Agrobacterium* sp.) which mainly occurs in cultivated soils and appears to be unknown in undisturbed areas. ***Susceptible*** Australian native plants include *Abutilon*, *Araucaria*, *Brachychiton*, *Cordyline australis*, *Eucalyptus tereticornis*, *Ficus benjamina, Lythrum salicaria*. ***Omalanthus populifolius*** in the tropics is often disfigured by a bacterial disease.

FUNGAL DISEASES

The native flora of Australia has evolved in such a way as to render it resistant to many of the fungi (and bacteria) that commonly infect introduced cultivated flower crops. Many of the Australian native plants have a tough sclerophyllous foliage which makes it difficult for pathogens, eg downy mildews, to gain access particularly in their natural undisturbed habitats. Root tissue of these plants also tends to be woodier than that of exotic plants, making them less accessible for common root attacking fungi, eg *Rhizoctonia* and *Pythium*.

Families most affected by Phytophthora, Armillaria, stem cankers, leaf spots and blight include Proteaceae, Myrtaceae, Papilionaceae, Haemodoraceae, Goodeniaceae, Epacridaceae, Poaceae and Chenopodiaceae. These families seem to be least affected by rusts (Shearer 1994).
Families most affected by rusts, eg Cyperaceae, Restionaceae and Orchidaceae, seem to be least affected by *Phytophthora*, *Armillaria*, stem canker, leaf spots and blight.

Cankers (probably > 50 different genera of fungi) may affect trunks, stems and branches of many native plants (Shearer 1994, Wills and Keighery 1994). In WA cankers occur mainly in the Proteaceae and Myrtaceae.

Botryosphaeria ribis affects many plants including eucalypt and banksia (especially *B. speciosa*).
Cryptodiaporthe (= *Diplodina*) cause diffuse cankers and high mortality of *Banksia coccinea*, *B. grandis* and *Dryandra sessilis*. Possibly endemic with limited host range in the Proteaceae.
Cytospora spp. affects eucalypt (Fig. 370), eg tuart.
Endothia gyrosa in WA causes large target-like cankers on marri, tuart and other eucalypts causing crown decline and mortality.
Sporotrichum destructor affects red-flowering gum (*E. ficifolia*) and enters through bark injuries and causes large cankers on stems and trunks. These swell and split to reveal wood beneath and become coated with a powdery mass of white spores. Leaves and small branches wither, larger branches and trees ***die***. *S. destructor* also attacks *E. calophylla* and *E. haematoxylin* in WA, but with less vigour than on red-flowering gum. Stem canker is mainly found on cultivated trees, not those grown naturally.
Others: Canker fungi have been associated with crown decline in wandoo (*E. wandoo*). ***Phomopsis*** has been isolated from dying branches of *Calothamnus quadrifidus* (Wills and Keighery 1994). ***Zythiostroma*** causes stem cankers of *B. baxteri*.

Cankers are considered to be ***favoured*** by stress, eg unusual weather (6 months rain deficiency followed by a heat wave). See Trees K 5.

Damping off (*Botrytis cinerea, Cylindrocladium* sp., *Pythium* spp. *Phytophthora* spp., *Rhizoctonia* spp.). Australian native plants are ***susceptible*** to damping off diseases in nurseries in the same way that introduced plants are. See Seedlings N 66.

Fungal leaf spots are ***relatively common*** and affect a range of Australian species (Fig. 371). They appear as black or dark brown spots on foliage and may cause leaf fall, however, many of them are of little significance except that they are unsightly. There are at least 2 pathogenic fungi for every plant species and there are almost 25,000 species of flowering plants described from Australia (Pascoe and Sutton 1987), eg

173 from *Acacia* including *Colletogloeum* (17 spp.)

119 from *Banksia*	41 from *Correa*
34 from *Leptospermum*	34 from *Olearia*
12 from *Melaleuca*	13 from *Callistemon*.

Kangaroo paws (*Anigozanthos* spp.), especially the red and green kangaroo paw (*A. manglesii*) and some *A. flavidus* hybrids, may be seriously affected by ***ink spot*** (*Alternaria alternata*).
Parahebe perfoliata is an example of a native plant which is ***severely affected*** by leaf spotting fungi. This is the principal reason for that plant's lack of popularity as an ornamental.

The common foliar diseases of native flowers rarely cause plant losses but their presence affects the marketability of blooms and foliage. Their control is necessary for the successful cultivation of native flowers and foliage. See Annuals A 5.

Grey mould (*Botrytis cinerea*) is mainly a problem on ***seedlings and cuttings***, but may also affect ***leaves, stems and flowers*** of fineleaved species, eg *Astroloma ciliatum, Callistemon* (Fig. 372), *Eremophila, Grevillea pilulifera, Thryptomene*. A grey fungal mass of spores develops on the unsightly lesions in shaded situations. See Greenhouses N 22.

Powdery mildews (Erysiphales) cause a white mealy growth on ***leaf upper and undersurfaces*** and ***stems***. Powdery mildews which do not normally attack foliage in the bush can become important under cultivation especially during the production of seedlings in humid microclimates of nurseries. As well as being a problem in ***nurseries***, these diseases can damage plants in the ***field*** especially under close spacing and overhead watering. Fungicide sprays can control these diseases in a nursery situation. See Annuals A 6.

Root, crown and collar rots

Armillaria root rot, straw rot (*Armillaria* spp.) possibly has a wider host range than *Phytophthora cinnamomi*. *A. luteobubalina* mostly attacks ***woody perennials*** (Fig. 373) in the ***Proteaceae***, eg *Banksia brownii*, *B. occidentalis formosa,* ***Myrtaceae***, eg jarrah, karri, tuart, wandoo, ***Papilionaceae***, ***Epacridaceae*** and ***Mimosaceae***, eg wattle, and is replaced in the bush areas by field resistant herbaceous perennials (Shearer 1994). Also *Callistris preisii*. *Armillaria* kills ***broom bush*** (*Choretum glomeratum*) which is the only food plant of the larvae of the rare brown ***azure butterfly*** (*Ogyris otames*) (Wills and Keighery 1994). See Trees K 4.

Phytophthora root rot, cinnamon fungus, jarrah dieback (*Phytophthora cinnamomi* ***(Pc)***, *Phytophthora* spp., *P. nicotianae*, *P. citricola*, *P. megasperma)*. These fungi (Fig. 374) occur throughout Australia but have been most studied in WA. They cause debilitating root problems and are a ***major threat to wild flower production***, in particular the cultivation of several native flower species in WA, eg banksia, boronia, dryandra, eucalypt, Geraldton wax. Most species in the Proteaceae, Papilionaceae and Epacridaceae are susceptible and a few in the Myrtaceae. ***Pc*** attacks 1,500-2,000 of the 9,000 species in the southwest of WA mostly woody perennials which are replaced by herbaceous perennials (James 1994). The first symptom is wilting of new growth followed by a decline and death over a period of time, trees may take years to die. In wildflower production ***Pc*** is considered to kill **>** ***50% of plants*** in some commercial native crops. ***Pc*** is the most destructive *Phytophthora* species of the seven species found in south west of WA. ***Pc*** is listed as one of the 5 key threatening processes under the ***Endangered Species Protection Act 1992*** and has a major effect on Australian biodiversity in WA and other states (Bridgewater and Edgar 1994,). Species endangered due to ***Pc*** include *B. brownii.* Communities severely affected by ***Pc*** are more prone to weed invasion and larger communities may become less complex (Wilson et al. 1994) and dominated by fewer resistant species, eg dominant banksia trees may become extinct locally (Kieghery et al. 1994). ***Epacridaceae*** and ***Proteaceae*** are replaced by ***monocotyledons***, eg rushes and sedges (Websdane et al. 1994). ***Pc*** is the main reason for the WA Nursery Accreditation Scheme. See Trees K 6.

Others: Pythium, ***Rhizoctonia*** and other species may cause root problems. .

See Trees K 7, Vegetables M 7.

Rusts (Uredinales) may severely affect some Australian plants (Shearer 1994). Families mainly affected include Asteraceae, Colchicaceae, Chenopodiaceae, Goodeniaceae, Haemodoraceae, Poaceae, Mimosaceae, Orchidaceae. ***Fireweed*** (*Senecio lautus* subsp. *maritimus*) leaves are commonly covered in rust (*Puccinia lagenophorae*), plants may die. ***Australian hollyhock*** (*Lavatera plebeia*) is attacked by *P. malvacearum*. ***Kangaroo paws***, cat's paws, *Conostylis* and *Hemodorum* are attacked by (*Puccinia hemodori*). ***Orchids*** by *Puccinia* and *Uromyces,* which may reduce flowering and survival of endangered species. ***Wattles*** are attacked by many species of rusts including rust galls (*Uromycladium* spp. (Fig. 375), especially *U. tepperianum*) causing the production of large woody rust-coloured galls on stems and developing seed pods, severely affected trees may die. See Annuals A 7, Orchids G 4, Wattle K 131.

Smuts (Ustilaginales) commonly affect native ***rushes*** (Restionaceae) and ***sedges*** (Cyperaceae) which are considered to have some resistance to *Phytophthora* and stem canker fungi in WA (Websdane et al. 1994). They often increase in wild sites affected by ***Pc*** and their use as barrier planting to protect ***Pc*** susceptible plantings is being researched. Most smuts are systemic within the host and produce their spores in its inflorescence so there is a ***loss of seed***. An exception is culm smut (*Ustilago lyginiae*). Some smuts may cause localised extinction of host species. Smut diseases may affect sustainability of bush harvesting and export requirements. See Dahlia C 24, Onion M 67, Sweetcorn M 88, Turfgrasses L 7.

Wilts: With the exception of ***myrtle wilt*** (*Chalara australis*) of myrtle (*Nothofagus cunninghamii*) in Tasmania and Victoria, wilt diseases of annual, herbaceous perennial and woody native plants have been little researched. See Trees K 7, Vegetables M 9.

Wood rots (Basidiomycetes) attack many native trees. Common wood rots include:
Common honeycomb (*Osmoporus gunni*)
Luminous toadstool (*Pleurotus* sp.)
Red wood rot (*Pycnosporus* spp.)
Ring-barking fuscoporia (*Fuscoporia laevigata)*
Tinder punks (*Phellinus* spp.) (Fig. 376)
Yellowish wood rot (*Polyporus versicolor*)
Others, eg *Fomes, Ganoderma, Poria*
Many wood rot fungi can decay ***stumps and logs*** of softwoods and hardwoods (stump removers), eg golden tuft mushroom (*Gymnopilus pampeanus*), *Poria* spp. *Peniophora gigantea* (Marks et al. 1982). See Trees K 8.

PARASITIC PLANTS

There are many parasitic plants which affect both native and exotic plant species.
Broomrape (*Orobanche* spp., Orobanchaceae)
Devil's twine (*Cassytha* spp., Lauraceae)
Dodder (*Cuscuta* spp., Convolvulaceae)
True mistletoe (*Amyema*, *Dendrophthoe*, *Notothixos*)
Native cherry (*Exocarpos* spp.)
West Australian Christmas tree (*Nuytsia floribunda*)
See Trees K 9.

NEMATODE DISEASES

Nematode diseases usually buildup on areas that have been under intense cultivation.

Root knot nematode (*Meloidogyne* spp.) causes galls on roots of hibiscus, grevillea, mint bush (*Prostanthera*), *Myoporum*. See Vegetables M 10.
Root lesion nematodes (*Pratylenchus* spp.) may affect many Myrtaceae, eg eucalypt, grevillea, hardenbergia. See Vegetables M 10.
Foliar nematodes (*Aphelenchoides* spp.) may occur on kangaroo paw, several Asteraceae, ferns (*Asplenium*, *Blechnum* spp., *Pteris tremula*) and reduce vigour and cause ***death***. Attacks are worse during the cooler months. See Ferns E 2.
Stem and bulb (*Ditylenchus dipsaci*) occurs on stems of acacia and cassia and on bulbs. See Daffodils C 20.
Burrowing nematode (*Radopholus similis*) has been found on *Lagunaria patersonii*, *Syncarpia glomulifera* and brush box (*Tristania conferta*). It forms burrows in the soft outer tissues of roots. These burrows can form entry points for pathogenic root fungus, eg *Armillaria*.

See Vegetables M 10.

INSECTS AND ALLIED PESTS

Few native trees escape insect attack, but not all insects found on trees cause damage. Insect attacks causing ***major damage*** to trees are usually ***sporadic*** and ***localised*** and only a ***small number of insect species*** are involved. Trees planted outside their natural range, or on marginal sites for the species, and isolated trees left after clearing, or scattered trees in improved pasture are most prone to insect damage. Some insects occur in large numbers and affect growth and survival of trees.

Aphids (Aphididae, Hemiptera): Exotic aphids are not common on native flora (CSIRO 1991). Most pest species have been introduced into Australia. Some infest a wide range of plants, eg ***green peach aphid*** (*Myzus persicae*) may infest *Hymenosporium,* orchids, ferns, greenhouse plants. Aphids damage new fronds of ferns, new shoots and flower spikes of orchids. Others, eg ***pine aphid*** (*Cinara thujafolia*), may infest *Callitris*. Some aphids feed on roots, congregate in colonies and are covered with white or grey wax. Many species secrete copious honeydew. See Roses J 4.

Borers are often credited with causing some native plants, eg wattles, to be ***short-lived***. Others species commonly attacked include banksia, bottlebrush, eucalypt, cypress pine (*Callitris*), *Prostanthera*, melaleuca. Adults of some borers, eg jewel beetles, are ***pollinators*** of native plants.

Beetle borers (Coleoptera):
- ***Auger beetles*** (Bostrichidae)
- ***Jewel beetles*** (Buprestidae)
- ***Longicorn beetles*** (Cerambycidae), eg ***common eucalypt longicorn*** (*Phoracantha semipunctata*)
- ***Weevils*** (Curculionidae), eg ***apple root weevils*** (*Perperus* spp.), ***elephant beetle*** (*Xylotrupes gideon*), ***elephant weevil*** (*Orthorhinus cylindrirostris*), ***kurrajong weevil*** (*Axionicus insignis*)

Moth borers (Lepidoptera):
- ***Ghost moths*** (Hepialidae) (Fig. 377)
- ***Oecophorid borers*** (Oecophoridae), eg ***fruit-tree borer*** (*Maroga melanostigma*)
- ***Wood moths*** (Cossidae), eg ***Australian goat moth*** (*Culama caliginosa*)
- ***Twig girdlers*** (various species)

See Eucalypt K 59, Trees K 10, K 11, K 12.

Bugs (Hemiptera), both introduced and native, may be pests. Some only attack one genus, eg ***acacia spotting bug*** (*Rayieria tumidiceps*), ***eucalyptus tip bug*** (*Amorbus alternatus*), while others infest many, eg ***crusader bug*** (*Mictus profana*). Some introduced bugs are naturalised.

Bronze orange bug (*Musgraveia sulciventris*) sucks sap from young shoots of cultivated citrus and native species, eg *Eremocitrus*, *Microcitrus*. See Citrus F 36.
Cotton harlequin bug (*Tectocoris diophthalmus*) which is a pest of cotton also infests native species of *Abutilon* and *Hibiscus*. See Hibiscus K 82.
Crusader bug (*Mictis profana*) is a pest of many plants, eg eucalypt, wattle (Fig. 378). See Trees K 12.
Harlequin bug (*Dindymus versicolor*) is not usually a pest but may damage abutilon, *Alyogone*, hibiscus, *Thomasia* and other plants. See Vegetables M 12.
Metallic shield bug (*Scutiphora pedicellata,* Scutelleridae) is brightly coloured and decorative, but may reach ***nuisance levels***. It feeds on many plants, eg fig, cottonwood (*Hibiscus tiliaceus*) and melaleuca. Their feeding on fig may be followed by sap exudation. See Melaleuca K 98, Vegetables M 12.
Rutherglen bug (*Nysius vinitor*) is a pest of *Brachycome*, *Helichrysum* and *Helipterum*. They congregate on young shoots and suck sap causing wilting and sometimes ***death of plants***. Nymphs, which do not fly, live on seeds of capeweed and other Asteraceae. See Stone fruits F 130.
Others: ***Coon bug*** (*Oxycarenus arctatus*) and *Leptocoris lurida.* ***Pale cotton stainer*** (*Dysdercus sidae,* Pyrrhocoridae) grows to 10 mm long, is reddish brown with a black spot on each wing cover and yellow underneath (Hely et al, 1982).

See Trees K 12, Vegetables M 12.

Caterpillars (Lepidoptera): Most Australian plants may be attacked by one or more moth and/or butterfly caterpillars. Many are host specific, eg ***autumn gum moth*** (*Mnesampela privata*) only attacks eucalypt, ***white cedar moth*** (*Leptocneria reducta*) only attacks white cedar, some, eg ***native budworm*** (*Helicoverpa punctigera*), can attack many native and exotic plants. Some feed on leaves, flowers, seeds and stored seed. Others bore in shoot tips, branches and trunks, or girdle twigs.

Bag-shelter moth (*Ochrogaster lunifer*)
Case moths, bag moths (Psychidae)
Cup moths (*Doratifera* spp.)
Cutworms (Noctuidae)
Emperor gum moth (*Opodiphthera eucalypti*) (Fig. 379)
Lightbrown apple moth (*Epiphyas postvittana*)
Loopers (Geometridae)
Painted apple moth (*Teia anartoides*)
Web moths (Pyralidae)

See Annuals A 8, Eucalypt K 60, Vegetables M 13.

European earwig (*Forficula auricularia*) usually feeds on organic matter but may attack seedlings and eat leaves and petals. See Vegetables M 14.

Froghoppers, spittle bugs, leafhoppers, planthoppers, treehoppers (Hemiptera): Some species, eg **gumtree hoppers** (*Eurymela* spp.), are host specific but most species can attack a wide range of plants.

Froghoppers and spittle bugs (Cercopoidea):
Common froghopper (*Chaetophyes compacta*)
Spine-tailed froghopper (*Machaerota finitima*)
Leafhoppers, jassids (Cicadellidae):
Apple leafhopper (*Edwardsiana australis*)
Zygina zealandica on *Pelargonium australe* (Fig. 380)
Planthoppers (Delphacidae, Flatidae, Ricaniidae):
Brown planthopper (*Nilaparvata lugens*, Delphacidae)
Green planthopper (*Siphanta acuta*, Flatidae)
Passionvine hopper (*Scolypopa* australis, Ricaniidae)
Treehoppers (Membracidae):
Green treehopper (*Sextius virescens*)
Spiny treehopper (*Sertorius australis*)

See Eucalypt K 61, Trees K 14, K 15.

Gall insects are common on native plants and are usually host specific.

Coccid galls (Eriococcidae): ***Apiomorpha spp***. produce the most unusual galls on twigs and leaves of eucalypts. Other species produce galls on casuarina. See Eucalypt K 61, 63.
Flies (Diptera) produce blossom galls on flower heads of eucalypt and wattle. See Wattle K 135.
Psyllids (Psyllidae) may cause large swellings on leaves of eucalypts and other native plants. See Eucalypts K 62.
Thrips (Thysanoptera) cause bladder-like galls on leaves of lilly-pilly (*Acmena, Syzygium*), wattle and other native plants. See Wattle K 135.
Wasps (Hymenoptera): ***Eulophid wasps*** (Eulophidae) infest bluegum. On Geraldton wax they infest flowers reducing the value of the plant as well as increasing the chance of rejection on phytosanitary grounds (Fig. 381). ***Megastigmus*** (Torymidae) forms galls on banksia, citrus, everlasting (*Helichrysum*), eucalypt, hakea, kurrajong, others. ***Seed chalcids*** (Eurytomidae) cause galls on bottlebrush, eucalypt, other natives. ***Xenostigmus*** causes galls on hakea buds and other native plants.
Weevils (Curculionidae) may cause galls on eucalypts and other plants.

See Citrus F 37, Eucalypt K 61, Trees K 14, Wattle K 135.

Grasshoppers, katydids, locusts (Orthoptera) may move into areas in large numbers and cause severe damage. Most will strip foliage from any plant in their path. Young trees planted into paddocks or in belts along paddock fences may be damaged or killed. Insecticides usually give good control but involve application over large areas causing problems environmentally. Important pests include:
Australian plague locust (*Chortoicetes terminifera*)
Small plague grasshopper (*Austroicetes cruciata*)
Wingless grasshopper (*Phaulacridium vittatum*)
Katydids (*Caedicia* spp.)
See Citrus F 38, Vegetables M 13.

Leafeating beetles (Coleoptera): Some may attack only one genus, eg ***eucalyptus leaf beetles,*** eucalyptus tortoise beetles (*Chrysophtharta* spp., *Paropsis* spp.), only attack eucalypts. ***Fireblight beetle*** (*Pyrgoides orphana*) attacks wattles. Others attack a range of plants.

Flea beetles (Galerucinae, Chrysomelidae) chew tiny holes in leaves (Fig. 382). See Hibiscus K 82.
Leaf beetles (Chrysomelidae), and sometimes their larvae, feed on foliage of native.
Redshouldered leaf beetle (*Monolepta australis*)
Swarming leaf beetles (*Rhyparida* spp.)
See Trees K 15
Scarab beetles (Scarabaeidae) chew foliage, flower heads and fruit of many native and exotic plants, larvae feed on grass roots.
Christmas beetles (*Anoplognathus* spp.)
Spring beetles (*Liparetus* spp.)
See Trees K 16, Turfgrasses L 11.

See Eucalypt K 61.

Leafminers are host specific. Larvae of a range of insects including beetles, moths, flies and sawflies feed on the internal tissue of leaves. The mine may be a narrow line or a blotch, usually the pattern is symptomatic of the species.

Fly leafminers (Diptera)
Pittosporum leafminer (*Phytoliriomyza pittosporphylli*)
Moth leafminers (Lepidoptera)
Blackbutt leafminer (*Acrocercops laciniella*)
Jarrah leafminer (*Perthida glyphopa*)
Phyllonorycter aglaozona on *Kennedia*, *Glycine*
Lomatia leafminer (*A. antimima*) (Fig. 383)
Macadamia leafminer (*A. chionosema*)
Nepticula anazona on swamp mahogany (*Lophostemon suaveolens)*
Silkyoak leafminer, grevillea leafminer (*Peraglyphis atimana*)
Wattle leafminer (*A. plebeia*)
Sawfly leafminers (Hymenoptera)
Leafblister sawfly (*Phylacteophaga* spp.)

Leafminers are difficult to control. Hard oval lumps (pupae) can be seen in most blisters, by then it is too late to spray that season. Avoid planting very susceptible species as specimen plants. See Azalea K 28, Cineraria A 28, Trees K 15.

Lerps, psyllids (Psyllidae, Hemiptera) are small sap sucking insects which attack the leaves of many native plants. Many are host specific.

Lerp insects form a cover, or a lerp, as protection for the nymphs but unlike scales the nymph remains fully mobile through all stages under the lerp. Both male and female adults have wings. Most species, eg ***brown basket lerp*** (*Cardiaspinis fiscella*), feed on eucalypt leaves. Some lerp insects cause galls or pimples on bottlebrush leaves.
Psyllids are free-living (they do not form a lerp), eg
Callistemon psyllid (Psyllidae) (Fig. 384)
Moreton Bay fig psyllid (*Mycopsylla fici*)
Kurrajong star psyllid (*Protyora sterculiae*)

See Eucalypt K 62, Trees K 15.

Mealybugs (Pseudoccidae, Hemiptera) infest native ferns, orchids, palms, lilies, cordylines on occasions, grevilleas and wattles. They persistently and ***severely attack*** the developing crown of ***palms***. Developing fronds are misshapen and stunted and prolonged attacks may weaken and kill plants. ***Wattle mealybug*** (*Melanococcus albizziae*) may infest wattles. See Greenhouses N 25.

Mites (Acarina, Arachnida):

Eriophyid mites (Eriophyidae) may feed on leaf undersurfaces of banksia leaves causing them to roll under. ***Eucalypt leaf blister mite*** (Eriophyidae) feeds from tiny disfiguring galls on the upper surfaces of leaves. ***New shoots*** of casuarina (Fig. 385), eucalypt, wattle, teatree and other plants may be bunched and distorted due to the feeding of eriophyid mites on the developing tissues. See Eucalypt K 63, Grapevine F 62, Pome fruits F 114.

Spider mites (Tetranychidae), especially ***twospotted mite*** (*Tetranychus urticae*), may attack many plants but is controlled by *Stethorus* beetles and other predators. See Beans (French) M 29.

Others: Heavy mite numbers cause leaf silvering of Myrtaceous plants including ***Calothamnus***. New shoots of ***hakea and grevillea*** can be grossly distorted and stunted. Several species of ***melaleuca*** are subject to mite infestation in developing flower buds which turn brown and fail to develop, aborting before reaching maturity.

Sawflies (Hymenoptera) lay eggs into slits cut in leaf uppersurfaces. Larvae are sometimes called ***spitfires*** and are important defoliators of native trees and shrubs especially bottlebrush, cypress pine, eucalypt and paperbark. Most are host specific (an exception is pear and cherry slug).

Callistemon sawfly (*Lophyrotoma* sp.)
Cypress pine sawfly (*Zenarge turneri*)
Leafblister sawfly (*Phylacteophago* spp.)
Pear and cherry slug (*Caliroa cerasi*)
Ringed sawfly (*Pterygophorus cinctus*)
Steelblue sawfly (*Perga affinis affinis*) (Fig. 386)

See Eucalypt K 63, Trees K 16.

Scales (Hemiptera) are common pests of Australian plants. Some infest many species, eg ***black scale*** (*Saissetia oleae*) and ***cottony cushion scale*** (*Icerya purchasi*), others only attack a few species, eg ***gumtree scale*** (*Eriococcus coriaceus*).

Armoured scales (Diaspididae) do not produce honeydew. ***White louse scale*** (*Unaspis citri*) resembles shredded coconut sprinkled over leaves and stems of plants on which it feeds, eg ***Rutaceae***. These are the males, females are less conspicuous. Controlled by predatory caterpillars.

Eriococcid scales (Eriococcidae): ***Apiomorpha*** is confined to eucalypts and forms distinctive galls on leaves and stems. ***Cylindrococcus*** forms conical galls on casuarina, and ***Sphaerococcus*** blister-like galls on eucalypt. More common eriococcid scales include ***gumtree scale*** (*Eriococcus coriaceus*) and ***macadamia felted coccid*** (*E. ironsidei*). ***Teatree scale, manuka blight*** (*E. orariensis*) is similar to gumtree scale but is found mainly on *Leptospermum*.

Margarodid scales (Margarodidae):
Cottony cushion scale (*Icerya purchasi*) (Fig. 387)

Soft scales (Coccidae) produce honeydew on which sooty mould grows.
Black scale (*Saissetia oleae*)
Soft brown scale (*Coccus hesperidum*)
Cottony pigface scale (*Pulvinariella mesembryanthemi*)
Cottony saltbush scale (*Pulvinaria maskelli*) is a sporadic pest of *Atriplex nummularia.*
Wattle tick scale (*Cryptes baccatus*)

Others: ***Casuarina scale*** (*Frenchia casuarinae,* Asterolecaniidae)

See Citrus F 39, F 41, Trees K 16.

Seed insects: ***Ants*** (Formicidae), ***beetles*** (Coleoptera), ***bugs*** (Hemiptera), ***caterpillars*** (Lepidoptera) (Fig.388) and ***wasps*** (Hymenoptera) may damage seeds on the plant and on the ground. See Eucalypt K 63, Seeds N 74.

Stick insects, leaf insects (Phasmatidae) may damage many species of ***eucalypts and wattles*** in a forest situation. The ***spiny leaf insect*** (*Extatosoma tiaratum*) which may be found in gardens, is large, solitary, slow-moving, bright-green or brown and up to 120 mm long. It chews lumps out of leaves from a range of plants. The ***spurlegged phasmatid*** (*Didymuria violescens*) may completely defoliate forest trees but is uncommon in gardens. See Eucalypt K 64.

Termites (Isoptera) are specially abundant in tropical regions. Some species nest in familiar termite mounds, others in trees or underground tunnels. They eat wood and wood products and can be very destructive to trees both living and dead. Cypress pine (*Callitris* spp.) can be grown in areas where termites are a problem. See Trees K 17.

Thrips (Thysanoptera) are tiny and difficult to see. Some attack flowers, leaves or young growth causing distortion. Some species, eg ***greenhouse thrips*** (*Heliothrips haemorrhoidalis*), infest a wide range of plants, others, eg ***leafrolling thrips*** (*Teuchothrips* sp.), attack only a few species.

Greenhouse thrips (*Heliothrips haemorrhoidalis,* Thripidae) attacks foliage of tender species, eg ferns, *Cissus*, *Passiflora.* It prefers cool moist conditions and may be severe on greenhouse plants, numbers are reduced drastically by hot dry weather. Usually controlled by spraying. See Greenhouses N 24.

Plague thrips (*Thrips imaginis,* Thripidae) feeds on buds and flowers of thin-textured petals and stamens of some native plants, eg *Alyogyne*, baeckea, hibbertia, hibiscus, eucalypt, and *Leptospermum*. Seed formation may be prevented. See Roses J 6.

Gall-making thrips (Phlaeothripidae) produce bladder-like galls on leaves of *Syzygium*, casuarina and some wattles, eg *A. aneura, A. pendula*. See Wattle K 135.

Leafrolling thrips (*Teuchothrips* sp., Phlaeothripidae) infests new leaves of bottlebrush and melaleuca. See Bottlebrush K 37.

Others: Onion thrips (*Thrips tabaci*) and ***western flower thrips*** (*Frankliniella occidentalis*) may assist spread of virus diseases, eg tomato spotted wilt virus, to susceptible native plants.

Tip borers (Lepidoptera): Various ***moth*** caterpillars tunnel down shoot tips for about 100 mm of many native plants, eg bottlebrush (Fig. 389), melaleuca. See Trees K 17.

Weevils (Curculionidae, Coleoptera): Many ***adult weevils*** feed on leaves, young bark and buds of native plants. ***Eucalypt weevil*** (*Gonipterus scutellatus*) if numerous, may seriously damage young trees. ***Larvae of some weevils*** feed on roots, eg ***catasarcus weevils*** (*Catasarcus* spp.) in WA. ***Larvae of other weevils***, eg ***elephant weevil*** (*Orthorhinus cylindrirostris*), bore into trunks and roots of brush box (*Lophostemon conferta*), black bean, eucalypt and other trees. A ***ringbarking weevil*** (Curculionidae) kills many Myrtaceae (Fig. 390). See Trees K 12, K 17.

Whiteflies: ***Greenhouse whitefly*** (*Trialeurodes vaporariorum*) and ***other species***, are small, white, winged insects, 2-3 mm long. They attack soft-foliaged plants. See Greenhouses N 24.

Others: ***Argentine ant*** (*Linepithema humile*). ***Millipedes*** (Diplopoda) mainly feed on rotting vegetation, but may attack tubers, bulbs, fleshy roots of orchids, lilies and palms, etc. ***Slaters*** (Porcellionidae) feed on organic matter but also eat soft shoots and root tips of orchids especially in greenhouses. ***Passionvine hopper*** (*Scolypopa australis*) is a common pest of *Passiflora* spp., grevillea and many other plants.

SNAILS AND SLUGS

There are many ***native species*** of snails and slugs in Australia, all pest species are introduced. Plants damaged include herbaceous and young native plants, eg kangaroo paw, ferns, lily, orchids, grevillea and salt bushes. Damaged leaves and stems may act as ***entry points for fungi***. Young plants of white cedar may be ***ringbarked***, resulting in death of plants. See Seedlings N 70.

VERTEBRATE PESTS

Wattles and other trees may be damaged by ***cockatoos*** feeding on wood moth larvae in the trunks. ***Cockatoos and other birds*** feed on cones of bunyas and other trees. Introduced ***rabbits*** and ***native possums*** graze on plants. See Fruit F 13.

Non-parasitic

Environment: Many native species or some varieties of native species are sensitive to ***frost***, eg some grevilleas. Some native plants are not as ***drought-tolerant*** as previously thought, eg reduced water supply to Geraldton wax, causes a decrease in total flower production and retards plant growth. ***Excess humidity*** may cause leaf blackening, eg on *Grevillea biternata* (often called sweating).

Fire adaptation: ***Lignotubers*** (swollen woody tissue) at, or just under the ground, are produced by some eucalypts. These allow the plant to rapidly regenerate after fire. ***Seed*** of some native plants, eg wattle, have a hard coat which must be broken, eg by bushfires, to allow moisture to enter the seed and commence germination.

Genetic problems: The ***provenance*** (place of origin of seed from a natural forest) from which plants are derived, determines their future performance and susceptibility to diseases and pests. Some unimportant genetic abnormalities, eg ***fasciation*** (Fig. 391), are not uncommon.

Humans may reduce native vegetation by clearing land for agriculture and horticulture, mining, forestry, urban development and tourism.

Medicinal uses, fodder and food: Many species have been researched for these purposes (Collins et al. 1990). See Bush Fruits F 29.

Nutrient deficiencies, toxicities: Native plants suffer from deficiencies and toxicities in the same way that exotics do. ***Iron deficiency:*** Banksia, crowea, *Dampiera*, eucalypt, eriostemon, grevillea, *Prostanthera*, wattle and other Australian plants may suffer from iron deficiency. New growth is often yellow between the veins. New growth of *Hypocalymma cardifolium* may be pinkish instead of pale green. ***Boron deficiency:*** Wattles especially *A. adunca* and *A. spectabilis* may be severely affected by lack of ***boron***. Only ***small amounts are required by plants*** and excessive quantities are very toxic. Deficiency symptoms are extremely variable depending on the species. Deficiency may cause wilting and defoliation of the upper parts of shoots followed by death of the terminal bud and dieback of the shoots. Leaves may become thickened and lateral buds develop. Boron compounds, eg borax or boric acid, can be applied at low concentrations to the soil or as a foliar spray. ***Phosphorus deficiency*** is uncommon in native plants except perhaps in rainforest situations. Heath land communities have developed on phosphorus deficient soils and have evolved a tight phosphorus cycle so that the element is not wasted. The element is usually withdrawn from all old leaves before they are shed and specialised root systems such as ***proteoid roots and mycorrhizae*** probably play a part in the uptake of phosphorus. See Trees K 18. ***Phosphorus toxicity:*** ***Excess phosphorus can be toxic*** to some native plants causing marginal leaf burn and death of older leaves. Dieback starts at the tip of each leaf and spreads towards the base followed by premature defoliation giving plants a sparse appearance. Toxic effects of excess phosphorus may be offset by addition of some other elements, eg iron, but ***advice*** should be obtained. Plants sensitive to high levels of phosphorus are mainly found in the Proteaceae, eg some species of banksia, grevillea and hakea. Phosphorus toxicity arises from using ***high levels of fertilisers containing phosphorus***, eg superphosphate and blood and bone. Phosphorus toxicity is mainly a problem for plants grown in ***containers*** and not common in garden plants, phosphorus is fixed and rendered immobile in soil. Correcting phosphorus toxicity is difficult. Only use fertiliser with very low quantities of phosphorus. ***Salt damage*** can be caused by excess fertiliser applications, soil salt and by windborne salt. See Citrus F 43, Trees K 20.

Sooty mould (various fungi) grows on ***honeydew*** secreted by various ***sap sucking insects*** including aphids, lerp insects, mealybugs, planthoppers, scales, whiteflies (Fig. 392).

WEEDS

Native plantings suffer from the same annual and perennial broadleaved and grass weed problems as exotic plantings. ***Private and public gardens*** are commonly invaded by exotic and native weeds, eg cotoneaster and wattle seedlings. ***Bush areas*** may be invaded by both exotic or native weed species, eg prickly-pear, Cootamundra wattle, pittosporum. Ornamental species may escape from gardens and invade surrounding bushland. ***Overseas***, some native plants have become major weeds, eg hakeas. See Trees K 21.

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GrowSearch (database Qld DPI)
International Plant Propagators Soc. (IPPS)
National Workshop for Australian Native Flowers Procs (Qld University, Gatton College Feb 1994)
Nuytsia Society for Growing Australian Plants

See Annuals A 10, Bush fruits and nuts F 29, Preface xii, Trees, shrubs and climbers K 22

Remember, always check for recent references

MANAGEMENT

Selection

An overview of the native cut flower industry is outlined by Coombs (1995). The same care in selection, establishment, maintenance and postharvest treatment must be taken with native plants as with exotic plants. Native plants are not necessarily easier to look after than exotic plants in an urban situation. More exotic plants become weeds, suggesting that they are hardier and more adaptable than many native species. Some native plants cannot be grown successfully in plantations, and are harvested from bush stands, eg *Agonis parviceps.* Species ***susceptible*** to particular problems should not be used as specimen plants but rather planted in less conspicuous groups. Many species are ***grafted*** onto ***Phytophthora-resistant rootstocks***. Plants should be ***Phytophthora- and pest-free***. In WA the National Industry Accreditation Scheme, Australia *(NIASA*) ensures that planting material is ***Phytophthora-free*** and of a high horticultural standard. See Nurseries N 51.

Establishment

Propagated by cuttings, seed, transplants, tissue culture. Seed treatments include scarification, boiling water, seed storage techniques, chemicals including growth regulators and smoke-derived materials (Roche et al. 1994). ***Cultural methods:*** *Phytophthora cinnamomi* and related species are the major soil diseases affecting native plants. As it is extremely difficult to eradicate *Phytophthora* once the soil or plants are infected, the site chosen must be *Phytophthora*-free. In such sites, unsterilised soil or potting mix must not be brought into the area on implements, vehicles, footwear or animals. Fence the area under cultivation and use vehicle and foot baths to ensure soil diseases are not introduced. See Nurseries N 53. Provide good drainage. Obtain ***pre-plant*** soil and water analyses, including weed, disease and pest analyses. Post-plant water, fertilise, mulch and prune as recommended. ***Insects in plantations*** are easier to control because of better management and easer access to individual plants. Plants are of uniform age and development and there are no other native plants to increase numbers of pest insects. The best bush-picked flowers come from areas that are cleared and allowed to regenerate, often the clearing process removes many insects and it takes time for them to recolonise the regrowth area and cause damage. The fertiliser history of ***old land*** should be known, eg soil phosphorus levels < 25 ppm have been suggested for banksia, dryandra and hakea. ***Weeds*** such as capeweed and wild turnip, may already be established. ***Insects***, eg scarab beetles, may carry over from pasture and damage new crops. Permission must be obtained before clearing ***new land*** over a certain area. ***Weed problems*** may be less initially but there may be some regeneration of native vegetation and germination of other weeds. ***Native insects***, eg weevils, can attack crops, particularly if the ground has not been fallowed.

Maintenance

Many of the insects which attack native plants cause no lasting damage as often their natural predators and parasites provide some control providing chemical sprays are not used. Many plants grow too large anyway to be safely sprayed. There are diseases and pests that affect ***roots and trunks*** that cause ***serious damage*** every year while others only occasionally appear in plague proportions. ***Phytophthora spp.*** are a constant threat to plantings. ***Termites*** may kill proteas, larvae of ***native weevils*** may ringbark plants below ground level and kill > 50% of Myrtaceae plants, eg species of *Chamelaucium* and *Verticordia.* Larvae of beetles and moths may ***bore*** into stems of woody plants and may severely damage wildflower or protea plantations. ***Foliage- or flower-feeding insects*** are unlikely to kill plants unless damage is severe, there are some exceptions; however, they may reduce ***marketability*** of the final product and increase the chance of rejection on phytosanitary grounds. ***Gall-forming wasps*** on Geraldton wax lowers the value of plants. ***Beetles and caterpillars*** that feed on flowers and foliage and ***scales and bugs***, may also be problems. ***Thrips*** have the potential to cause leaf damage or distort new growth and they may be found in flowers. Good control of most of these insects in young plantings is mostly obtained with insecticides but may fail if insects feed in difficult to reach places. Pollen or nectar or both is a source of food for many insects including bees, wasps, ants and beetles. These insects do not damage the flower but may cause rejection on phytosanitary grounds. They are probably best removed by shaking and then by effective postharvest treatments. ***To reduce insects in plantation flowers*** place reject and good flowers into separate bins. All infested reject flowers should be removed from the plantation area and destroyed/burnt. All reject flowers should be cut from trees and destroyed. This helps prune trees for future flower production and also removes pests from the plantation. ***Pesticides and growth regulators*** are registered for use on some native plants.

Postharvest

Prevention and control of postharvest diseases and pests should be commenced in the field. ***Postharvest bacterial and fungal diseases*** may occur on flowers. See Annuals A 11. ***Bud and flower drop*** may also be a problem. ***Quarantine pests:*** Flowers leaving Australia may require treatment with insecticides. Recent techniques considered include a combination of low and high temperature, carbon dioxide, aerosol sprays, eg pyrethrin, hot water dips and gamma radiation. ***Cool fresh flowers*** as recommended as soon as possible after harvest. In commercial situations treat as recommended for that species. One acceptable short term handling condition is 2^{O}C and 95% relative humidity. Research on the use of chlorination technology to maintain hygiene in flower packing shed is being carried out. Jones and Moody (1993) describes ***postharvest procedures*** for some native plants.

Fig. 375. Gall rust (*Uromycladium* sp.) on wattle.

Fig. 376. Giant tinder punk (*Phellinus zealandicus*) on eucalypt. B. A. Fuhrer.

Fig. 377. Ghost moth (*Aenetus* sp.). ***Left :*** Caterpillar in tunnel. ***Right :*** Webbing and frass covering the tunnel entrance. H. J. Elliott.

Fig. 378. Nymph of crusader bug (*Mictis profana*) sucks sap from new shoots on wattle.

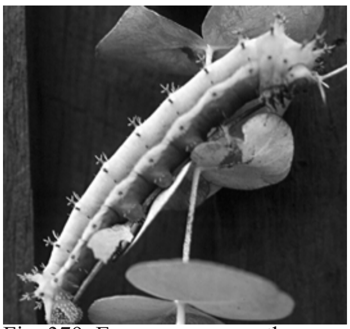

Fig. 379. Emperor gum moth (*Opodiphthera eucalypti*) caterpillar on eucalypt.

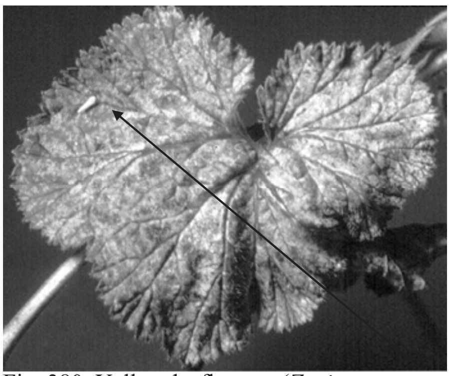

Fig. 380. Yellow leafhopper (*Zygina zealandica*) sucks sap from leaves of *Pelargonium australe.*

Fig. 381. Gall on flower caused by the Geraldton wax gall wasp (Eulophidae). B. Woods and M. Grimm.

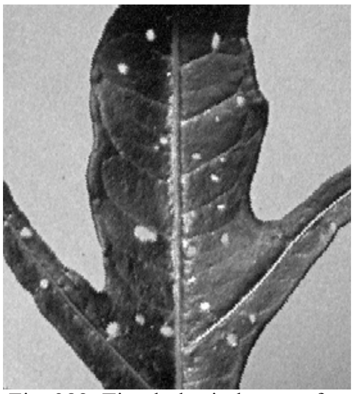

Fig. 382. Tiny holes in leaves of *Solanum laciniatum* caused by flea beetles (Chrysomelidae).

Fig. 383. Leaf blotch caused by lomatia leaf miner (*Acrocercops antimima*).

Fig. 384. Fluffy psyllids (Psyllidae) on *Callistemon* shoots.

Fig. 385. Witches's broom on casuarina caused by eriophyid mites (Eriophyidae). Unconfirmed.

Fig. 386. Larvae (spitfires) of steelblue sawfly(*Perga* spp.) spitting and tapping on eucalypt stem.

Fig. 387. Cottony cushion scale (*Icerya purchasi*) on *Acacia howittii*.

Fig. 388. Damage to hakea seed by moth caterpillars (Lepidoptera).

Fig. 389. Tiny moth caterpillars (Lepidoptera) tunnel into and kill *Callistemon* shoot tips.

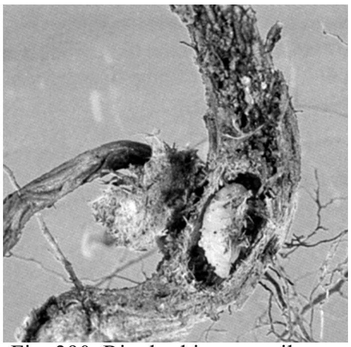

Fig. 390. Ringbarking weevil (Curculionidae). Pupa in pupal cell in Myrtaceae stem below ground level. B. Woods and M. Grimm.

Fig. 391. Fasciation (genetic abnormality) on casuarina and wattle.

Fig. 392. Sooty mould (various fungi) grows on the honeydew secreted by sap sucking insects, eg psyllids, soft scales. Dept. of Agric., NSW

Bonsai

PESTS AND DISEASES
Non-parasitic
- Fertilising
- Light
- Mycorrhiza
- Pesticide injury
- Re-potting
- Temperature
- Watering and humidity
- Wires

WEEDS

Bonsai is the art of growing miniature trees or other plants in a tray or container. The word ***'bonsai' means 'tray-planted' or 'growing in a shallow vessel'***, hence the importance of non-parasitic problems. The most common problems in order of importance are:

Underwatering
Overwatering
Too much fertiliser

Bonsai plants are susceptible to the same pests and diseases as their larger, naturally growing counterparts. For example, ***azaleas*** (*Rhododendron* spp.) may be affected by azalea leaf gall (Fig. 393), fungal leaf spots, phytophthora root rot, powdery mildew, azalea lace bug, azalea leafminer, greenhouse thrips or iron deficiency. ***Pines*** (*Pinus* spp.) may be affected by needle cast fungi, pine adelgid (Fig. 394) or nutrient deficiencies. ***Indoor bonsai*** may also succumb to problems commonly occurring on house or greenhouse plants including aphids, greenhouse thrips, mealybugs, scales, twospotted mite, snails and slugs, fungus gnats (Sciaridae), millipedes, slaters and algae.

PESTS AND DISEASES
Non-parasitic

Fertilising: Although too much fertiliser is an important problem affecting bonsai, bonsai do need to be fertilised to maintain vigour, colour and even growth.

How to fertilise: Water a dry plant with plain water first, then apply the diluted fertiliser. If used at too high a ***concentration***, fertilisers can ***burn roots***. Do not overfertilise, only feed during the growing period. To reduce the danger of salt buildup occasionally replace a regular fertiliser application with a water application. Fertilising should cease when growth slows and trees move into winter dormancy.

Which fertiliser: Do not use high nitrogenous fertilisers, eg Aquasol®, as those promote lush growth and long internodes. Choose fertilisers to suit the particular plant. Those containing ***superphosphate*** are to be avoided with many Australian native plants. Some organic fertilisers have an ***offensive smell*** as they decompose and may attract insects such as fungus gnats and garden maggots. Some may burn moss. Check concentrations of all fertiliser applications with experienced growers.

Light: Bonsai plants must receive the same amount of light they would receive under natural conditions, this means that ***indoor bonsai*** must receive additional light if they are to thrive. Bonsai located continuously indoors must be placed near a window, in a greenhouse or provided with artificial light, eg fluorescent cool white or daylight bulbs, for 16-18 hours a day. Plants must be a prescribed distance from the tubes. Replace tubes, one at a time, once per year, to prevent a sudden increase in light intensity.

Mycorrhiza is a ***symbiotic association*** of a fungus with the ***roots*** of a plant. The fungus apparently ***improves plant growth*** by increasing the absorbing surface of the root system, selectively absorbing and accumulating certain nutrients, keeping feeder roots functioning longer and making feeder roots more resistant to infections by certain soil fungi (Agrios 1988). Mycorrhizae may be attached to the ***outside***, or in the ***inside***, of roots. They may be host specific, ie a fungus that is symbiotic with one species may not live on the roots of another and vice versa. Trees used for bonsai that have mycorrhizae should never be bare-rooted, ie the soil should not be completely removed from the root system. See Trees K 18.

Pesticide injury: Some sprays may damage certain species, check the label. ***Oil sprays*** may damage conifers, maples, beech, walnut and other plants.

Re-potting: Bonsai must be re-potted every year initially but large specimens may only need re-potting every 2 years. Many new bonsai growers fail to give newly potted or re-potted plant material ***sufficient attention*** during the ***recovery phase***.

Temperature

Dormancy: ***Hardy bonsai***, eg beeches, maples, firs, junipers, spruces and pines, survive freezing temperatures during winter by going into ***full dormancy***, they do not grow during that period. The dormancy needs of hardy bonsai are well recognised. Without the exposure to cold, usually near freezing, they may defoliate, show shoot dieback and decline in general health. These plants are not really suitable for indoor bonsai unless they are put in the refrigerator or placed outside or near open windows during winter.

Resting period: ***Non-hardy bonsai*** for indoors are drawn from a wide variety of habitats from the subtropics to temperate regions of the world. Plants from temperate regions enjoy winter temperatures of 4-7^{o}C (but not freezing temperatures) which is called a resting period. Providing a resting period for these temperate region plants is not so essential for bonsai except when it is required for ***flowering***, eg Kurume azaleas (*Rhododendron obtusum*) need a resting period of 4 weeks of 4^{o}C to ensure a flush of flowers in spring. The common olive (*Oleae europea*) fails to produce flower buds if denied a cool spell the previous autumn or early winter.

Watering and humidity

Underwatering is the ***most important*** cause of ***death*** while ***overwatering*** is the second most important cause. This is because there is little soil to retain moisture and bonsai dry out quickly. Regular attention must be given to watering.

When to water: The ideal time to water is when the soil surface appears to start drying out. Do not water plants if the surface of the root ball is wet, plants must not become waterlogged. ***Monitor*** soil moisture and only water when necessary.

How to water: All bonsai pots should be watered gently and slowly. To ensure thorough watering of small pots they can be immersed in water up to the base of the plant stem and soaked until bubbles stop rising in the water.

Misting the leaves with water in ***hot dry weather*** will avoid leaf browning. During hot dry summer days, leaves may need misting with water several times a day to prevent browning of foliage.

Wires may damage bonsai, especially ***conifers***.

WEEDS

Some species used for bonsai are actually ***urban weeds***, eg firethorn. ***Mosses*** are probably the most popular of ground covers for bonsai, some species are very beautiful. ***Algae and liverworts*** can be a problem. See Greenhouses N 27.

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Bonsai Today
Bonsai (Journal of the American Bonsai Soc.)
City, Regional, State, Territory, National Socs.
The Bonsai Bulletin
World Tropical Bonsai Forum

See Containers N 20, House plants N 37

Remember, always check for recent references

MANAGEMENT

Some bonsai can live hundreds of years if cared for properly. Depending on the species they can be grown indoors or outdoors. The art of bonsai requires much skill, time and patience. The first step is to get advice from an expert, obtain a good book on bonsai and collect some basic tools. If enthusiasm still persists, possibly attend classes or join a bonsai society.

Selection

Which species? Some plants are better suited for bonsai than others. Small leaved trees such as Chinese elm (*Ulmus parviflora*) have ***leaves*** which grow in proportion to the other parts, while the ***bark*** of Chinese elm and the ***flowers and fruit*** of *Carissa*, *Serissa*, *Malpighia* and pomegranate, are attractive.

Exotic bonsai include ***deciduous species***, eg cherry, Chinese elm, plum, and maple, and ***evergreen species***, eg azalea, bamboo, cedar, juniper, pine.

Australian native plants suitable for bonsai include:

Banksia (*Banksia* spp.)	Fig (*Ficus* spp.)	Melaleuca (*Melaleuca* spp.)
Bottlebrush (*Callistemon* spp.)	Grevillea (*Grevillea* spp.)	Pittosporum (*Pittosporum* spp.)
Casuarina (*Allocasuarina*, *Casuarina*)	Hakea (*Hakea* spp.)	Tea-tree (*Leptospermum spp.*)
Christmas bush (*Ceratopetalum* sp.)	Kunzea (*Kunzea* spp.)	Wattle (*Acacia* spp.)
Cypress pine (*Callitris* spp.)	Kurrajong (*Brachychiton* spp.)	Others, eg *Araucaria*, *Agonis,*
Eucalypt (*Eucalyptus* spp.)	Lilly-pillies (*Acmena, Eugenia, Syzygium*)	*Melia, Microstrobos*, *Podocarpus*

Outdoor bonsai: Because there is little soil to ***retain moisture*** they dry out quickly so most outdoor bonsai are best kept in a sheltered, cool area with ample light, filtered shade or morning sun and afternoon shade. Some bonsai such as pines and many evergreen plants, can ***tolerate*** more sun than many deciduous plants. Bonsai normally grown outdoors are ***not*** intended for ***continuous indoor display***, and should only be brought indoors for a few days at a time for display purposes.

Indoor bonsai must be able to grow ***under low light intensity*** (or there must be an artificial light source) and have ***no need*** of a cool or dormant period. Outdoor species, such as firethorns, which would not require annual cold dormancy to survive, and subtropical and tropical plants, would therefore be suitable. Temperate zone bonsai can be grown indoors successfully, but only when a chilling or dormant period can be supplied, either by keeping the window open or by some other means. Indoor bonsai may be summered outdoors. Plants suitable for indoor bonsai include:

Azaleas (*Rhododendron* spp.)
Box (*Buxus* spp.)
Chinese sweetplum (*Sageretia thea*)
Cotoneaster (*Cotoneaster* spp.)
English ivy (*Hedera helix*)
False heather (*Cuphea hyssopifolia*)
Fig (*Ficus* spp.)
Firethorn (*Pyracantha coccinea)*
Greek myrtle (*Myrtus communis*)
Serissa (*Serissa* sp.)

Plant quarantine: New plants should be quarantined for ***at least 2-3 weeks*** and examined daily for pests and diseases prior to placing them with the general collection.

Establishment and maintenance

Bonsai can be started by propagating from seed or cuttings, or by transplanting stunted trees or parts of trees growing in the wild, into containers. Bonsai should be ***inspected daily*** and being of manageable size, any pest and disease may be dealt with by hand before it becomes widespread. *A* ***bonsai calendar*** should be prepared which should include all maintenance activities for a full year.

Cultural methods: Careful ***watering*** and ***fertilising*** are necessary to keep plants healthy. The ***size*** and ***shape*** of the trees is controlled by pinching off the new growth and by wiring the branches. The grower bends and wires the trunk and branches to grow into the desired shape. ***Re-potting*** should be carried out when necessary. The ***seasons*** must be taken into account, bonsai may require more shade in summer, or frost protection in winter, or a new site. Plants are kept ***small*** by pruning roots and branches and by re-potting. Container size also partly determines the final size of the tree.

Sanitation: ***Bonsai areas*** should be ***cleaned thoroughly*** at least 4 times a year to remove pests and hiding places for slaters, snails, etc. Sometimes ***affected plant parts*** can be ***carefully cleaned*** with water, all dead leaves and twigs should be promptly removed. Fallen leaves should be removed from pots and surrounding areas to reduce likelihood of pests and diseases.

Pesticides: Only use pesticides registered for ***indoor plants*** on ***bonsai indoors***. For all pesticide applications to bonsai, check that the pesticide is registered for use on that particular plant species and follow label safety directions.

Postharvest

There are ***guidelines*** for preparing bonsai for exhibition, display and the judging of quality bonsai. When selling bonsai to home gardeners it is essential to ***provide instructions*** on their care throughout the year. Many purchases in unskilled hands, slowly ***die*** over a period of time.

Fig. 393. Azalea leaf gall (*Exobasidium vaccinii*).

Fig. 394. Pine adelgid, woolly pine aphid (*Pineus* sp.) on radiata pine (*P. radiata*). H. J. Elliott

Compost

PESTS AND DISEASES
Parasitic
Non-parasitic
- Ants
- Earthworms
- Environment
- Flies
- Legionnaires' disease
- Nutrient deficiencies, toxicities
- pH
- Suppressive compost
- Toxins

WEEDS

***Composting** is simply a means of speeding up the natural breakdown of organic materials.*

PESTS AND DISEASES
Parasitic

Efficient composting involves ***decomposition*** of organic materials and ***pasteurisation*** (killing disease-causing microorganisms but not disease suppressive microorganisms). Many pests and diseases present in infected and infested crop debris may survive, and/or multiply in or on, ***improperly treated compost***, and may be a source of infection for crops on which it is to be used, or a source of insects or airborne spores. Whether the compost is a ***source*** of pests and diseases depends on the ***crop*** to which it is be applied. Some pests and diseases spread in compost have a narrow host range. ***Sclerotium white rot*** (*Sclerotium cepivorum*) of onions and garlic can only attack these plants, compost contaminated with sclerotia of this disease should not be applied to onion and garlic crops but could be applied to other crops. ***Sclerotium stem rot*** (*Sclerotium rolfsii*) can attack a wide range of crops and in warm climates, contaminated compost could cause disease of many species. The use of ***uncomposted*** or ***improperly composted*** organic waste is concerning many people. More than ***30%*** of loads of ***fruit and vegetable waste (market organics)*** taken for recycling in Melbourne, contained plant pathogens; only ***5%*** of loads of ***organic home garden waste (green organics)*** recorded any incidence of plant disease pathogens (Saunders 1996).

Virus and virus-like diseases, eg
- Odontoglossum ringspot virus (possibly)
- Tobacco mosaic virus

Bacterial diseases, eg
- Bacteria wilt of tomato (*Pseudomonas solanacearum*)
- Bacteria blights of bean (various species)

Fungal diseases, eg
- Alternaria of tomato (*Alternaria* sp.)
- Damping off (*Fusarium* spp., *Phytophthora* spp., *Pythium*, *Rhizoctonia solani*)
- Fusarium diseases/wilts (*Fusarium* spp.)
- Grey mould (*Botrytis cinerea*)
- Sclerotinia rots (*Sclerotinia* spp.)
- Sclerotium stem rot (*Sclerotium rolfsii*)
- White rot of onions (*Sclerotium cepivorum*)

Seed from parasitic plants, eg
- Broomrape (*Orobanche* spp.)
- Dodder (*Cuscuta* spp.)

Nematode diseases, eg
- Cyst nematodes (*Globodera*, *Heterodera*)
- Dagger nematodes (*Xiphinema* spp.)
- Pin nematodes (*Paratylenchus* spp.)
- Root knot nematodes (*Meloidogyne* spp.)
- Root lesion nematodes (*Pratylenchus* spp).
- Stem nematodes (*Ditylenchus* spp.)
- Stunt nematodes (*Tylenchorhynchus* spp.)

Insects and allied pests, eg
- Beetle larvae (Coleoptera)
- Cutworms (*Agrotis* spp.)
- Elm leaf beetle (*Pyrrhalta luteola*)
- Mole crickets (*Gryllotapa* spp.)
- Termites (Isoptera)
- Wireworms (Elateridae, Coleoptera)

Vertebrate pests, eg
- Rodents may feed and breed in compost heaps

Non-parasitic

Ants (Formicidae) may be attracted to food scraps and other materials in compost. See Turfgrasses L 8, Trees K 19.

Earthworms

Compost earthworms are commonly introduced species (native earthworms prefer low nutrient environments). Earthworms eat large quantities of soil and organic materials, and are effective in reducing the size of bulky litter and incorporating it into soils. They cannot survive at temperatures > 25°C which are generated in most composting processes. Earthworms can only be added to such a system after the temperature has dropped. But it seems that there is little need to add earthworms to this type of compost heap. Microorganisms have already done the work that the earthworms might have otherwise started.

Vermicomposting is an alternative way of converting organic wastes into a useful material. ***Tiger earthworms*** (*Eisenia foetida*) eat their way through organic wastes such as various manures and food scraps. Separated castings are called 'vermicompost' (from vermis the Latin for worm). Vermicomposts vary widely in general nutrients and trace elements to the extent that some can be toxic to plants in soil-less potting mixes. Phosphorus levels may be too high for some plants.

Environment

Moisture: The microorganisms responsible for the breakdown of plant materials in compost heaps need ***oxygen***; in its absence, composting will not proceed. If the ***compost is too wet***, oxygen will not be available and aerobic microorganisms will be replaced by anaerobic ones which may create ***toxic products*** and have an ***unpleasant smell***. These conditions are favourable breeding sites for various ***flies***. If the ***compost is too dry***, microorganisms will not be able to reproduce and then will not decompose the plant material.

Temperature: Microorganisms feed and multiply on the organic matter in the compost ***(decomposition)***. The heat given off by the microorganisms during these processes is kept in the heap by the insulating properties of the organic materials, causing the temperature to rise in the centre of the heap. This heat (if it reaches 55-60°C for about 3 weeks) will kill most plant parasitic microorganisms ***(pasteurisation),*** but is too low to kill disease suppressive ones (Fig. 395). The heap must be ***turned regularly*** (Fig. 396) to ensure that all the material in the heap spends some time in the ***centre***. If the required temperature is ***not reached*** there will not be pasteurisation. If the temperatures in the centre are ***too high*** (> 60°C), then the microorganisms bringing about the composting process will die off and the composting process will take longer.

Flies (Diptera) can breed in compost, eg ***house fly*** (*Musca domestica*), ***bush fly*** (*Musca vetustissima*), ***lesser house fly*** (*Fannia canicularis*), ***blowflies*** (Calliphoridae).

Garden flies (Diptera), eg ***garden maggot*** (*Bibio imitator*), ***garden soldier fly*** (*Exaireta spinigera*) feed on decaying organic matter and are often found in overwet compost heaps with poor drainage (Fig. 397). ***Maggots*** are usually dull brown, legless, up to 15 mm long, with more or less cylindrical bodies covered with protuberances. If plants are deep rooted, the loosening of soil by the maggots has little effect. Some injury may occur with ***shallow rooted plants*** due to drying out of the loosened soil. ***Flies*** are nectar feeding. ***Overwinter*** probably as pupae. ***Spread*** by adults flying. Reduce moisture in compost and provide adequate drainage.

Legionnaires' disease: Research is continuing to determine the risk to gardeners, nursery workers and those involved with potting media manufacture (Steele 1994). See Potting mix N 64, Soils N 81.

Nutrient deficiencies, toxicities: A carbon/nitrogen ratio of 30 or less (% C divided by % N in the organic materials used) should provide enough of all other nutrients except perhaps phosphorus (Handreck 1993). Manure from grain-fed animals, eg poultry, will supply phosphorus as will a light dressing of superphosphate. The need to add extra phosphorus is probably rare.

pH: Plant sap is acidic so compost heaps may start off acidic at about pH 6. However, the addition of lime increases the loss of nitrogen from compost and should not be added unless the materials being composted have a very low pH , eg fruit, and the pH of the matured compost is too low. A more desirable way is to add gypsum. Both ***superphosphate and gypsum*** reduce the level of undesirable odours coming from compost heaps and also reduce losses of nitrogen. Sawdusts and barks are often more acidic (in the range of pH 3-5) and this retards composting unless lime is added.

Suppressive compost: Some types of compost retard ***development of some soilborne diseases***, eg *Fusarium*, *Phytophthora*, *Rhizoctonia.* Composts may be specially designed to control certain diseases (Anon. 1996). ***Suppressiveness*** is due to some of the organisms in the compost preying on the pathogens, some compete with them for nutrients and some manufacture antibiotics (Anon. 1996, Moody 1996). The suppressiveness may last for months or years.

Bark of some eucalypts becomes strongly suppressive to disease organisms after a number of weeks of ***ageing***. Some pine bark composts are suppressive, others are not. Composting bark should contain some materials which are easily decomposed for suppressiveness to develop.
Sawdust composts are often not suppressive.

The high temperature microflora responsible for ***composting*** is gradually ***replaced*** as the pile cools by the microflora that is typically present in organic matter in the soil ***(curing)***. The aim is to ***recolonise the compost*** with as diverse a flora as possible. The new microflora prevents pathogen recolonisation. This curing process for *Pinus radiata* takes about 2-4 weeks. To adequately control *Pythium* it is considered necessary to add at least 25% (but not more than 45%) pine bark compost to the potting mix. Some hardwoods in the USA require curing for 2-3 months and suppression lasts for 2 years. Other materials may have shorter effective cycles. ***Overcured composts*** are ineffective disease suppressants while ***undercured composts*** may be conducive to some diseases. Poor physical structure, drainage and nutrient imbalance of potting media may cause the ***suppression to be lost***, eg good air capacity is essential to prevent *Phytophthora cinnamomi* sporulation and zoospore release.

Toxins

Sawdust is composted because it may ***tie up nitrogen*** and may contain large amounts of ***phenols*** that can inhibit the growth of plants. Most problems can be overcome by composting sawdust for 6 weeks with added fertilisers. ***Pine sawdusts*** generally contain less toxins and tie up less nitrogen than ***hardwood sawdusts***. Hoop pine is relatively free from toxins and may not need to be composted.
Bark of radiata pine needs to be stacked for at least 6 weeks and turned every 2 weeks to reduce the phenol content ***(ageing).*** This will also kill disease organisms. The material may be composted but where it comprises only a small proportion of the final mix, this does not appear to be necessary.
Pesticide residues: Do not to place material from pesticide-treated plants in compost bins, eg from treated lawn clippings, manure.
Plant and human health hazards: Do not add any phytotoxic materials, eg old fertiliser formulations or pesticides, to compost heaps as they might damage plants and some may be a ***health hazard***. ***Pesticide legislation*** regulates the disposal of pesticides and must be followed. Do not add dog droppings or human excreta/urine to compost heaps as they are ***potential health hazards***.

WEEDS

Perennial weeds: Vegetative reproductive structures, eg bulbs and cut up bits of roots and stems, added to compost, may grow in compost or grow after the compost is used. Weeds from surrounding areas may invade compost. ***Weed seed*** may be spread by a variety of means including wind and contaminate improperly stored, and/or uncovered compost heaps. Seed may also originate from annual and perennial weeds put on compost and which is then improperly composted.

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State/Territory Departments of Agriculture/Primary Industry eg
Compost for Home Gardeners (Vic Agnote)
Control of Flies in Compost (Vic Agnote)
See Mulch N 50, Potting mix N 65, Soil N 82

Remember, always check for recent references

MANAGEMENT

To ensure the production of disease-free and good quality compost, seek advice or obtain/borrow a pamphlet or book on composting. The introduction of the ***Australian standard*** (AS 95301) for composts, soil conditioners and mulches should ensure good quality control of those sold commercially.

Unsuitable materials to compost include bones or meat scraps as this encourages animals. ***Diseased plants*** should not be composted as diseases may be carried over to future crops if composting is inefficient. ***Weeds*** which have gone to seed or weeds with tough underground rhizomes or bulbs should also be avoided. ***Commercial growers*** should know which pests, diseases and weeds are of concern for their crops, and ensure that they are not being spread or multiplied via compost. ***Some materials are difficult to compost:*** Fibrous or woody materials do not make good compost, eg sawdust, wood shavings or tough oily leaves such as those from eucalypts or conifers; do not use paper unless it is torn into pieces.

Composting: ***Temperatures*** in the centre of compost should be monitored. Plant parasitic pests and diseases and many weed seeds are killed by temperatures of 60^{o}C for about 30 minutes ***(pasteurisation)***. Composting at temperatures of about 55^{o}C for about 2-3 weeks destroys most pathogens. Correct conditions must be provided for the microorganisms to bring this about, ie adequate moisture (not too wet), good aeration, a pH close to neutral plus a recommended complete fertiliser. ***Heaps*** must be turned every 2-3 weeks to ensure that all the material is ***decomposed*** and ***pasteurised*** (otherwise disease and pest organisms and weed seeds and weed parts may be distributed with the compost when it is used). After turning, lightly water. Compost should be ready to use in 2-3 months in summer but longer in winter.

Storage: ***Compost*** dried to < 40% can be stored indefinitely under cover, there will a small amount of decomposition until it dries to about 30% moisture. ***Cover*** to avoid contamination with airborne weeds seeds and fungal spores, to prevent aerobic decomposition which could result in it being toxic to plants, and leaching by rain whereby nutrients may be lost.

Use: Compost can be ***spread over*** beds to a depth of ***50-80 mm*** and dug into topsoil. Prior to use, ***incompletely*** composted material may be ***pasteurised*** or treated with ***fumigants*** to destroy nematodes, soilborne diseases, insect pests and rodents.

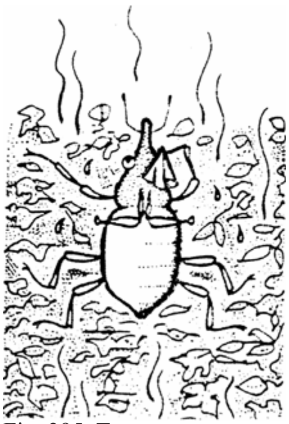
Fig. 395. Temperatures of 55-60^{o}C kill most pest organisms. CSIRO.

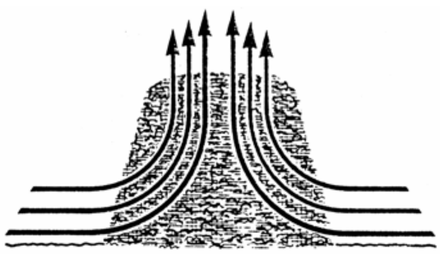
Fig. 396. Steam rising during turning of a free-standing compost heap. CSIRO.


Fig. 397. Garden soldier fly (*Exaireta spinigera*).
Top : Adult fly (12 mm long).
Lower : Maggots (15 mm long).

Containers (outdoor)

PESTS AND DISEASES
Non-parasitic
- Containers
- Nutrient deficiencies, toxicities
- Potting mix
- Re-potting
- Situation/site
- Watering

WEEDS

Plants grown in containers outdoors are susceptible to the same pests and diseases as their naturally growing counterparts in the ground, eg ***kumquats*** may be affected by ***citrus butterflies, scales*** and ***nutrient deficiencies***.

PESTS AND DISEASES
Parasitic

Some parasitic problems, eg ***snails and slugs***, may affect a range of containers outdoors, feeding on leaves and stems. See Seedlings N 70.

Non-parasitic

Containers are popular as decorative items on verandahs and balconies as well as in the home. Containers can be made of terracotta, ceramic, plastic, timber and even logs and stumps. Containers of all types must have sufficient ***drainage***. Pots may ***split*** when there is vigorous root growth, eg palms.

Hanging baskets tend to be very susceptible to ***drying out*** when placed in an open sunny position. Because of the limited volume of mix, it is undesirable to grow vigorous species in them as they quickly become pot bound. The cheapest basket is a wire frame lined with paper bark or synthetic lining, plastic and terracotta hanging baskets are also available.

Plastic pots are lighter in weight and most now have some inbuilt resistance to degradation due to exposure to the sun. Soil (and roots) may develop excessively high temperature during summer in sunny positions. Direct sun shining on pots can kill roots (Handreck and Bunker 1996).

Terracotta pots have long been used in the home garden. They are more expensive than polythene pots and are breakable. Because of the porous nature of unglazed terracotta, potting media may dry out rapidly (although this has a beneficial cooling effect during summer) and salts can accumulate on the pot wall.

Wooden tubs are attractive and expensive but may rot with time.

Nutrient deficiencies, toxicities

Regular small amounts of fertiliser keep container plants growing strongly. This may be obtained by regular fertilising or by the use of blood and bone and other slow-release fertilisers. Always apply fertiliser to moist soil to avoid burning young roots.

Too much fertiliser for potted plants or the wrong type can be disastrous especially if the soil becomes dry. Very high pot ***temperatures*** can lead to 'dumping' of nutrients from controlled-release fertilisers; when accompanied by a drying of the mix, the resulting salinity can kill plants (Handreck and Bunker). Use mushroom compost sparingly as it may contain high levels of ***salts***.

Particular plants require special nutrients, eg grow Proteaceous plants in low phosphate mixes.

Salt deposition around drainage holes, on the outside of terracotta pots, and on the surface of the mix in the pot is the result of evaporation of drainage water. Very soluble salts in the deposits will redissolve. The presence of a deposit indicates little about the overall level of salts in the pot.

Potting mix

Free-draining: Potting mixes must be free-draining. Special potting mixes are available for some plants, eg orchids, African violets and bulbs.

Compaction: Mushroom compost and leaf moulds should be used sparingly. If growing plants in containers for > 1 year, avoid using readily decomposable material in the potting mix. The use of mushroom compost and leaf mould leads to compaction and reduced volume and aeration of the potting mix. Such materials are of the greatest benefit when used as a surface mulch.

Re-potting: Repot plants only when the container is filled with roots. Do not put small plants into large containers, some prefer to be crowded. Some plants such as palms, commonly crack their containers.

Situation/site: For container gardening to be successful the right plant must be chosen for the situation/site.

Humidity: Container plants are better grouped together, the massed leaves creating a microclimate which produces a higher humidity.

Season: Container plants may need to be moved from place to place depending on the season and the species being grown.

Sunlight: Sun-loving plants need at least 3-4 hours sunlight each day to grow successfully.

Temperature: Very high or very low temperatures are often unfavourable. Plants may be scorched if placed adjacent to brick walls in summer.

Wind: Balconies are often windy, plants chosen should be able to withstand breezes.

Watering

Restricted root system: Container plants of all types have restricted root systems and are susceptible to drying out.

Mulches: Surface mulches help to reduce evaporation and cool the soil surface. However, it can be difficult to see whether the mix is dry.

When and how to water: On hot summer days daily watering may be needed, perhaps twice daily if the plants are in full sunlight. Water thoroughly. Fill the space between soil and rim slowly with water until it seeps out the drainage holes. Dripper irrigation systems can be used. Any wilting will be accompanied by a period of below-optimum growth.

Others: Algae, liverworts, moss, ants, glasshouse sciarids, millipedes and slaters which occur in greenhouses also affect house plants. See Greenhouses N 27, House plants N 36.

WEEDS

Weed-free mixes: Mixes should be weed-free to start with and this can be achieved by either pasteurisation or using guaranteed weed-free mix.
Weeds in containers: Annual and perennial weeds in containers may be removed by hand before they set seed. Do not allow perennial weeds to establish as the underground parts of some, eg bulbs (oxalis), can be difficult to remove by hand. Some weeds are introduced into gardens from potted plants. ***Liverworts and mosses*** may grow in pots in humid, sheltered sites. See Greenhouses N 27.
Maintenance of a weed-free mix: ***Granular pre-emergence herbicides*** which kill germinating weed seeds are registered for outdoor containers. They are applied to the surface of the soil after potting up, or in spring and autumn, after all emerged weeds have been removed either by hand or with shielded post-emergence herbicides which kill rhizomes and other underground parts of perennial weeds. ***Weed mat*** may be cut to shape and bark or similar material, placed on top. However, it can be difficult to check if plants need watering. Overseas herbicide-impregnated weed mats are being researched.

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Fertilising Container Grown Plants (NT Agnote)
Fertilising Container Plants (Vic Agnote)
Potting Mix Ingredients for the Top End (NT Agnote)

See House plants N 37, Interior plantscapes N 46, Mulch N 50, Potting mix N 65

MANAGEMENT

Remember, always check for recent references

Selection

Outdoor container plants are increasingly popular and are ideal when space is limited. For container plants to be successful, the right plant must be chosen for the situation. Some plants can more easily and conveniently be grown in containers than in soil. Plants that tend to grow or spread quickly, eg bamboo, can be contained, or plants that may be sensitive to frost, eg citrus, can be moved to more sheltered positions during cold weather. Select ***problem-free*** species from ***disease-free*** exotic or native plants**:** ***Annuals***, eg everlasting (*Helichrysum*), marigold (*Tagetes*), nasturtium, pansy, petunia, phlox; ***cacti and succulents,*** especially those without spines, eg kalanchoe; ***ferns***, eg the easy growing fish bone fern (*Nephrolepsis);* ***flowering bulbs***, eg daffodil, hyacinth, lily, tulip; ***fruit*** may be both useful and decorative, eg strawberry, apple and peach if grown on dwarfing rootstocks, also quince, fig, pomegranate, dwarf types of citrus, eg kumquat, Meyer lemon and mandarin; ***grasses***, eg lemon grass; ***herbs***, eg the low or dwarf species including chives, parsley, thyme, tarragon, basil, savory, mint, marjoram, oregano, pennyroyal, prostrate rosemary and dwarf lavender; ***orchids***, eg cymbidium, dendrobium; ***palms***, eg parlor palm (*Chamaedorea elegans*), lady palm (*Raphis excelsa*); most palms are strictly tropical plants, there are exceptions; ***trees, shrubs and climbers***, eg azalea, boronia, camellia, correa, hydrangea, fuchsia, daphne, geranium, lime, miniature and small floribunda roses, *Micromyrtus ciliata*; ***vegetables***, if the correct varieties are selected and given the right conditions of soil, moisture, nutrients and aspect, can be grown successfully in containers on balconies or parts of gardens where space is limited, eg lettuce, spring onion, dwarf and mini-tomato, capsicum; ***xeriscape plants***, eg bottlebrush, lavender, nasturtium, sacred bamboo.

Establishment and maintenance

Containers should be set up using the correct size pot, potting mix and irrigation system. ***Regular maintenance*** involves varying watering regimes during winter and summer, moving containers to accommodate seasonal changes, fertilising, repotting and pruning. ***Pests and diseases*** on a small number of container plants can be controlled by hand picking diseased leaves or pests, eg caterpillars and snails. Aphids may be wiped off. ***Pesticides*** registered for house plants, can be a convenient way to control most pests on outdoor container plants. A few pellets or a dust of snail bait on the mix surface (according to label directions) will control snails and slugs if they are a problem.

Postharvest

Depending on the plants being grown in containers there ***may or may not be a postharvest component***, eg daphne picked for cut flowers, herbs for cooking or drying will have a postharvest component. Vegetables and fruit, eg strawberries, require normal postharvest care.

Garden Centres

Garden centres sell plants to home gardeners who can reasonably expect them to perform well after planting out.

SELECTION

Considerations include:

Horticultural requirements: Sell what the local ***market demands***. In some areas legislation prevents the sale of ornamental plants that are likely to become weeds in that particular climatic area. Plants should carry appropriate labelling.
Cultural methods: Only sell plants suitable to local climates and at recommended times of year.
Resistant varieties: Avoid selling plants or cultivars known to be ***very susceptible*** to disfiguring diseases or pests.
Disease-free planting material: ***Plants*** may carry ***diseases***; ***media*** in containers may be contaminated with ***weed seeds***, ***diseases*** and ***insect pests***, eg black vine weevil. Garden centres should buy plants for re-sale from ***accredited wholesale nurseries*** guaranteed free from specified diseases, pests and weeds or from reputable wholesalers. Horticultural and stock acts regulate labelling and health status of some plants being sold. For ***certain types of plants***, eg some wild flowers in WA, only plants obtained from accredited *Phytophthora*-free nurseries should be sold. See Nurseries N 51.

MAINTENANCE IN GARDEN CENTRES

Plant material for sale should be fresh and well displayed, not damaged and should be sold as quickly as possible.

Cultural methods: Adequately water plants. Plants held for some time may need to be ***fertilised***.
Sanitation: Any dead leaves, shoots or broken parts should be pruned off and destroyed.
Pesticides: If pesticides have to be applied to plants in garden centres only use those registered for use in such a situation, eg public areas.

POSTHARVEST

Only sell plants during the ***recommended season***, otherwise give the purchaser ***advice*** on extra care to ensure survival when planted out. Plants should have healthy new growth and be in ***weed-free*** pots. Make sure plants from warm climate nurseries are ***hardened*** properly if necessary, prior to sale.

APPROVED SCHEMES

Some states have approved schemes for garden centres. Some of these are promotional schemes for members. ***Criteria*** which members must meet for approval include:

- ***Premises*** clean and attractive.
- ***Premises*** safe for customers and children, eg pools fenced, chemicals stored correctly.
- ***Pathways*** clean and wide enough to carry a wheelchair (Fig. 398).
- ***Signs*** neat and easily read.
- Wide range of ***stock*** available.
- ***Plants*** and ***surroundings areas*** free of diseases, pests and weeds.
- ***Plant material*** fresh and well displayed.
- ***Seasonal displays***.
- ***Prices*** clearly marked and easy to read and understand.
- ***Customer comforts*** available, eg ***seating***, refreshments and rest rooms.
- ***Umbrellas*** available on request.
- Printed and/or computerised ***gardening information*** available for customers and staff (Lake 1996).
- ***Staff*** neat and tidy and clearly identifiable to customers as staff members.
- ***Staff*** should be qualified/experienced and able to give technical assistance and advice.
- ***Transaction handling facilities*** available and clearly displayed, eg credit cards, EFTPOS.
- ***Facilities*** for moving customer's purchases to their vehicle, eg trolleys, baskets or staff members.

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Associations, Journals etc.
Australian Horticulture
Gardening Australia
Garden Centres of Australia
State/Territory Nursery Industry Assocs.
The International Garden Centres Assocs.

See Nurseries N 57

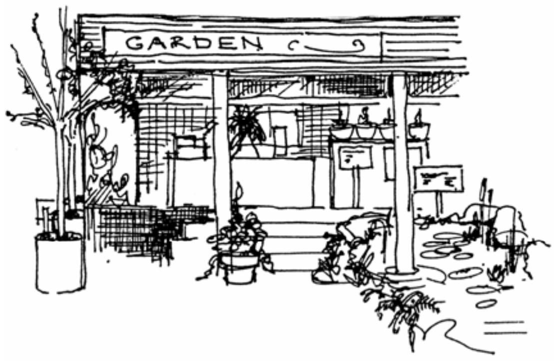

Fig. 398. Garden Centre. Steps inhibit trolley and wheelchair access.

Greenhouses

Greenhouse plants are susceptible to the same pests and diseases as their naturally growing counterparts outdoors. For example ***azaleas*** (*Rhododendron* spp.) may be affected by fungal leaf spots, phytophthora root rot, powdery mildew, azalea lace bug, azalea leafminer, greenhouse thrips or iron deficiency. ***Additionally*** they may become affected with problems common in greenhouses.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

House plants are remarkably free from virus diseases. However, ***some flowers***, eg carnation, orchids, strawberries and ***vegetables***, eg tomato, are susceptible to viruses. All are ***spread*** by vegetative propagation material, some also by insects which can be controlled by insect-proofing greenhouses, biological control agents or insecticides, some are also spread by seed. Some viruses which are spread by handling and have a wide host range are ***common in greenhouses***, eg ***tobacco mosaic*** and ***cucumber mosaic virus***. See Annuals A 4, Vegetables M 4.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) occurs occasionally on soft fleshy greenhouse plants particularly if overwatering occurs. See Vegetables M 5.

FUNGAL DISEASES

Damping off (various species of fungi) affects most types of seedlings, cuttings and other propagation material. See Seedlings N 66.

Grey mould, ***Botrytis***
Blossom blight, flower blight, petal blight

Scientific name: Imperfect Fungi:
Grey mould (*Botrytis cinerea*), also
Chocolate spot (*B. fabae*)
Grey mould (*B. gladiolorum*)

Host range: ***Ornamentals***, eg African violet, bulbs, cyclamen, freesia, orchids, petunia, ***fruit***, eg English gooseberry, strawberry, ***vegetables***, eg onion, ***field crops*** and ***weeds***. ***B. fabae*** occurs on broad bean and ***B. gladiolorum*** on gladiolus.

Symptoms: *Botrytis* occurs in ***greenhouses*** and in the ***field*** but is usually most important ***postharvest***. *Botrytis* is a weak pathogen that grows saprophytically on dying or dead plant material. It can penetrate plant tissue directly if provided with a food source. Infection often begins when it establishes in senescing floral parts producing abundant spores in cool humid weather. ***Aerial damping off*** may develop on seedlings (Fig. 399). ***Blossom blight*** develops on petals (Fig. 186, Roses J 1). Small ring-like markings (reddish in light-coloured varieties or creamy white in dark-coloured varieties) develop where individual spores have germinated on petals towards the end of the growing season. ***Blotches and spots*** develop on leaves and fruit and flower stems, ***cankers, rots and spots*** on stems and twigs, ***neck rots*** on bulbs, corms, tubers, ***rots*** on fruit or vegetables. Ripe fruit can be infected by touching a dead petal, the ground or dead leaves. Blossom blights often precede and lead to fruit rots which typically begin as a blossom-end rot of vegetables. Plant stems may also become blighted if they contact infected blossoms. Under moist conditions and favourable temperatures, grey furry spores develop on diseased parts. Small, hard, flat, black irregular fungal structures (sclerotia) may develop in the fungal growth. Plant parts and plants may die. *Botrytis* grows from fruit to fruit or from vegetable to vegetable ***postharvest*** (nesting).

Overwintering: Infected host plants, crop debris in the field and around packing sheds, trimmed stalks and leaves, infected soil, infected bulbs held over from season to season for seed production. Sclerotia in the soil germinate to infect new plantings. Seedborne on some plants, eg beans. Sclerotia in soil or in crop residues.

Spread: Spores are spread by wind and air currents from infected plants and crop debris. ***Introduction*** of infected plants, contaminated seed (sclerotia in bean seed), soil on machinery, tools and plant debris, eg compost. By mycelium growing from infected plant parts to healthy material. Sclerotia in the soil germinate to infect new plantings.

Conditions favouring: ***Cool weather crops***; cool, cloudy, foggy weather or heavy dew, especially near harvest, or after potting; poor ventilation, drainage and growing conditions;

overcrowding; presence of organic matter; prolonged wet humid weather or excessive overhead irrigation, especially at night; trimmed stalks and leaves around packing houses; plant injury during cultivation, harvest and packing. Optimum temperature is 18-23°C but *Botrytis* is active at temperatures as low as 10°C. De-leaving and flower picking should not leave snags as the site for *Botrytis* and other fungal infections. Cultivars with ***compact flowers*** and ***fruit bunches*** are ***susceptible***. Other factors include free moisture on the surface of fruit (a wet period of 9 hours is required for infection to take place); imperfect curing of bulbs especially when crops have been given nitrogen late in the season. Under ***cool, moist conditions*** the fungus produces a large number of airborne spores which begin new infections by invading tissue through injury or through natural openings (stomata) particularly in the presence of free water. ***During marketing***, the combination of injury, cool temperatures, high humidity and poor ventilation allowing ethylene buildup may favour further damage. ***Pollen*** is known to stimulate germination of spores of *B. cinerea* (Fletcher 1984). Showery weather is not necessary for severe outbreaks.

Control may be difficult if conditions favour disease development. Disease management strategies should be intensified during crop finishing and postharvest.

Cultural methods: Avoid overhead irrigation and wet and humid conditions. Space plants to provide good natural ventilation/aeration especially during damp conditions. Reduce humidity in greenhouses and shadehouses by ventilation and heating. Provide adequate ventilation during growth, transport of flowers. Avoid injury during cultivation, harvest and storage. Practice crop rotation to avoid buildup of inoculum. Try to keep foliage dry with good ventilation and heat. Avoid prolonged conditions of leaf wetness and high relative humidity. Remove lower leaves of shoots to give better aeration and expose berries to sunlight after the pea-size stage. Avoid irrigation during the period approaching maturity. ***Excessive nitrogen content*** can make some plants more susceptible, eg grape bunches.

Sanitation: Remove/destroy old, senescing or infected flower heads, fallen leaves, dead plant material, weeds, prunings and plant debris promptly at regular intervals in greenhouses (and in the field) as *Botrytis* grows freely on them and produces vast quantities of spores. Do not allow them to accumulate around plants, packing sheds and greenhouses. Rogue and burn badly infected plants. Ensure strict hygiene in and around packing houses. Prune badly damaged affected leaves and stems. Do not allow old crops to remain standing.

Biological control: By fungi, eg *Myrothecium verrucaria, Gliocladium roseum, Trichoderma viride* (Hausbeck and Moorman 1996). A bacterium, *Bacillus subtilis,* provides some control of *Botrytis* and *Rhizoctonia*. *Pseudomonas fluorescens* strain PB 2B10E reduces disease on petunia overseas by 77%.

Resistant varieties: Some varieties are more susceptible. Multi-petalled flowers and grapes with tight bunches or thin skins, are more susceptible.

Disease-free planting material: Do not use seed from infected crops.

Physical and mechanical methods: Plastic mulch and/or intervals of forced heated air reduce the incidence of *B. cinerea* on geraniums in greenhouses.

Pesticides: Fungicides are effective only if cultural and sanitation treatments are also carried out. Spray prior to harvesting flowers. Use sterilants in packing sheds. Apply fungicides early in the day so that they dry before nightfall. ***Gladiolus corm treatments:*** If *Botrytis* leaf spots have occurred during the growing season or if the weather is damp at digging, corms should be treated (see Gladiolus C 30). Dip corms in fungicides prior to planting. Apply registered fungicides as field sprays, prior to harvest or postharvest. Fungicides may damage flowers. ***Widespread resistance*** of *Botrytis* to fungicides has been detected.

Rhizopus soft rot (*Rhizopus stolonifer*)

is a minor disease in greenhouse grown crops. *Rhizopus* is commonly present in ***decaying plant material*** in ***soil***. ***Petals*** collapse with a wet rot which extends into the heart of the flower. Black fungal spores develop on the rotted tissue. The fungus may grow readily on ***packing material*** and invade flowers through injuries. Inoculum builds up on trimmings from flowers if these are left in or around packing sheds. ***Avoid injury***, keep flowers dry. Ensure ***good hygiene*** in packing shed. See Fruit F 6, Vegetables M 6.

Root, crown and stem rots

Fusarium root and stem rots (*Fusarium* spp.)
Phytophthora root rots (*Phytophthora* spp.)
Pythium root rot (*Pythium* spp.)
Cylindrocladium diseases (*Cylindrocladium* spp.)
Rhizoctonia stem (*Rhizoctonia solani*)
Sclerotinia rots (*Sclerotinia* spp.)
Sclerotium stem rot (*Sclerotium rolfsii*)
Thielaviopsis black root rot (*Thielaviopsis basicola*)
See Vegetables M 7.

Others:

Many fungal diseases which occur on greenhouse plants are host specific including ***fungal leaf spots*** (various species), ***powdery mildews*** (Erysiphales), ***rusts*** (Uredinales) and ***wilts***, eg fusarium wilt (*Fusarium oxysporum* f.spp.) and verticillium wilt (*Verticillium dahliae*).

NEMATODE DISEASES

Many species have a wide host range, eg ***root knot nematodes*** (*Meloidogyne* spp.). See Vegetables M 10. ***Foliar nematodes,*** leaf eelworms (*Aphelenchoides* spp.) are common on ferns and other plants. See Ferns E 2.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera)

Cotton aphid, melon aphid (*Aphis gossypii*)
Green peach aphid (*Myzus persicae*)
Lily aphid (*Aulacorthum circumflexum*)
Some aphids occurring in greenhouses have a ***wide host range***. Adults, nymphs, nymph skins and honeydew disfigure plants and give them a shiny, sticky appearance. ***Sooty mould*** may grow on the honeydew causing further disfigurement. Nymphs and adults feed by sucking sap. When infestations are heavy, distortion of shoots, leaves, buds and flowers may result. Leaves and whole plants may dry

and shrivel. The ***life cycles*** of most aphids in greenhouses are similar except for some variation in the length of time which it takes different species to develop. All species continue to go on, generation after generation, all the year round. Where there are only a few plants, aphid colonies can be removed ***by hand***, hosed off, spot treated using a small brush or cotton bud dipped in alcohol or methylated spirits. Do not injure the plant. Plants may be washed carefully with warm soapy water or dipped upside down in warm soapy water and rinsed in clear warm water. Large plants can be washed with a sponge. ***Predatory lacewings*** (*Mallada signata*) may be purchased. ***Parasitic wasps*** may control some species. Plants may be sprayed with an ***insecticide*** registered and recommended for use in greenhouses when aphids are first seen. Soft-foliaged plants may be placed in a plastic bag with a pest strip for several days to control aphids and other pests. Home gardeners can use one labelled for indoor plants. Take plants outside to treat unless label says otherwise. See Roses J 4, Vegetables M 11.

Caterpillars (Lepidoptera)

Lightbrown apple moth (*Epiphyas postvittana*)
Loopers (*Chrysodeixis* spp.) (Fig. 400)
Painted apple moth (*Teia anartoides*)
Moths can ***fly*** into greenhouses and polytunnels and subsequently breed inside. They can be ***difficult to control*** in conservatories where there are tall plants which are difficult to reach and treat. Caterpillars may be well camouflaged and hard to find, generally their droppings give them away. See Annuals A 8.

Greenhouse orthezia

(*Orthezia insignis*, Ortheziidae, Hemiptera) is a tropical species which can be ***troublesome*** in greenhouses. They are rather like Margarodidae and are related to scales and mealybugs. ***Nymphs*** are the size of pinheads, dark green with rows of minute waxy plates extending back over the bodies. ***Females*** have a white waxy, fluted egg sac which extends backwards for a distance of 2-3 times their body length. They ***resemble mealybugs*** closely in their habits, control is similar. See Greenhouses N 25.

Greenhouse thrips, black thrips

Scientific name: Thripidae, Thysanoptera:
Greenhouse thrips (*Heliothrips haemorrhoidalis*)
A cosmopolitan species, primarily an out-of-doors pest. Other thrips occur in greenhouses, eg ***plague thrips*** (*Thrips imaginis*); ***western flower thrips (WFT)*** (*Frankliniella occidentalis*) is potentially the ***most serious thrips pest*** in Australia (Hill 1994).

Host range: ***Ornamentals***, eg azalea, fuchsia, viburnum, indoor and outdoor plants, ***fruit***, eg citrus, grapevine, guava, passionfruit, persimmon, plum, prune.

Description and damage: ***Adults*** are elongated, dark brown to black, about 1.5 mm long (just visible to the naked eye). The fringed wings, legs and antennae are whitish in colour. Although winged, they rarely fly. ***Nymphs*** are initially whitish, then yellowish with red eyes. Nymphal stages carry a drop of excrement on the tip of the abdomen. Nymphs and adults suck sap mainly from ***leaf undersurfaces*** where they feed and produce disfiguring ***black spots of excreta***. Leaf uppersurfaces become ***silvery*** (Fig. 401). In severe infestations, thrips may feed from the uppersurface as well. ***Fruit***, eg ripe or almost ripe citrus, may be seriously blemished and have reduced shelf life.

Pest cycle: Gradual metamorphosis (egg, nymph, prepupa, pupa, adult) with many generations each season. There are no males. All adults, which may live for up to 3 months, lay eggs (1-2 eggs per day). Eggs are inserted singly into leaf undersurfaces or fruit tissue just under the surface. The eggs swell as they develop and cause minute pimples to appear on infested leaves or fruit. Nymphs hatch from these eggs and when fully grown enter a pre-pupal and pupal stage.

Overwintering: On the host plant. On indoor plants the cycle is continuous.

Spread: Adult thrips can only fly for a few centimetres. Spread is also by wind and on shrivelled leaves, visiting insects and by the movement of infested container plants, cuttings, etc. Thrips crawl from plant to plant.

Conditions favouring: Tropical and sub-tropical conditions, greenhouses. Shady, cool and fairly moist protected situations; thickly foliaged plants with clustered flowers or fruit allowed to hang until late summer in seasons of good summer rainfall. Often where light is low, for example in the centre or on the shady side of plants, on leaves near the ceiling. Hot, dry weather or heavy rain adversely affects greenhouse thrips outdoors.

Control: On some hosts damage is not economic so that control measures may not be necessary. The National ***WFT*** Strategy Group researches biological and chemical controls for ***WFT***.

Cultural methods: If practical, increase light intensity, raise temperature, lower humidity. Avoid overmoist conditions and planting susceptible species in such conditions.

Sanitation: If only a few shoots are affected they can be pruned off and destroyed.

Biological control: No biological control agents are available. A tiny wasp parasite (*Ceranisus* sp.) has been found abundantly on garden hosts of the greenhouse thrips in NSW coastal districts. Overseas, ***predatory mites*** (*Amblyseius* spp.) and a minute bug (*Orius tristicolor*) provide some control.

Physical and mechanical methods: Bug netting is used for western flower thrips overseas, but it should be used with care as the small size of the mesh can reduce ventilation (Parrella 1996).

Pesticides: Apply ***foliage treatments*** to protect new leaves when thrips are first observed. Because the eggs are inserted in plant tissues, a 2nd spray is usually necessary to kill the nymphs which have emerged from the eggs since the 1st spray. Two sprays at the above intervals at the first signs of infestation may provide control for a season. Parasitic wasps are frequently killed by sprays used to control other pests such as aphids and mealybugs. ***Soil treatments*** are available. Greenhouse thrips populations should be ***monitored*** (Brough et al. 1994).

Greenhouse whitefly

Scientific name: Aleyrodidae, Hemiptera:
Greenhouse whitefly (*Trialeurodes vaporariorum*)
Other whiteflies may be major pests in greenhouses, eg ***poinsettia whitefly,*** silverleaf whitefly (*Bemesia tabaci* type B). See Poinsettia K 116.

Host range: ***A serious and persistent pest*** of broadleaved plants in greenhouses and outdoors. ***Ornamentals***, eg boronia, fuchsia, ***fruit***, eg citrus, ***vegetables***, eg bean, cucurbits, tomato, ***weeds***.

Description and damage: ***Adults*** are small, delicate, white, moth-like, about 1.5 mm long with 2 pairs of white powdery wings which are folded when at rest (Fig. 402). They do not fly readily. ***Nymphs*** are translucent, greenish and scale-like with fine waxy marginal filaments. They are from 0.3-0.75 mm long depending on the nymphal stage. Nymphs and adults suck sap from new shoots and leaf undersurfaces of soft-foliaged plants. When disturbed, they rise in the air and flutter about the plant. Leaves develop a sandy mottle. Whiteflies secrete honeydew on which ***sooty mould*** grows, disfiguring plants. They may have to be washed before marketing or eating. Heavily infested ***seedlings*** may die. ***General:*** Severe infestations can cause plants to lose vigour and wilt. ***Yield*** may be reduced. Sometimes whiteflies may be present but do not cause any real damage.

Pest cycle: Gradual metamorphosis (egg, 4 nymph stages, adult) with many generations each year. Under favourable conditions 1 generation from egg to adult takes from 5-8 weeks. Each female lays several hundred eggs in circles or arcs on the undersurface of smoothleaved plants or scattered, about if leaves are hairy. After hatching, 1st stage nymphs crawl about on the underside of the leaf for up to 3 days before settling down to feed. Later nymphal stages complete their development at this site.

Overwintering: In cooler climates outdoors, as unhatched eggs on leaf undersurfaces and as adults. In warm climates and in greenhouses the cycle is continuous. In cooler areas outdoors, on host plants and as adults in sheltered places.

Spread: As adults flying assisted by wind. Also by the movement of infested plants carrying eggs, nymphs and/or adults.

Conditions favouring: Mild moist conditions as in greenhouses. Outdoors it is a sporadic pest in protected situations with humid atmospheres in late spring, summer and autumn.

Control:

Cultural methods: Reduce humidity to assist control in greenhouse and outdoor situations. Some plants, when used as companion plants are reputed to repel whiteflies, eg nasturtium.

Sanitation: Affected leaves can be removed.

Biological control: An introduced ***parasitic wasp*** (*Encarsia formosa*) lays one egg inside the body of the 4th stage nymph. The wasp larva feeds inside the whitefly nymph. Parasitised 4th stage nymphs turn ***black*** within a few days (unparasitised nymphs are white). The wasp larva pupates and emerges through a round hole. Infestations are often kept in check by this wasp and plants should be examined for parasitised nymphs; treatment may not be necessary. In greenhouses, parasitic wasps are frequently ***killed by sprays*** used to control other pests, eg mealybugs. A ***predatory lacewing*** (*Mallada signata*) may be purchased. Overseas ***more effective parasites***, eg *Eretmocerus mundus,* and ***predators***, eg ladybird (*Delphastus* sp.), are being researched, also a ***pathogenic fungus*** (*Verticillium lecanii*). Overseas ***poinsettia whitefly*** (*B. tabaci* type B) is parasitised by *Encarsia formosa, Beauveria* ***fungus*** (Naturalis-L) is also being researched.

Resistant varieties: Cultivars with ***hairy leaves*** and toxic sap are considered to slow whitefly development.

Physical and mechanical methods: ***Yellow boards*** or plastic sheets covered with a clear sticky grease attract whiteflies which stick when they land. Boards must be cleaned regularly and re-coated with the sticky material. The sticky material must not mask the yellow colour. Used for small areas outdoors and glasshouses. Keep well above plants so as not to catch parasites. Overseas, fluorescent yellow paints are used. Useful where pesticides cannot be used. Small outbreaks can be dispersed by hosing.

Pesticides: Whiteflies may be difficult to control, systemic sprays may be needed for persistent attacks. Outdoors, insecticides may be applied to leaf undersurfaces when seen. Repeat applications may be needed as insecticides may not kill eggs. Insecticides may also kill the parasites. ***Monitor*** whitefly populations and their parasites before applying an insecticide (Brough et al. 1994).

Longtailed mealybug

Scientific name: Pseudococcidae, Hemiptera:
Longtailed mealybug (*Pseudococcus longispinus*)
Other species also occur in greenhouses, eg
Citrophilous mealybug (*P. calceolariae*)
Tuber mealybug, obscure mealybug (*P. affinis*) is considered to be the most important root-feeding mealybug in Australia.

Host range: A pest of greenhouses, ferneries and indoor plants. ***Ornamentals***, eg herbaceous plants, orchids, palms, bulbs, ***fruit***, eg citrus, custard apple, grape, ***grasses and clovers.***

Description and damage: ***Adult females*** are slow moving, oval, wingless, flattened and 3-4 mm long with well developed legs, (Fig. 403). They are covered with a mealy white wax which forms short hair-like filaments usually longer than the body. ***Males*** in the early stages are similar to females, but form cottony cocoons about 3 mm long, within which they develop. Adult males are minute 2-winged insects with legs and do not feed. The length of the anal filaments and colour of a fluid exuded from dorsal glands can assist field identification of species. See Citrus F 38. ***Nymphs*** resemble adults. ***Above ground damage:*** Mealybugs feed by sucking sap in sheltered parts, eg sheaths, leaf bases, leaf undersurfaces. Infestations are often not noticed until mealybugs are numerous and unsightly. Soft foliaged plants wilt and may die. Infestations also occur on ***roots.*** This is only noticed when the plant is being re-potted, wilts or dies. Economic damage is caused by the excretion of large quantities of honeydew. ***Sooty mould*** develops on excreted honeydew, dirties leaves, stems and fruit (may cause end rots and fruit drop). ***Ants*** (Formicidae) are attracted to honeydew, fruit touching the ground is often covered with dirt from ant activity.

Pest cycle: Gradual incomplete metamorphosis (egg, 3-4 nymph stages, adult), many generations each year. Longtailed mealybugs produce about 200 young in 2-3 weeks. Eggs hatch as they are being laid. Eggs of other species, eg citrophilous and tuber mealybug, are laid in a loose cottony mass, light yellow crawlers hatch 3-9 days later.

Overwintering: Outdoors, as eggs during cold weather, in greenhouses there is no overwintering, the cycle is continuous. Longtailed mealybugs observed on citrus in SA moved from the foliage to branches, trunks and soil in spring and a new generation returned to the foliage.

Spread: By mealybugs crawling from plant to plant, movement of infested plants (into glasshouses, purchasing infested plants, etc.), on ants, birds and clothing, by wind and visiting insects and birds.

Conditions favouring: Warm, humid conditions. Weakened plants, eg those grown in very dry situations or those held in pots for too long. Thickly-foliaged mature trees. Dusty trees. Use of strong Bordeaux mixture. Ants attracted to honeydew discourage the predatory mealybug ladybirds (*Cryptolaemus*).

Control: Control can be difficult.

Cultural methods: Good irrigation will help to reduce the effects of infestation, as adequate water replaces sap that is lost to sucking insects.

Sanitation: Severely infested plant parts can be pruned out and burnt. ***Severely infested*** small plants of little value in glasshouses and houses frequently have infested roots. These plants should be discarded as even regular control treatments can fail to eradicate this pest. ***Minor infestations*** may be spot treated by dabbing with a small brush or cotton bud dipped in alcohol or methylated spirits. Mealybugs may be picked off by hand and killed. Plants may be washed carefully with warm soapy water or dipped upside down in the water and then rinsed in clear tepid water. Large plants may be washed with a sponge. ***Sooty mould*** in the navels of mature oranges is not easy to remove by washing before packing.

Biological control: Natural control is not always completely effective. The most important ***predator*** is ***mealybug ladybird*** (*Cryptolaemus montrouzieri*) which can be purchased. It is black and red and 3.5 mm long, lays its yellow eggs singly in the mealybug egg sacs or near clusters of mealybugs. ***Larvae of the ladybird*** are about 3 times as long as mealybugs. They have long marginal filaments and are covered with white mealy material, so they may be ***mistaken for mealybugs*** but are more active and have biting mouthparts. Mealybug ladybird was introduced to WA and California as a biological control agent for mealybugs. ***Other predators*** include various lacewing larvae (*Chrysopa* sp., *Oligochrysa lutea*), *Mallada signata* can be purchased. The main ***parasite*** is a small wasp (*Leptomastix dactylopii*) which may be reared or purchased (Goodwin and Steiner 1996)

Resistant varieties: Some cultivars of plants are very susceptible. In Washington navels, mealybugs lodge in the navel encouraging rots and sooty mould. In some grapefruit, mealybugs shelter under the calyx or between 2 fruits or leaves which are touching one another.

Pesticides: Mealybugs are difficult to control with insecticides because they feed in difficult-to-reach places. ***Monitor*** mealybugs, parasites and predators at regular intervals before making a decision to release parasites or predators or apply an insecticide (Brough et al. 1994). In glasshouses, if parasites and predators are not being used, regular preventative foliage treatments may be necessary. Indoor plant insecticides may be used. Oil sprays may injure some indoor plants, eg ferns. If mealybugs are on ***roots*** of plants in pots, wet soil in pot thoroughly the night before to lessen the chance of root damage. Use enough liquid to wet the complete root zone. Place basin at base of pot plant and allow insecticide solution to soak in. Insecticides may disrupt natural controls. Spray with indoor plant insecticides, take outside for treatment unless label says otherwise. Treat soil with drenches or soil granules. Petroleum oil causes minimum harm and loosens the sooty mould but may damage soft-foliaged plants. ***Coastal brown ants*** (*Pheidole megacephala*) tend mealybugs for honeydew and move them around and fend off natural enemies. In outdoor infestations ants need to be controlled in spring by spraying lower trunk and beneath the canopy.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus,* Tarsonemidae) affects broadleaved plants, ***ornamentals***, eg dahlia, camellia, ***fruit***, eg avocado, citrus, lemon, ***vegetables***, eg bean, silver beet, rhubarb, ***weeds***, eg potato weed. ***Adults*** are microscopic, flat, active, 8-legged, shiny, translucent white or very pale yellow, oval-shaped. Females are about ***0.25 mm*** long, males are smaller. Only a few mites per shoot tip may cause extensive damage but they can be hard to find. Mites suck sap from ***undersurfaces of young leaves***, causing them to become narrowed, distorted, with edges curled under, and often with bronzed undersurfaces. ***Young stem growth*** may be distorted, plants look as if they have been damaged by hormone herbicide (2,4-D). By the time injury is observed mites may no longer be present, but have moved to undersides of developing leaves. Damage to young foliage can harm development of nursery trees. Broad mite damage is not as common as twospotted mite injury and spread is less rapid. Often only some shoots on a plant are affected. Young ***fruit*** of crops such as lemons and Valencia oranges may be severely blemished (silvery-green blemishes with 'sharkskin' textures, fruits low on the tree are usually affected first). Many generations each year. Before mating, pre-adult females are carried about by males, which move about actively. By this means new sites become infested. Unfertilised females produce only male young. Translucent flat oval eggs about 0.1 mm long, ***ornamented*** with tubercles (Fig. 404), stick firmly to the infested tissue near the veins. ***Favoured*** by warm, humid summer/autumn weather and new growth. ***Control*** is difficult. ***Biological control:*** Little is known of the natural enemies. A ladybird (*Scymnus* sp.) has been seen feeding on the mites. A predatory mite (*Amblyseius victoriensis*) may provide effective control on citrus. ***Pesticides:*** Spray affected plants thoroughly when infestation is first detected, especially leaf undersurfaces. Control any nearby weed growth. Insecticides do not give long-term protection and plants may be rapidly reinfested. Regular repeat treatments may be required if weather is warm and humid. Monitor mites and predators before applying an insecticide (Brough et al. 1994).

Cyclamen mite (*Phytonemus pallidus*, Tarsonemidae) may feed on plants in greenhouses, there may be races. ***Young leaves, buds and petals*** may be ***distorted***, flowers may not open properly. Leaf edges may be rolled or curled. Severe infestation results in stunted growth. Cyclamen mite is tiny, ***0.25 mm*** long (Fig. 404), adults are pale brown, nymphs are smaller, paler. Broad mite is slightly smaller, broader and moves faster then the cyclamen mite. Few natural enemies occur in glasshouses. Typhlodromid mites are known predators on outdoor crops but unlikely in greenhouses as routine sprays would probably kill them. Possibly *Phytoseiulus persimilis* may prey on cyclamen mites. See Cyclamen C 16.

Twospotted mite (*Tetranychus urticae*) is a ***serious pest*** of greenhouse. ***Adult mites*** are easily seen with a hand lens (Fig. 404). ***Nymphs*** initially have six legs but later nymphal stages have 8 legs. Nymphs and adults feed mostly on ***leaf undersurfaces*** and often quantities of webbing are readily seen. Leaves become speckled, yellow and fall. Do not confuse twospotted injury to leaves with damage caused by leafhoppers, whiteflies, thrips or deficiencies. Leaves of house plants can be misted or syringed or wiped with a moist cloth, regularly and frequently. Predatory mites are available for monocultures in greenhouses but are not really suitable for house plants. Some house plants are very susceptible, eg umbrella plant, cocos palm. Twospotted mites may be controlled by ***predatory mites***, eg *Phytoseiulus persimilis, Amblyseius,* and by a predatory midge (*Therodiplosis persicae*). See Beans (French) M 29.

There is a ***gradual metamorphosis*** (egg, nymph, adult) with usually many generations each year. In greenhouses the cycles are usually continuous. They are ***spread*** by introduction of infested plants, by wind, visiting insects, birds and man. Mites crawl from plant to plant.

Scales (Hemiptera)

Greenhouse plants susceptible to scale infestations include ferns (Fig. 405) and rubber plants.

Soft scales (Coccidae)
- Black scale (*Saissetia oleae*)
- Hemispherical scale (*S. coffeae*)
- Nigra scale (*Parasaissetia nigra*)
- Soft brown scale (*Coccus hesperidum*)

Armoured scales (Diaspididae
- White palm scale (*Phenacaspis eugeniae*)

Scales suck sap from stems and leaves, causing disfigurement, poor growth and stunting. Severely infested plants can die. ***Soft scales*** secrete honeydew on which sooty mould grows, causing further disfigurement and attracting ants. Dead scale insects may cling to plants for a month or more. Living scale insects exude some juice when crushed, dead scales become dry and chaffy. ***Cultural methods:*** Indoor plants can be misted or wiped with a moist cloth but in glasshouses the high humidity can unfortunately encourage other pests, eg whiteflies, and diseases, eg powdery mildews. If only 1-2 plants are affected, prune out badly infested parts and wash off scales with soapy water, then rinse foliage in lukewarm clean water. This treatment is not suitable for soft-foliaged plants. ***Sanitation:*** Severely infested portions of some plants may have to be pruned out. ***Parasitic wasps*** may be purchased to control ***some armoured scales*** (Table 7, Greenhouses N 31). ***Resistant varieties:*** Some plants are more susceptible than others and are best avoided, eg *Ardisia*. ***Pesticides:*** Two sprays about 7-10 days apart are necessary. The 1st spray is applied when crawlers are active. It does not kill eggs so a 2nd spray about 10 days later is needed. In greenhouses the cycle is continuous. Watch for re-infestation and deal with it promptly. Any indoor house plant spray will be effective. In greenhouses, pressure canisters, pest strips, misters, pulsfogs, etc. may be used. Indoor plants, eg ferns, may be sensitive to petroleum oil sprays. Individual plants may be placed in a plastic bag with a pest strip for several days. Ants if present should be controlled by spraying a small area of surrounding soil regularly with household ant spray. See Citrus F 39, F 41.

Others: ***Black vine weevil*** (*Otiorhynchus sulcatus*) may be controlled with nematodes (Otinem® or by a fungus (*Metarhizium anisopliae*). ***Garden symphylid***, glasshouse symphylid (*Scutigerella immaculata*) is a small active animal which may feed on root hairs providing an entry point for soil fungal diseases. Adults are delicate white < 8 mm long with 12 pairs of legs and long mobile antennae, nymphs have 6-12 pairs of legs. See Vegetables M 18. ***Glasshouse leafhopper*** (*Hauptidia macroccana*) which occurs overseas can be checked by a tiny parasitic wasp (*Anagrus atomus*) which enters glasshouses or by using soap sprays. ***Millipedes*** (Diplopoda) are round with at least 11 body segments and 19 or more pairs of legs, 2 pairs/segment (Fig. 406). They feed on decaying organic matter but may feed on roots and plant material on the damp soil surface. ***Slaters***, pillbugs, woodlice (Crustacea) are light-grey , fat-bodied, segmented with 7 pairs of legs, and are up to 12 mm long (Fig. 406). They usually hide about the bases of plants, under flower pots, stones, damp leaves, in compost heaps and mainly feed on decaying damp organic matter. Some species also chew seedlings, young tender plants and strawberry fruit, near the ground, and may cause considerable damage. They may also feed amongst the foliage of ornamental plants in fern houses and glasshouses. Because they feed at night, they are not usually observed feeding. ***Overwinter*** as all stages. ***Spread*** by older stage nymphs and adults crawling from plant to plant, movement of infested containers, plants, soil, compost, manure. ***Favoured*** by damp conditions, contact with ground. Remove hiding places and plant and soil debris. Pesticides are generally not necessary. ***Wireworms*** (Elateridae) may occasionally be found in greenhouses.

SNAILS AND SLUGS

Slugs may invade greenhouses, especially if containers are on soil and surrounding areas are weedy. They may be carried in on plants. See Seedlings M 70.

Non-parasitic

Algae, liverworts and moss: ***Algae*** are common on the surface of media in pots and on floors which are overwet. Clean prior to treatment with algicides. Woven mesh or slotted black polythene sheet reduces algal growth on capillary mats (Handreck and Black 1994). See Turfgrasses L 13, Water N 91. ***Liverworts and mosses*** (Bryophyta) like fertiliser and water, cool climates but can survive hot summers. They grow in greenhouses and polyhouses and outdoors. See Turfgrasses L 15.

Spread by wind and water. ***Control is difficult***. They ***reproduce*** by spores and by vegetative means (Fig. 407) and are transferred during repotting. They must be controlled before they become established. Some pre-emergence herbicides have some control but are difficult to use in tubes and should not be used in greenhouses. Algicides give good control but often damage plants and may be expensive. ***Nursery hygiene and vigilance*** are necessary to prevent the production of windborne spores (Nichols 1995).

Ants (Formicidae, Hymenoptera) are attracted to ***honeydew*** secreted by aphids, mealybugs, scale or whiteflies which should be controlled. Occasionally ants feed on ***plants*** themselves and assist spread of scale and other insects. Ants may nest in containers, and it may be necessary to repot plants or drench pots with an insecticide. See Trees K 19, Turfgrasses L 8.

Environment: Environmental problems are the ***commonest problems*** associated with greenhouse plants. It is not possible here to describe the moisture, temperature and light requirements of each plant species, the onus is on the grower to find out each plant's requirements. Only then will the desired affect be achieved. See House plants N 36.

Fungus gnats (Mycetophilidae, Diptera) and ***black fungus gnats*** (Sciaridae, Diptera), eg glasshouse sciarids (*Bradysia* spp.), are grey or black ***flies,*** about 2-3 mm long which hover in groups around plants or run over the surface of pots at dusk. They can be a nuisance indoors around potted plants. ***Maggots*** of most species are small, thread-like, active, translucent, legless, about ***5-8 mm*** long with small dark heads (Fig. 406) which feed on decaying fungi in roots, cuttings and seedlings in soils which are wet (overwatered, poorly drained) or rich on organic matter. Roots may be scarred and root hairs eaten off. Overseas, maggots may transmit soilborne fungi, eg *Pythium*, and have been linked with the spread of *Botrytis, Fusarium, Thielaviopsis* and *Verticillium*. Plants lack vigour, leaves turn yellow. Maggots may leave a tiny slimy trail glistening on the mix surface. The ***only permanent cure*** is to avoid overmoist media. Allowing it to dry out as much as possible without injuring plants will kill many maggots, Plants may need to be repotted ***using less organic matter***. Overseas, fungus gnats may be ***controlled*** by *Bacillus thuringiensis* var. *israelensis*, parasitic nematodes (*Steinernema feltiae*) and predatory mites (*Geolaelaps, Stratiolaelaps*) (Gill and Dutky 1995). Artificial light traps capture enormous numbers of flies. 50 mm ***vermiculite*** on top of soil discourages adult flies from egg-laying (Goodwin and Steiner 1996). Soil may be drenched to kill maggots with an ***insecticide*** which does not injure roots or plant bases may be dusted to kill flies before egg laying. Overseas, an insect growth regulator, ***azadirachtin***, is applied as a soil-less media drench. In greenhouses, ***pest strips*** control the flies. See Mushrooms M 63. ***Shore flies*** (Ephydridae) occur in greenhouses, larvae and adults feed on ***algae*** (not plant roots or stems); larvae are maggot-like, wedge shaped and may spread *Pythium* and other diseases.

Nutrient deficiencies, toxicities should not occur today with the widespread use of slow-release fertilisers. However, whatever crop is being grown, learn to diagnose the deficiencies or toxicities that may occur on that crop.

Pesticide and chemical injury: Greenhouses tend to run at higher temperatures, and because they are enclosed areas any ***vapours*** produced by pesticides cannot quickly escape. Pesticide injury is common especially by oil sprays, dimethoate (Rogor®), and by the vapours of certain herbicides, eg oryzalin (Surflan®). Do not add wetting agents unless advice has been sought. ***Environmental pollution*** commonly occurs due to the presence of fertilisers and pesticides in drainage from a greenhouse. Recycling of irrigation and cleaning water in greenhouses is recommended.

WEEDS

It is essential to identify the types of weeds which may occur in a specific situation and some sort of weed control program is essential. ***Types of weeds:*** ***Annual broadleaved weeds***, eg cardamine, ***annual grass weeds***, eg winter grass, ***perennial broadleaved weeds***, eg oxalis and ***perennial grass weeds***, eg couch, can be common in greenhouses with poor weed control programs. ***Control:*** Soil pasteurisation will kill many weed seeds. After potting up, a pre-emergence herbicide, eg Ronstar® may be applied. Weeds should be reduced in areas immediately outside greenhouses. Do not expose mixes, etc, to windblown weed seed or allow them to be stored on floors contaminated with weeds seeds. Eradicating existing weed infestations can be difficult. For example, it is not possible to hand weed oxalis because the rhizome remains in the soil and the seeds are explosively spread. Oxalis may be hand treated with glyphosate using either a small directed hand spray or brush. Treat with Ronstar® to prevent seeds germinating. This needs to be carried out diligently to eradicate the problem. Containers should not be weed infested.

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Broad Mite (NSW Agfact, Vic Agnote)
Greenhouse Design for the Home Garden (Vic Agnote)
Greenhouse Management in the Home Garden (Vic Agnote)
Greenhouses (NSW Agfact)
Greenhouse Whitefly (NSW Agfact, Vic Agnote)
Management of Poly Houses (NSW Agnote)
Polythene Ducting (Vic Agnote)
Selection of Greenhouse Coverings (Vic Agnote)

Associations, Journals etc.
Greenhouse Grower
GrowSearch (database Qld DPI)

See Fruit F 15, Nurseries N 56, Potting mix N 65, Seedlings N 71, Seeds N 77, Vegetables M 19, Water N 92, Preface xii

Remember, always check for recent references

MANAGEMENT

Selection

Horticultural requirements: This depends on the plants being grown. Many plants are easy to grow and have minimal diseases and pests.

Resistant varieties: Use resistant varieties to control particular problems if necessary and where practical. Resistance may be enhanced by various means.

Disease-free planting material: Only plant disease, pest and weed-free material. See Nurseries N 53.

Establishment and maintenance

Diagnosis of present and potential disease, pests and weed problems enables an appropriate management plan to be prepared. ***Pest management programs*** have been developed for mealybugs, whiteflies, twospotted mite, etc.

Regular inspections and monitoring of all plants and equipment, eg temperature and humidity controls. in greenhouses, must be carried out. Sticky yellow boards can be used to monitor and trap aphids, fungus gnats, thrips and whiteflies.

Environmental considerations: Drainage containing fertilisers and pesticides from a greenhouse should be recycled. This also reduces water usage. See Nurseries N 53, N 55.

Cultural methods: Appropriate conditions must be provided, eg light, temperature, ventilation, humidity, irrigation, media, structures for ease of cleaning, hosing, etc. Group similar plants together.

Sanitation: Remove diseased plant material, eg dead cuttings, and weeds at regular intervals. High pressure clean floors to remove bacteria, algae and waste material. Disinfect floors, benches and other structures and disinfect immediately afterwards..

Biological control: Use biological control agents where possible (Table 7). Not all pests can be controlled in this way. Mixed crops make it harder to monitor pests and their biological control agents. Biological control agents must be released at the proper time.

Plant quarantine: Do not introduce infested plants or soil into greenhouses. Use a plant quarantine house to hold plants until disease and pest-freedom is ensured.

Physical and mechanical methods: Flyscreens on ventilators and doors keep out moths, aphids, thrips and other insects which might enter greenhouses, some may carry and spread virus diseases.

Pesticides: Just because a pesticide is registered for use on a particular plant for a particular pest does not mean that it is suitable for use in greenhouses. ***If pesticides are to be used***, effective regimes of fungicides for damping off, insecticides and herbicides must be developed and prescribed. ***Safety procedures*** for the use of pesticides in greenhouses must be prepared and include pesticide selection, persistence, re-entry procedures and plant handling procedures after application (Anon. 1994b). ***Spot spraying*** with pesticides before problems become widespread reduces pesticide use and avoids killing beneficial insects. ***Small outbreaks*** can be ***spot sprayed*** with small packs of pesticides registered for indoor plant use. Soft-foliaged plants in pots may be placed in a plastic bag with a pest strip for several days. Plants may need to be taken outside for treatment or to a holding area. Many pesticides damage plants at the higher temperatures in greenhouses and kill natural and released biological control agents (Table 7).

Pest management programs are available for some greenhouse pests. Complete control of pests is unlikely but a balance can be maintained and economic damage prevented. Techniques require careful management, particularly in the early stages when biological control agents must be introduced before pests are well established. Successful biological control programs require careful ***monitoring*** of the pest, the parasites and/or predators. This is often only possible in a ***monoculture crop*** and with ***trained staff***.

Postharvest

Harvest/sell plants at the recommended time. Some may need to be hardened off. Most commercial crops today are harvested, stored, graded and packaged according to recommended Quality Assurance standards. See Nurseries N 55.

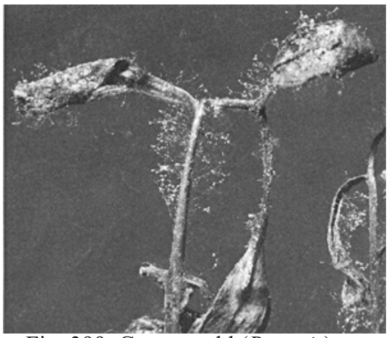
Fig. 399. Grey mould (*Botrytis*) on *Callistemon* shoots. B. A Fuhrer.

Fig. 400. Looper caterpillars (*Chrysodeixis* sp.) up to 40 mm long. Dept. of Agric., NSW.

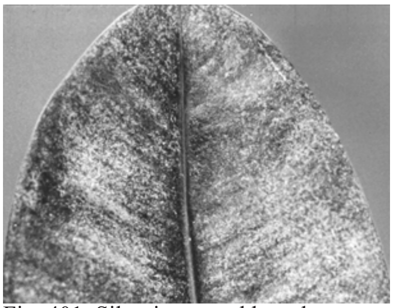
Fig. 401. Silvering on rubber plant (*Ficus* sp.) caused by greenhouse thrips (*Heliothrips haemorrhoidalis*).

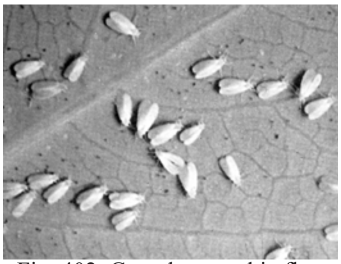
Fig. 402. Greenhouse whitefly (*Trialeurodes vaporariorum*)

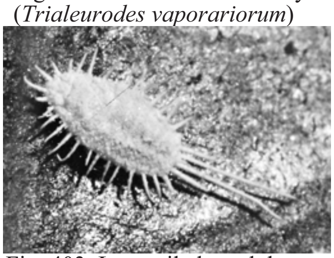
Fig. 403. Longtailed mealybug (*Pseudococcus longispinus*).

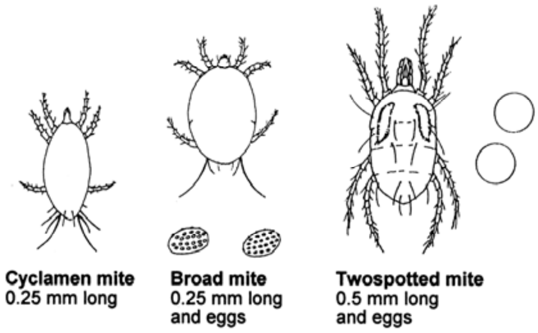

Fig. 404. Mites which attack cyclamen foliage. Mites are microscopic, the female is displayed.

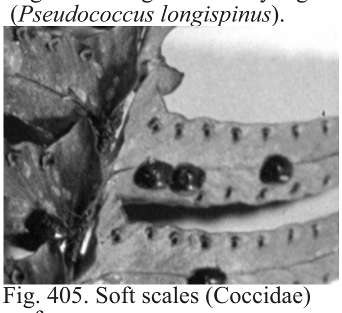
Fig. 405. Soft scales (Coccidae) on fern.

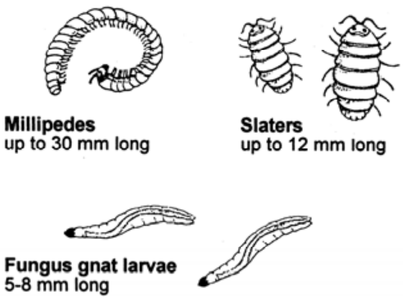

Fig. 406. Millipedes, slaters and fungus gnat (Sciaridae) larvae.

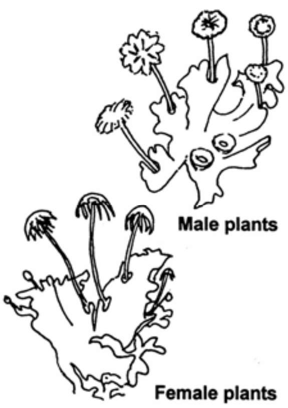

Fig. 407. Liverworts.

Table 7. Some biological control agents[a].

Pests and Diseases	**Some biological control agents[a]** They are not all equally effective	**Some pesticides** Use pesticides not toxic to the agents
INSECTS & ALLIED PESTS		
Aphids (Aphididae), eg cotton aphid (*Aphis gossypii*) green peach aphid (*Myzus persicae*)	**Predatory lacewing** (*Mallada signata*). **Overseas** parasitic wasps (*Aphytis* spp., *Aphidius* spp.) in combination give good control. Larvae of a **midge** (*Aphidoletes aphidimyza*) preys on > 60 species of aphids. Also a **fungus** (*Verticillium lecanii*).	pirimicarb (Pirimor®) (aphicide)
Black vine weevil (*Otiorhynchus sulcatus*)	**Otinem®** (*Heterorhabditis heliothidis)* A **fungus** (*Metarhizium* sp.) is being researched.	
Caterpillars (Lepidoptera), eg corn earworm (*Helicoverpa armigera*)	**Dipel®** (*Bacillus thuringiensis*), **parasitic wasps** (*Trichogramma*). Various **fungi**, eg *Beauveria* spp.	
Mealybugs (Pseudococcidae), eg citrus mealybug (*Planococcus citri*) longtailed mealybug (*Pseudococcus longispinus*)	**Predatory mealybug ladybird** (*Cryptolaemus montrouzieri*) (no resistance to insecticides). **Predatory lacewing** (*Mallada signata*) **Parasitic wasps** (*Leptomastix dactylopii*)	No resistance to pesticides
Scales (armoured scales), eg oleander scale (*Aspidiotus nerii*) oriental scale (*Aonidiella orientalis*) red scale (*A. aurantii*)	**Parasitic wasps** (*Aphytis* spp., *Comperiella* sp.) **Predatory ladybirds** and their larvae (*Chilocorus* spp., *Rhyzobius lophanthae*).	No resistance to pesticides
Spider mites (Tetranychidae), eg bean spider mite (*Tetranychus ludeni*) twospotted mite (*T. urticae*)	**Predatory mites** (*Phytoseiulus persimilis, Typhlodromus occidentalis*) **Predatory lacewing** (*Mallada signata*)	Predatory mites have resistance to some miticides, insecticides and fungicides
Thrips (Thripidae), eg onion thrips (*Thrips tabaci*) western flower thrips (*Frankliniella occidentalis*)	**No biological control agents** are available at present in Australia. In the USA, **predatory mites** (*Amblyseius cucumeris* and *A. barki*) reduce infestations. Various **fungi**, eg *Paecilomyces* spp.	
Whiteflies (Aleyrodidae), eg greenhouse whitefly (*Trialeurodes vaporariorum*) tobacco whitefly, cotton whitefly (*Bemisia tabaci*)	**Parasitic wasp** (*Encarsia formosa*) **In the UK**, the whitefly-active strain of the pathogenic **fungus** *Verticillium lecanii* (Mycotal®) is effective. ***Physical methods****:* Clear grease on yellow boards attract whitefly, but may also trap the parasitic wasps.	
SLUGS (various species)	**Overseas carabid beetles** (*Abax paralellepeds*) and **Nemaslug®** (*Phasmarhabdites* sp.).	
VIRUS AND VIRUS-LIKE DISEASES	**Some vectors** of virus and virus-like diseases, eg western flower thrips (*Frankliniella occidentalis*), could in the future, be effectively biologically controlled.	
BACTERIAL DISEASES ***Crown gall*** (*Agrobacterium* sp.)	**Nogall®** (a non-pathogenic *Agrobacterium* sp.).	
FUNGAL DISEASES ***Damping off*** (various fungi) **Soil fungal diseases**	**Suppressive mixes** contain micoorganisms antagonistic to damping off. ***Phytophthora*, *Pythium*** and ***Rhizoctonia*** by various bacteria and fungi, eg *Paecilomyces*, *Pseudomonas*, *Streptomyces* and *Trichoderma*. **Mycorrhizal fungi** are considered to protect some plants from some fungal diseases.	Herbicides, fungicides and other pesticides may be toxic.
Fusarium wilt	**Overseas***,* Mycostop® (*Streptomyces griseoviridis*) secretes an antibiotic which inhibits seed and soilborne pathogens, eg *Fusarium oxysporum* f.sp. *dianthi*. A saprophytic ***Fusarium* sp.** is also being researched.	
Grey mould (*Botrytis cinerea*)	**Overseas,** various **fungi,** eg *Gliocladium roseum, Myrothecium verrucaria, Trichoderma viride*, and **bacteria,** eg *Bacillus subtilis.*	
Powdery mildew (Erysiphales)	Various **fungi** parasitise powdery mildew fungi, eg *Ampelomyces quisqualis*, *Verticillium lecanii*.	

[a] Bodman et al. 1994. *Pest Control in Ornamental crops.* Qld DPI, Brisbane.
Broadley, R. and Thomas, M. 1995. *The Good Bug Book*. Qld DPI, Dept. of Primary Industries, Brisbane.
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Herbs

A herb may be defined as ***'a plant or plant part valued for its medicinal, savoury or aromatic qualities'*** (Kowalchik and Hylton 1987). Herbs therefore include trees, shrubs, ornamental plants, vegetables, weeds and many low-lying plants that have a fleshy or juicy stem when young. Some herbs are annuals but most are perennials, the tops may die but the roots remain alive and produce new plants year after year.

PESTS AND DISEASES
Non-parasitic
- Poisonous properties
- Potential weeds

WEEDS

PESTS AND DISEASES

Individual herbs are susceptible to a range of pests and diseases in the same way that other plants are (Figs. 408-412). The pests and diseases which affect herbs and all other plants change with time, as exotic pests or diseases may enter Australia. A ***leafmining moth*** (*Diaalectica scalariella*), released to control Paterson's curse (*Echium plantagineum*) also mines in the leaves of ***other Boraginaceae***, eg the herbs, ***borage*** (*Borago officinalis*) and ***forget-me-not*** (*Myosotis* spp.).

Chicory (*Cichorum intybus,* Asteraceae)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Cucumber mosaic
  - Lettuce necrotic yellows
- **Fungal diseases**
  - Anthracnose (*Marssonina anattoniana*)
  - Fungal leaf spot (*Cercospora*)
  - Root rot (*Phoma* sp.)
  - Sclerotinia rot (*Sclerotinia sclerotiorum*)
  - Rust, leaf rust (*Puccinia hieracii*)
- **Nematode diseases**
  - Root knot nematode (*Meloidogyne*)
  - Stem and bulb nematode (*Ditylenchus*)
- **Insects and allied pests**
  - Caterpillars (Lepidoptera)
- **Snails and slugs**

Chives (*Allium shoenoprasum,* Liliaceae)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Various virus diseases
- **Fungal diseases**
  - Black mould (*Aspergillus*)
  - Downy mildew (*Peronospora destructor*)
  - Rust (*Puccinia allii*) (Fig. 410)
  - White rot (*Sclerotium cepivorum*)
- **Nematode diseases**
  - Spiral nematode (*Helicotylenchus*)
- **Insects and allied pests**
  - Bulb and potato aphid (*Rhopalosiphoninus latysiphon*)
  - Onion thrips (*Thrips tabaci*)
- **Snails and slugs**

Garlic (*Allium sativum,* Liliaceae)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
  - Garlic mosaic virus
  - Garlic yellow streak virus
  - Lettuce necrotic yellows virus
  - Onion yellow dwarf virus
- **Fungal diseases**
  - Black mould (*Aspergillus niger*)
  - Downy mildew (*Peronospora destructor*)
  - Rust (*Puccinia allii*)
  - Soot (*Embellisia allii*)
  - White rot (*Sclerotium cepivorum*)
- **Nematode diseases**
  - Root knot nematode (*Meloidogyne*)
  - Root lesion nematode (*Pratylenchus*)
  - Stem and bulb nematode (*Ditylenchus dipsaci*)
- **Insects and allied pests**
  - Bulb and potato aphid (*Rhopalosiphoninus latysiphon*)
  - Bulb mite (*Rhizoglyphus echinopus*)
  - Onion thrips (*Thrips tabaci*)
  - Wheat curl mite (*Aceria tulipae*)
- **Snails and Slugs**
  - Garlic snail (*Oxychilus alliarius*)

Mint (*Mentha* spp.*,* Lamiaceae)

PESTS AND DISEASES
Parasitic
- **Virus and virus-like diseases**
- **Fungal diseases**
  - Rust (*Puccinia menthae*)
  - Verticillium wilt (*Verticillium dahliae*)
- **Nematode diseases**
  - Root lesion nematode (*Pratylenchus*)
  - Spiral nematode (*Rotylenchus*)
- **Insects and allied pests**
  - Caterpillars (Lepidoptera)
  - Grasshoppers (Orthoptera)
  - Metallic flea beetles (*Altica*)
  - Mint aphid (*Ovatus crataegarius*)

Parsley (*Petroselinum crispum,* Apiaceae)

PESTS AND DISEASES
Parasitic
- **Virus diseases**
  - Beet western yellow virus
  - Carrot red leaf virus
- **Fungal diseases**
  - Fungal leaf spots (*Septoria petroselini*)
  - Sclerotinia rot (*Sclerotinia* spp.)
  - Rhizoctonia crown rot (*Rhizoctonia* sp.)
- **Nematode diseases**
  - Root knot nematode (*Meloidogyne*)
  - Root lesion nematode (*Pratylenchus*)
- **Insects and allied pests**
  - Carrot aphid (*Cavierella aegopodii*)
  - Parsley aphid (*Dysaphis apiifolia*)
  - Spider mites (*Tetranychus*)
- **Snails and slugs**
- **Vertebrate pests**

Non-parasitic
- Potassium deficiency
- Sunscorch
- Temperature

Non-parasitic

Poisonous properties: At least 36 herbs are quite simply ***dangerous***, eg wormwood;some are overtly poisonous, others may not kill you but can make you very ill, others through prolonged use may be carcinogenic or damage internal organs, others can cause skin irritation (Kowalchik and Hylton (eds) 1987, Sears 1995).

Potential weeds: Many ***common weeds*** are herbs, eg dandelion, and ***many herbs*** may themselves become weeds, eg dill, mint.

WEEDS

Weed control is important in herb crops to ensure that there is ***no contamination*** by foreign plant material at harvest. Areas to be planted should have low weed populations and any weeds present should be controlled ***prior to planting***. Because herb gardens are readily invaded by annual and perennial broadleaved and grass weeds (Fig. 413), they should be edged to prevent invasion by perennial weeds from surrounding areas. Herbicides are registered for use in herb gardens, but hand weeding and mulching is preferred and widely practised.

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Taylor, R. 1996. *Tea Tree : Boosting Oil Production.* Rural Research, 172, Spring.

State/Territory Departments of Agriculture/Primary Industry eg

Endive in the Home Garden (Vic Agnote)
Eucalypt Oil from Blue Mallee (NSW Agfact)
Garlic Growing (NSW Agfact)
GrowSearch (Qld DPI database)
Herbs (Vic Agnote)
Herbs and their Uses (Vic Agnote)
Mint Growing (NSW Agfact)
Mint Oils (NSW Agfact)
Parsley Growing (NSW Agfact)
Tea Tree Oil (NSW Agfact)
Tea-tree Oil : Plantation Management (NSW Agfact)

Associations, Journals etc.

Australian Essential Oils Association
Australian Herb Society (Herbology Magazine)
Australian Organic Herbs Association
Focus on Herbs (magazine)
Good Fruit & Vegetables
GrowSearch (database Qld DPI)
International Herb Growers Assoc.
Organic Herb Growers Assoc. of Australia (Herb Grower)
State/Territory Herb Societies
The Spice Assoc. Australasia

See Annuals A 10, Bush fruits and Nuts F 29, Fruit and nuts F 15, Preface xii, Vegetables M 19

Remember, always check for recent references

MANAGEMENT

Selection

Herbs are used for perfumes, medicinal remedies, drugs, companion plantings, insect repellents, cosmetics, garden edgings and hedges, and cooking; although herbs generally have little food value, they make food tasty. An overview of the herb and spice industry is presented by Coombs (1995). Choose varieties with some ***resistance*** to local problems. Only plant ***disease-free*** seed, cuttings and other propagation material.

Establishment and Maintenance

Where possible use ***non-chemical methods of control***. Most herbs require ***rich soils*** and open sunny, well drained sites, some require only morning sun. Herb gardens have many ***traditional designs***, eg authentic knot, medicinal, dye, fragrance, everlasting and kitchen. Herbs may also be grown in hydroponic systems, containers or in xeriscapes. They grow well with little care, but must be kept ***weed-free***. Herb gardens often need to be dug up every few years and ***replanted***. Regular care, trimming, adequate watering in summer (many are shallow rooted), fertilising, pruning and weeding, is essential. Avoid overwatering in winter. Some are suitable as companion plants. ***Remove*** dead leaves and stems. Only use ***pesticides*** registered for use on herbs. Observe withholding periods. Some herb growers have sought ***organic accreditation*** for some of their products (enviroherbs) with Biological Farmers of Australia ***(BFA)***.

Postharvest

Postharvest and quality control ***procedures*** have been developed for commercial producers. Both commercial and hobby producers are subject to quarantine and therapeutic goods administration ***regulations***. ***Harvest*** at the correct stage, eg the intensity of flavour and aroma of mint, is dependent on the level of essential oil in the plant which is at its maximum at the beginning of flowering. Harvest early in the morning when plants are turgid and before any temporary wilting occurs. Cut correctly, eg cut mint with shears or a sickle bar mower, and bunch. ***Storage conditions*** depends on whether the herb is to be used fresh or dried. Fresh mint after harvest should be kept moist and cooled prior to marketing. Dried herbs must be kept dry and may be pounded to a fine powder, placed in airtight containers and stored for use later. ***When herbs are used for food or medical remedies,*** they must be prepared ***hygienically*** using the correct dosage rate. ***Health regulations*** must be adhered to. ***Many herbs produce lethal poisons***, so before using in cooking, for salads or medicinal use, be certain of ***identity*** and ensure that lethal plants have not been grown by ***error*** or that herbs are not ***contaminated*** with other plants.

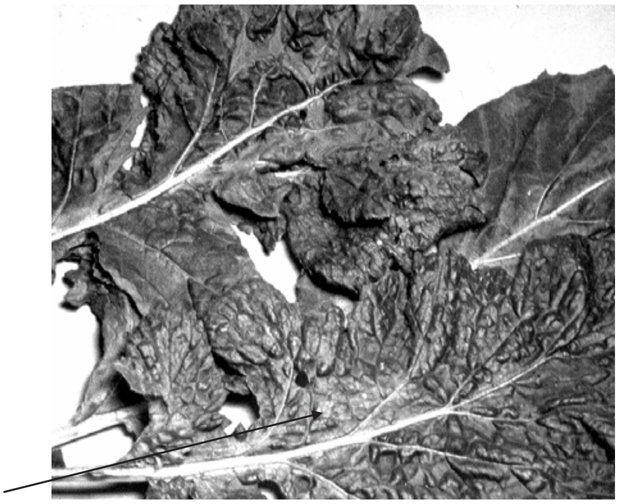

Fig. 408. Light and dark green mosaic (virus) on leaves of horse radish (*Armoracia rusticana*).

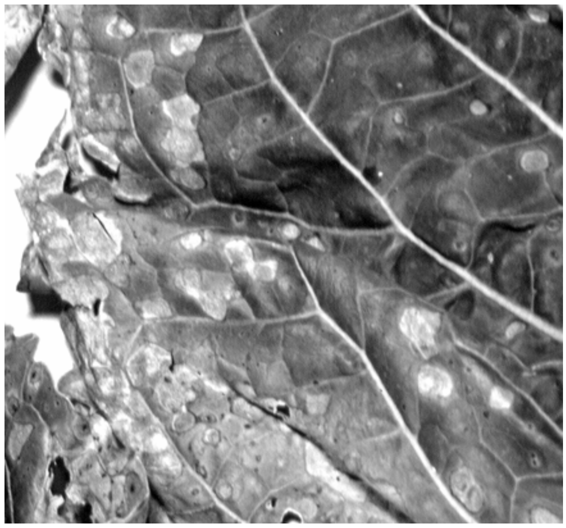

Fig. 409. Fungal leaf spot on horse radish (*Armoracia rusticana*).

Fig. 410. Rust (*Puccinia allii*) on chives (*Allium shoenoprasum*).

Fig. 411. Pink wax scale (*Ceroplastes rubens*) on bay tree (*Laurus nobilis*).

Fig. 412. Mealybugs (*Pseudococcus* sp.) on (*Calendula officinalis*).

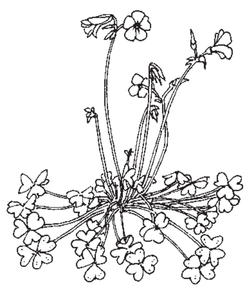

Fig. 413. Soursob (*Oxalis pers caprae*) is a perennial *weed,* produces oxalic acid.

House Plants

Tropical rainforest foliage

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Fungal diseases
Fungal leaf spots
Grey mould
Powdery mildews
Root, crown and stem rots, wilts
Insects and allied pests
Aphids
Caterpillars
Greenhouse thrips
Greenhouse whitefly
Mealybug
Mites
Scales
Non-parasitic
Algae, liverworts, moss
Dust
Environment
Insects
Mechanical injury
Nutrient deficiencies, toxicities
People-pressure
Pesticide, chemical injury
WEEDS

Individual house plants are susceptible to a range of diseases and pests in the same way that other plants are, eg ***African violets*** may be affected by powdery mildew or mealybugs. ***House plants*** are also susceptible to non-parasitic problems which commonly occur in ***container plants***, eg overwatering. The main problems affecting house plants are non-parasitic, eg incorrect watering, temperature, humidity. See Containers N 19.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

House plants are remarkably free from virus diseases. There are some exceptions, eg poinsettia.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia carotovora* pv. *carotovora*) occurs occasionally on soft fleshy indoor plants particularly if overwatering occurs. See Vegetables M 5.

FUNGAL DISEASES

Fungal leaf spots are uncommon. Do not confuse fungal leaf spots with those caused by ***misting***. Avoid crowded blocks of similar plants, overwatering, humid conditions, eg bathrooms. Move plants to a less humid environment. Do not purchase infected plants. Trim out all infected leaves. See Annuals A 5.

Grey mould (*Botrytis cinerea*) initially may cause spotting of ***flowers, leaves, stems and collars***. If humid conditions continue, a grey fungal growth develops on diseased parts. Avoid overwatering. Move to a warmer area and/or improve ventilation. Remove dead plant material. Whole plants may need to be discarded. See Greenhouses N 22, Fruit F 5.

Powdery mildews (Erysiphales) develop on leaves and stems and can spread rapidly causing extensive damage. The most important step is to move affected plants to a ***less humid environment***, eg remove African violets from the bathroom. Severely infected plants should be destroyed or badly affected parts of a plant may be pruned out and destroyed. See Annuals A 6.

Root, crown and stem rots, wilts: *Pythium*, *Phytophthora,* and *Rhizoctonia solani* commonly cause root and collar rots of soft, succulent plants, especially in poorly drained potting mixes sitting in water and being consistently overwatered and overfertilised. *Fusarium* wilt diseases may occur. See Vegetables M 7.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera): ***Cotton aphid***, melon aphid (*Aphis gossypii*) and ***green peach aphid*** (*Myzus persicae*) are slow moving, winged or wingless, plump, about 2 mm long, green, yellow, pink or brown depending on the species (Fig. 414). Aphids suck sap from ***shoots, leaves, buds and flowers*** causing distortion. Leaves may dry and shrivel. Nymph skins, honeydew and associated sooty mould is found on infested parts. Some house plants are very susceptible to aphid infestation, eg *Aphelandra* spp. See Roses J 4.

Caterpillars (Lepidoptera) of ***budworms*** (*Helicoverpa* spp.), ***leafroller moths*** (Tortricidae), ***loopers*** (*Chrysodeixis* spp.) chew buds, leaves and stems but may be well camouflaged and hard to find, droppings may give them away (Fig. 415). They vary in colour and size depending on the species. ***Leafroller caterpillars*** are about 18 mm long, green and feed between webbed leaves. When disturbed they wriggle and move back into shelter, fall to the ground or hang suspended by a thread. Moths may fly indoors and lay eggs on plants, or plants may be purchased with eggs or caterpillars on them. Caterpillars can be removed by hand. See Annuals A 8, Vegetables M 13.

Greenhouse thrips (*Heliothrips haemorrhoidalis*) are dark brown, about 1.5 mm long, they rasp and suck sap from ***leaves*** making them look silvery. Thrips and dark brown dots of excreta (Fig. 416) are found mostly on ***leaf undersurfaces***. If practical, increase light intensity, raise temperature and lower humidity. See Greenhouses N 24.

Greenhouse whitefly (*Trialeurodes vaporariorum*) is small, white, about 1 mm long with 2 pairs of white wings (Fig. 417), 1st stage nymphs are scale-like. Nymphs and adults suck sap, ***leaves*** develop a sandy mottle. Whiteflies, nymphs, honeydew and associated sooty mould may be found on ***leaf undersurfaces***. See Greenhouses N 24.

Mealybugs (Pseudococcidae) are common and serious pests. They are up to 3 mm long, slow moving, wingless, flattened, elongate and mealy white with short hair-like filaments. They suck sap and feed on ***leaf bases*** and ***leaf undersurfaces***, and are only noticed when they are obvious and established (Fig. 418). Honeydew, associated ants and sooty mould cause further disfigurement. Soft foliaged plants wilt and may die. Mealybugs may also infest roots and are noticed during repotting. Control can be difficult. See Greenhouses N 25.

Mites (Acarina)

Broad mite (*Polyphagotarsonemus latus*) feed on leaf undersurfaces and cause ***new leaves*** to curve under. See Greenhouses N 26.

Twospotted mite (*Tetranychus urticae*) suck sap and produce webbing on ***leaf undersurfaces***. Leaves become mottled, yellow and fall (Fig. 419). House plants, eg umbrella trees and palms, are susceptible during winter months especially if artificial heating is used and air is dry. Regularly mist leaf undersurfaces to prevent the buildup of large numbers. See Beans (French) M 29.

Cyclamen mite (*Phytonemus pallidus*) distorts young leaves, buds and petals, flowers may not open properly. ***Leaf edges*** may be rolled or curled. Growth may be stunted. Cyclamen mite is very small, 0.25 mm long, and pale brown. Broad mite is smaller, broader and moves faster then the cyclamen mite. See Cyclamen C 16.

See Greenhouses N 26.

Scales (Hemiptera)

Soft scales (Coccidae) may infest a wide range of house plants, eg ferns and rubber plants. Soft brown scale is probably the most common.
Black scale (*Saissetia oleae*)
Hemispherical scale (*S. coffeae*)
Nigra scale (*Parasaissetia nigra*)
Soft brown scale (*Coccus hesperidum*)
Scales suck sap from leaves and stems, causing poor growth, stunting and disfigurement (Fig. 420). Severely infested plants can die. Honeydew, ants and sooty mould cause further disfigurement.

Armoured scales (Diaspididae)
Fern scale (*Pinnaspis caricis*)
Oleander, ivy scale (*Aspidiotus nerii*)
White palm scale (*Phenacaspis eugeniae*)

Scale insects may cling to plants for months after they are dead. Living scale insects will exude some juice when crushed, dead scales become dry and chaffy. See Citrus F 39, F 41, Greenhouses N 27.

Non-parasitic

Algae, liverworts and moss may grow on damp surfaces of pots and mixes. Mosses may be attractive. See Greenhouses N 27, Turfgrasses L 13, L 15.

Dust is unattractive and interferes with the process of respiration and photosynthesis. Clean leaves regularly with tepid water to keep them breathing properly and increase amount of light reaching them. Dust may help spread *Rhizoctonia* (Handreck and Black 1994).

Environment

Acclimatisation of house plants may be necessary. Irrigation, fertilising, temperature and light conditions for new plants should be carefully considered.

Dust can be removed by gentle wiping or by spraying with water until it runs off. Delicate plants, eg maidenhair fern, cannot be cleaned.

Humidity: 40-50% relative humidity is favourable for house plant growth and comfortable for most people. Many types of home heating can contribute towards ***low humidity***, situations close to radiators should be avoided. Low humidity situations can be alleviated by placing pots on trays of moist vermiculite, sphagnum moss or gravel which act as source of evaporation and maintain a moist atmosphere around plants. An alternative is to mist foliage every few days with tepid water. Plants in groups in a trough are easier to manage than single pots in saucers and create a more humid microclimate. ***Too high humidity*** may occur in bathrooms, enclosed verandahs and terrariums.

Light is required for normal growth and is an important factor affecting house plants. Most plants need as much light as possible indoors, though direct sunlight is not essential and filtered sunlight is usually preferable. ***Where light is limited***, flowering plants fail to flower and foliage plants are more suitable. Some foliage house plants tolerate less light than others, eg fruit salad plant (*Monstera deliciosa*) or the cast-iron plant (*Aspidistra elatior*). ***Coloured leaf forms*** need more light than green forms. Plants reputed to prefer shade still need some light, dark and gloomy corners suit very few plants. Plants required for decoration where light is insufficient should be given periods during the day in a well lit situation. Turn plants regularly as their leaves grow towards the light. As seasons change it may be necessary to change the position of some plants to increase or decrease the light they receive. Rubber plants like bright light but not direct sun. Direct sunlight causes wilting and burning of leaves. Windows facing north and west can let in strong sunlight.

Oedema occurs when plants take up more water than they can transpire through their leaves. Leaves or stems develop ***characteristic swellings***. Circular patterns develop on leaves of *Schefflera* sp. (Fig. 421) White waxy lumps on stems of *Hibiscus arnhemensis* in greenhouses disappear when plants are taken outside. See Geranium A 35.

Temperature: Many of the popular house plants are tropical or subtropical in origin, so temperature is important. For many plants large ***fluctuations*** between day and night temperatures can be harmful or even fatal. This is one reason why plants often suffer in office buildings where the heating is switched off during the night, weekends and holidays. Leaves may be ***sunscorched*** through windows (Fig. 421).

Plant type	Day temperature	Night temperature
Cool loving plants *Fatshedera*	15-18^{o}C	As low as 8^{o}C
Moderate temperature *Dracaena*	18-20^{o}C	10-12^{o}C
Warm temperature *Ficus*	20-28C^{o}	Can fall to 15^{o}C

If the mean room temperature range is between 15-20°C most known 'house plants' can be grown. ***House temperatures*** are usually suitable for the average house plant. A steady warm temperature during the day with a slight fall during the night is generally satisfactory. ***Avoid sharp fluctuations*** in temperature, if you heat your room up each evening it might be better to place plants elsewhere. ***Avoid*** being too close to air conditioners during summer. ***Avoid*** being to close to open windows, cold draughts and gas heaters in winter. Even when windows are closed in winter care should be taken with plants on window sills. Even with curtains closed behind them they are in an environment where temperatures drop to near freezing outside. Put newspaper between plants and window or move plants.

Ventilation: A close stale atmosphere is unsuitable. They need fresh air but not directly through windows. Indirect ventilation though windows in adjoining rooms is safest, particularly during cool weather. Ventilation can be increased as days become warmer.

Water: Overwatering is the most important problem affecting house plants, especially for beginners (Fig. 421). Correct watering cannot be defined in terms of measured amounts and fixed intervals. Watering must be related to the needs of individual plants. Correct watering includes using the ***correct potting mix*** (if it is too fine it may hold too much water or it may become compacted) and using ***water at room temperature***. During winter stand water overnight to allow the chlorine to evaporate and the water to reach room temperature. ***Do not water while the soil is still wet*** from a previous watering, it should be allowed to dry out between waterings. When watering is required, allow time to wet the mix in the container completely, soak the whole root ball well and allow any excess to drain. If a plant has been allowed to become extremely dry and the potting mix has come away from the sides, the whole container should be submerged in water and allowed to remain there until the bubbles have stopped. ***Restrict watering during the dormant period*** in winter and increase when growth is active in summer. As a general rule you can double the number of days between watering during winter compared with summer. If watering is not reduced during winter water will sit in the saucer and rot will soon set in. ***Do not wet the leaves of hairy leafed plants*** or plants that are tightly crowned. Water around pot rim, from below by partly immersing the pot in water or by wick, eg African violets. ***Do not allow pots to stand*** permanently in trays of water unless they are bog plants. Any water in the drainage tray should be discarded.

Insects: ***Ants*** (Formicidae, Hymenoptera) are attracted to honeydew secreted by aphids, mealybugs, whiteflies and assist the spread of scale and other insects. Ants are difficult to control. The insect infestations should be cleaned up. Occasionally ants nest in containers. When this occurs either re-pot the plant or drench pots with a recommended insecticide outdoors. See Turfgrasses L 8, Trees K 19. ***Fungus gnats*** (Diptera) maggots are slender, white, translucent, legless, about 5-8 mm long and feed on decaying fungi in roots and damp organic matter. They may leave a tiny slimy trail glistening on the potting mix surface. Plants lack vigour, leaves may yellow and small roots may be eaten off. See Greenhouses N 28, Mushrooms M 63. ***Springtails*** (Collembola) are small white slender active insects mostly < 6 mm long, found in soil, around the bottom of pots and in water that drains from pots after plants have been watered. They are most obvious when the soil surface is watered frequently. See Turfgrasses L 14.

Mechanical injury may be caused by children or animals, plants in corridors are easily damaged.

Nutrient deficiencies, toxicities: Deficiencies are not common, owing to the development of good fertilisers for house plants. The main aim is to maintain a steady growth of healthy foliage. Use a minimum amount of fertiliser consistent with healthy growth. ***Too much fertiliser*** can lead to a buildup of mineral salts in the mix and damage the plant. ***Guidelines for fertilising:*** Many fertilisers are available for house plants, apply according to label instructions. Before applying any fertiliser soil should be moist, water beforehand and allow plant to drain thoroughly before applying the fertiliser. Cease or reduce fertilising during winter when the plant is not growing. ***Evaporation of water*** may cause ***white crusting*** of salts on the surface of the media or pot.

People-pressure diseases include cigarette butts, parties, office workers, children, animals, cleaners. Plants in ***corridors*** are easily damaged by humans brushing past, children breaking or playing among them.

Pesticide, chemical injury: Only use ***fungicides or insecticides*** labelled for indoor plants and follow manufacturer's instructions carefully. ***Aerosols*** if held too close may freeze plant tissue. ***Clensel®*** and various ***soaps*** are used. ***White oil*** heavily diluted with water may be used on leaves of heavy textured plants, eg rubber trees. Leaf gloss and polishes should be used sparingly, ***excessive use*** can cause leaves to turn black or yellow and die. ***Oil sprays may damage*** softer-textured plants such as ferns. ***Fluoride*** in water may reduce the vase life of cut flowers. Fluoride from superphosphate, perlite and some peats may cause leaf spotting on *Chlorophytum*, *Dracaena*, *Gladiolus*, etc, when grown in soil-less media (Handreck and Black 1994). ***Pollutants:*** House plants may be sensitive to gas, deodorants and air fresheners. Gas fumes are toxic to most plants.

WEEDS

Weeds are not generally a problem, odd ones that do grow can be easily removed by hand.

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Indoor Plants (SA Adel. Bot. Garden leaflet)
Associations, Journals etc.
Australian Horticulture
GrowSearch (database Qld DPI)
See Australian native plants N 9, Containers N 20, Greenhouses N 28, Interior Plantscapes N 46

Remember, always check for recent references

MANAGEMENT

Selection and establishment

Horticultural requirements: Learn the correct name of house plants then look up/buy one of the many books available to check on its proper culture. Choose quality plants of proven species and of good colour. Buy house plants only during the warmer months so they are less likely to suffer cold stress during the trip home. Buy **flowering house plants** in the early stages of budding.

Cultural requirements: **Purchase plants** to suit **the conditions** under which they are expected to grow, ie match individual plants to the environment. It is not possible here to describe temperature, light, humidity, fertiliser, watering, pruning and potting mix requirements of each plant species, the onus is on the owner to find out each plant's requirements. Only then will the desired affect be achieved. Plants that prefer shade still need some light. Dark and gloomy corners suit very few plants. Plants also need room in which to grow. Many flowering house plants, eg African violets, need a lot of light, warmth and humidity to do well. Do not overwater, when temperatures drop to near freezing outside, put newspaper between plants and window or move the plants away. Plants dislike drafts and like good ventilation and clean air. Fill water container and stand overnight. This allows chlorine to evaporate and water to reach room temperature. **Potting media** should be free-draining and slightly acid. **Containers** should be appropriate for the plant.

Resistant varieties: Select plants with some **resistance** to pests and diseases. Some house plants are subject to common problems that can be so serious plants have to be discarded, eg *Syngonium* is susceptible to a fungal stem rot (*Ceratocystis fimbriata*), African violets to mealybugs and powdery mildew in humid situations, but many are hardy and suitable for beginners, eg cast-iron plant (*Aspidistra*).

Disease-free plants: **Inspect new plants** for pests, eg mealybugs, mites, scales, and diseases, eg powdery mildew, which can be transported on plants. Diseases present at purchase may remain undetected for a considerable time. Buy plants and potting mixes from reputable suppliers.

Maintenance

Regular inspections: **Examine** house plants every week for problems. Remember, the main problems are ***cultural***, when problems do arise try and identify the cause. **Do not confuse damage** caused to leaves by whitefly with that caused by leafhoppers, twospotted mites or thrips. Generally **re-pot** when there is a fine web of roots on the outside of the soil ball after removing the pot, but this depends on the species. Roots of palms commonly become too big for the container. House plants can remain in pots for at least 12 months.

Sanitation: Promptly remove dead leaves and flowers as diseases readily grow on them. Infested or damaged shoots can be pruned off. **Severely affected plants** may have to be discarded. Keep plants clean and dusted, regularly misting leaf undersurfaces to prevent the buildup of large numbers of twospotted mites. Every few weeks, mist both surfaces of monsteras and similar plants with water and carefully wipe clean to remove insect pests and accumulated dust. Mist soft-foliaged plants, eg maidenhair fern, gently with water. When seen, caterpillars may be removed by hand and aphids, mealybugs, whiteflies and scales carefully wiped off with a damp cloth or cotton bud dipped in methylated spirit.

Plant quarantine: **Avoid introducing infected plants** into clean collections. Isolate new plants until certain that they are pest, disease and weed-free.

Pesticides: If it is considered necessary to use an insecticide or fungicide, select one clearly labelled for indoor plant use. Garden sprays and dusts should not be used indoors.

Postharvest

Throw away house plant: Flowering house plants are more often **short term plants**. When flowering is finished they are replaced. Many flowering house plants, eg African violets, need a lot of light, warmth and humidity to do well. Think of these plants as a long lasting bunch of flowers which provide many weeks of flowering for a fraction of the cost of cut flowers. Some, eg chrysanthemums, can be planted in the garden.

Senescence and size: Even in very good conditions, **potted plants do not last forever**. Some will have to be removed if they grow too large, eg *Ficus*, palms, philodendrons. **Rapid growth** is not always desirable.

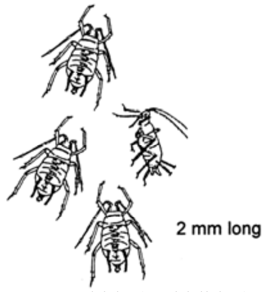

Fig. 414. Aphids (Aphididae) suck sap from new growth.

Fig. 415. Looper caterpillar (*Chrysodeixis* sp.) chewing leaves.

Fig. 416. Greenhouse thrips (*Heliothrips haemorrhoidalis*) on *Araucaria*; silvering and tarry spots of excreta.

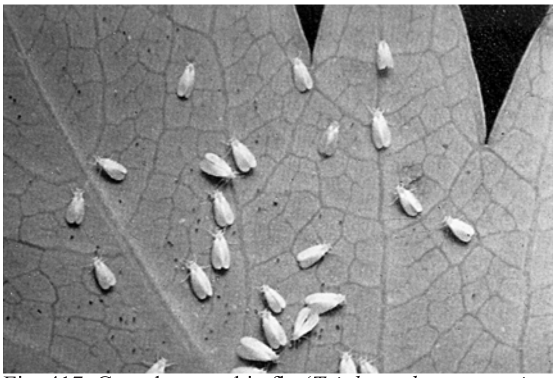

Fig. 417. Greenhouse whitefly (*Trialeurodes vaporariorum*).

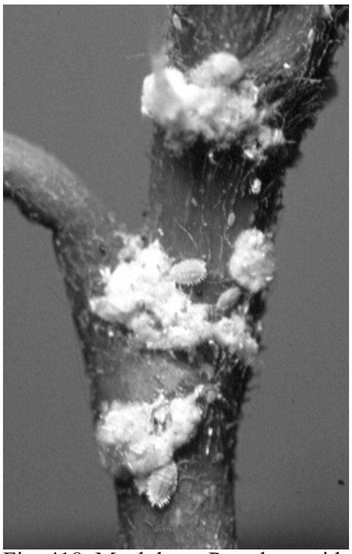

Fig. 418. Mealybugs Pseudococcidae).

Fig. 419. Twospotted mite (*Tetranychus urticae*) injury to frangipani.

Fig. 420. Soft scales (Coccidae) clustered on *Platycerium* sp.

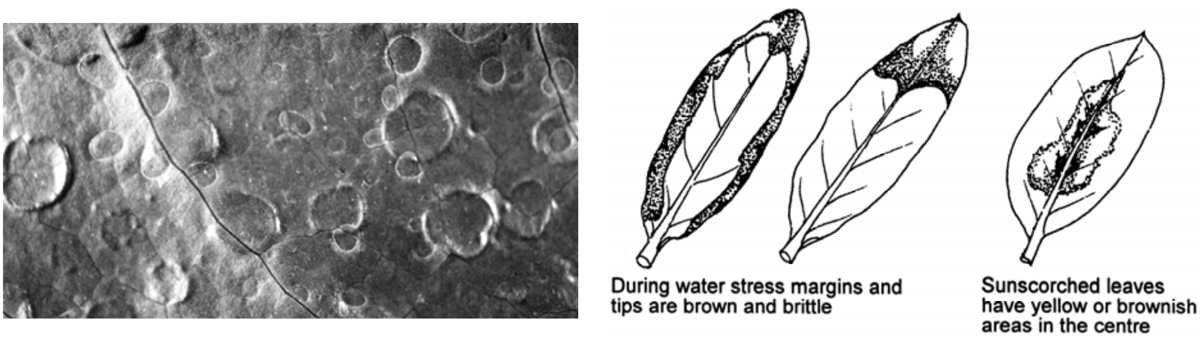

Fig. 421. Environmental problems. ***Left :*** Rings of oedema on leaves of umbrella tree (*Schefflera actinophylla*). ***Right :*** Leaves showing symptom of water stress and sunscorch.

Table 8. Symptoms of cultural problems on house plants.

PROBLEM	TOO LOW	TOO HIGH
HUMIDITY	**Low humidity (prolonged):** • Plants lose their lustre, wilt, leaf edges become brown and crinkly, lower leaves may yellow and fall.	**High humidity:** • Symptoms include the development of oedema, powdery mildews and other fungal and bacterial diseases.
FERTILISER	**Too little fertiliser:** • Leaves pale green, lower leaves may yellow and drop. • New leaves are small or growth stops. • Plants may be stunted.	**Too much fertiliser:** • New growth is weak, susceptible to pests and disease. • Plant may wilt readily. • Stems may be elongated. • Few or no flowers; flowering plants may have excessive amount of foliage. • White crust of salts on the soil surface or on outside of clay pots • Leaves touching rim of pots may wilt, rot and fall. • Green scum (algae).
LIGHT	**Too little light:** • Spindly growth. • Leaves on new stems may be pale and small.	**Too much light:** • Leaves tend to curl under. • New leaves may be undersized.
TEMPERATURE	**Too cold:** • Leaves wilt and curl, they may become entirely discoloured and fall off; other problems may cause similar symptoms. • Some leaves become olive green in colour. • Sometimes leaves turn white. **Frost:** • Many house plants are sensitive to frost, so exercise care when taking outdoors for cleaning or when leaving close to windows during winter. All *Ficus* species are sensitive to frost.	**Sunscorch** (plants in north and west facing windows which let in strong sunlight): • Wilting and sunscorch (burning) of leaves. • Yellow or brown spots appear on the leaves, often within the leaf margins (Fig. 421). • Leaves on one side may brown. • Cacti tend to turn yellow. • Shaded pattern on leaves. **Too hot (sudden rise and fall of temperatures):** • Leaves wilt, yellow, brown and fall off (leaf fall may also be caused by other problems). • Plant tissue may become glassy and translucent.
WATERING	**Too little water:** • Soil at top of pot always dry. • Leaves may wilt or may curl under. • Lower leaves may yellow and fall; may also be caused by natural senescence and other problems. • Edges and tips of leaves are brittle and brown (Fig. 421). **Water on leaves:** • Plants with hairy or fuzzy leaves develop ugly white or brown sunken areas if cold water is left on their leaves. After the water evaporates a salt residue is sometimes left which is unsightly. • Encourages bacterial and fungal leaf diseases.	**Too much water:** • Soil at top of pot is always wet (note though, people often water the plant before they bring it in for advice). • Algae and fungi on mix. • Fungus gnat larvae and possibly other insects, such as millipedes. • Fungal and bacterial stem and root rots, plants may become mushy and dark in colour. • Oedema on plant leaves. • Leaf edges and tips are soft to touch and brown/grey (Fig. 421).

Hydroponic systems

PESTS AND DISEASES

Parasitic
- **Virus and virus-like diseases**
  - Lettuce big vein virus
- **Bacterial diseases**
  - Bacterial leaf and flower bight
- **Fungal diseases**
  - Waterborne fungal diseases
- **Insects and allied pests**

Non-parasitic
- Algae
- Environment
- Nutrient deficiencies, toxicities
- Pesticide injury
- Root death

Hydroponics is the science of growing plants without soil. Land plants normally obtain nitrogen, phosphorus, potassium and other nutrients from the soil. In hydroponics the nutrients are added to the water, enabling fertilisers to be used more efficiently.

Plants grown hydroponically are generally susceptible to the same pests and diseases as their naturally grown counterparts in soil. However, in hydroponic systems, some ***soilborne diseases*** are eliminated, but others may become more difficult to control. Pests and diseases affecting the ***foliage*** often develop quickly because of the intense nature of production.

With the development of nutrient film techniques ***(NFT)*** where plants are grown with their roots bathed in a flowing stream of nutrient solution, it was considered that the spread of ***waterborne diseases*** might be a major problem. Root-invading organisms in the nutrient solution would be able to recirculate for long periods and the pathogens in the system would multiply and spread quickly. Despite these forebodings, ***the main problems associated with hydroponic systems*** have proved to be the non-parasitic problems of nutrition and physiology rather than with parasitic diseases and pests.

The ***soilborne fungal diseases*** which can pose a problem in hydroponic systems, include those bacteria and fungi which need an ***aquatic environment to thrive***, eg *Olpidium* (which spreads lettuce big vein virus), *Pythium* and *Phytophthora* spp. *Fusarium* diseases are not such a problem, an exception being *Fusarium oxysporum* var. *dianthi*, which affects carnation. ***Bacteria***, which also need an aquatic environment, may cause diseases of carnation and lettuce.

Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Plants are susceptible to the same virus diseases they would become infected with if grown under other systems. Most virus diseases of annual and herbaceous plants presently grown hydroponically may be ***spread*** by ***vegetative propagation***, ***insects***, eg aphids, leafhoppers and thrips, or the use of infected ***seed***. Some are also spread in ***plant sap*** during plant contact or on hands and tools. These virus diseases are ***controlled*** in the same way as they would be on plants grown in soil, ie by the use of ***virus-tested seed*** and ***propagation material***, control of ***insect vectors*** and ***strict hygiene***. Whether a hydroponic crop becomes infected with virus and virus-like diseases depends on whether the crop is susceptible or not.

Lettuce big vein virus affects lettuce causing enlarged, transparent ***veins***. Infected plants mature slowly and are generally unattractive with small ***coarse hearts*** and upright, ***ruffled leaves***. Plants infected early are stunted. ***Overwinters*** in water supplies, the fungus is common in soil, zoospores carrying the virus occur in river water and dams. This is the only well known virus disease ***spread*** by a soil/waterborne fungus (*Olpidium brassicae*). The motile fungal zoospores penetrate growing roots and transmit the virus particles into the plant. Symptoms are ***favoured*** by air temperatures < 20^{o}C. Higher temperatures mask symptoms (plants are still infected). Outdoors, lettuce big vein is common in winter and is favoured by wet, heavy soil. The most effective way of control is the use of ***resistant varieties***. ***Do not introduce*** seedlings already infected with lettuce big vein virus to hydroponic systems. ***Disinfect*** all water used in hydroponic systems. See Water N 90.

BACTERIAL DISEASES

Plants get the same bacterial diseases they would get under other growing systems. Diseases affecting the ***aerial parts of plants*** should be ***controlled*** in the same way as if they were grown under other systems, eg the use of cultural methods (environmental control), use of resistant varieties, and pesticides.

Bacteria causing plant diseases generally have ***motile cells*** which means that they can swim and therefore be ***spread in water***. Many bacterial diseases including those that can attack aerial parts are also spread by ***water splash*** and ***irrigation***, ***accidental introduction*** of infected crop debris and soil, the use of ***infected seed*** and the ***movement*** of machinery and people through the crop. It is important to know how a particular disease is spread within the hydroponic system.

Bacterial leaf and flower blight (*Pseudomonas andropogonis*) affects carnation causing pale brown spots with watersoaked margins on ***leaves, stems, calyces and flowers***. Spots coalesce to form large irregular lesions. Bacteria invade the vascular tissues via the lower leaf blades. ***Overwinters*** in infected propagation material and crop debris. ***Spread*** by water splash, by movement of machinery and people through crops and by nutrient solutions in hydroponic systems. ***Favoured*** by warm, wet weather. See Carnation A 16.

FUNGAL DISEASES

Waterborne fungal diseases: Water moulds or aquatic fungi (Oomycetes) cause ***waterborne diseases*** and include *Phytophthora, Pythium* and *Olpidium* (transmits lettuce big vein virus), which produce ***motile spores*** (zoospores) that can swim through water. The zoospores are actively attracted to ***growing root tips***. Once a plant root is infected, fungal zoospores are freed from infected plant material into water to reinfect the growing root tips of neighbouring plants.

Table 9. Examples of waterborne diseases.

Crop	Waterborne diseases
Capsicum	Pythium root rot (*Pythium aphanidermatum*)
Carnation	Bacterial leaf and flower blight (*Pseudomonas androgonis*) Bacterial wilt (*Pseudomonas caryophyli*) Fusarium wilt (*Fusarium oxysporum* var. *dianthi*)
Lettuce	Lettuce big vein virus Bacterial soft rot/varnish spot (*Pseudomonas* spp.) Bacterial leaf spot (*Xanthomonas campestris* pv. *vitians*) Pythium root rots (*Pythium* spp.)
Strawberry	Pythium root rot (*Pythium coloratum*)

Spread: By spores swimming, by flood or drainage water, nutrient solutions, by machinery and people moving through crops.

Control: Providing hygiene is excellent, hydroponic systems of all types are remarkably free from disease problems. ***Train staff*** in nursery hygiene procedures and the reasons for them.

Sanitation**:* ***Disinfect media, containers and all equipment (including machinery) to prevent the ***introduction*** of bacteria and fungi into the nutrient solution, because once introduced, they can multiply rapidly. The system, whether non-cycling or re-cycling, must be ***discarded*** between crops or after a disease outbreak and flushed with water or nutrients regularly, as recommended. Containers and solutions are either discarded after 1 crop or thoroughly disinfected with steam or chemicals. Rockwool may be used for 3-4 years providing it is pasteurised before re-use. All ***dead plant material*** must be promptly removed to prevent the development of grey mould (*Botrytis cinerea*). To prevent the spread of diseases work within 'clean' areas first then in 'dirty' areas and do not smoke in hydroponic areas.

Biological control: All plants have a natural population of fungi and bacteria on their roots, whether grown in soil or hydroponics. Such fungi include *Alternaria, Botrytis, Colletotrichum, Fusarium, Pythium, Rhizopus, Trichoderma*. Bacteria include *Bacillus* and *Pseudomonas*. The source of many of these organisms is probably the water supply and air currents. Their presence is known in many instances to have a ***beneficial effect***, many release substances that stimulate plant growth and some may be antagonistic to disease organisms. ***Biological control treatments*** with microorganisms which might normally inhabit the root zone would increase yields (Hangar and Price 1983) and are being researched. Materials are also ***exuded*** from ***plant roots*** which form a good growth for bacteria and fungi, the majority of which are beneficial rather than detrimental.

Plant quarantine: ***Do not introduce*** contaminated water, infected plants, seed, soil, organic matter or plant debris.

Resistant varieties: This is the ***most effective*** control especially for *Fusarium* diseases.

Disease-free planting material: Planting stock must be ***free from pathogens*** and placed in disease-free solutions.

Physical and mechanical methods: ***Water*** disinfection treatments include filtration, ultra-violet light sterilisation, disinfectants. ***Growing media treatments*** include pasteurisation. Gravel and other substrates for hydroponic systems must be ***stored*** on disease-free surfaces, do not allow water to accumulate under gravel.

Pesticides: In theory an effective method of controlling diseases in hydroponic systems is to add systemic fungicides to the nutrient solution. However, it is not easy to control root diseases in nutrient film techniques as roots do not have any ***protective cuticle*** and most fungicides a have an immediate, and usually harmful effect on the root cells. Many fungicides have been screened but most have proved to be phytotoxic, even some of those known to be the least phytotoxic. Care should be taken when applying fungicides to ***foliage*** to avoid run-off. ***No chemicals are presently registered for use in hydroponic systems*** and so a permit has to be obtained to use them in this way. Low dosages required to avoid phytotoxicity means that fungi may be only ***suppressed*** and not killed. There could be a buildup of diseases and ***resistant strains*** may develop. Fungicides are rarely needed to control root diseases and when they are needed the rate of application is only about 1/10th of the rate needed on soils. Research has shown that adding 100 ppm soluble silicon to nutrient solutions may reduce *Pythium* root rot on cucumbers (Cherif et al. 1994).

INSECTS AND ALLIED PESTS

Insect pests are not a major concern of hydroponic systems. Pests which do occur are those that would normally attack the plant under conventional growing systems, eg aphids (Aphididae) (Fig. 422), greenhouse thrips (*Heliothrips haemorrhoidalis*), greenhouse whitefly (*Trialeurodes vaporariorum*) and twospotted mite (*Tetranychus urticae*). They are controlled in a similar manner. ***Biological control:*** Twospotted mite predators and whitefly parasites may be used for biological control and where these fail, recommended miticides and insecticides may be used. Where ***insecticides*** are used to spray plants, care must be taken not to spray all pesticides to run-off as chemical entering a nutrient solution will be taken up by the roots.

Tomato aphids have been eliminated after 3 days in ***NFT*** by the addition of prescribed insecticide to the nutrition solution. The technique of adding systemic insecticides to the nutrient solution is attractive, however, in practice it has not proved to be very successful. Often ***residues*** in ***fruit and vegetables*** have been too high and some are too phytotoxic, eg dimethoate. ***Pest management programs*** must be prepared.

Non-parasitic

Algae may grow in the solution or on the medium and are a ***common problem***. They are unattractive and compete for nutrients and air, and can cause blockages in pipes and orifices. Algae need light, moisture and nutrients in order to flourish. Growth ***in the nutrient solution*** is best controlled by eliminating places where light may enter the medium. Growth ***on the surface of the medium*** is best controlled by keeping the surface dry, by using subsurface irrigation and by choosing a medium that is coarse enough not to attract moisture to the surface. See Greenhouses N 27, Turfgrasses L 13, Water N 91.

Environment: ***Aeration:*** Oxygen is essential for the normal functioning of roots. Where plants are grown with their roots permanently immersed in liquid, as in a tank system, some form of solution aeration is necessary. If it is not provided, serious nutritional or root disease problems may occur. Other ***environment requirements***, eg light and temperature, must be provided as necessary.

Nutrient deficiencies, toxicities are the most ***common problems*** and are usually due to incorrect media preparation, changing and recharging, flushing and watering (Fig. 423). Hydroponic systems require extra care during hot weather to avoid roots drying out too much between waterings. Soft, dead areas on leaves may indicate nutrient toxicity (Fig 424) or waterlogging, brittle dead areas on leaf edges and tips usually indicate water stress. ***Collar burn*** is caused by a gradual accumulation of ***salt*** at stem level just above the level of the solution or aggregate. It occurs where the nutrient solution on the surface evaporates and a heavy deposit can cause localised salt burn which if severe will ringbark the stem and cause the plant to wilt. This can be controlled by flushing with water. Collar burn may ***predispose*** plants to grey mould (*Botrytis* spp.).

Pesticide injury: No pesticides are presently registered specifically for use in hydroponic systems. Permits or work orders have to be obtained. Both insecticides and fungicides are used in hydroponic systems but many may injure plants. Aerial parts of plants may be sprayed.

Root death: As a plant grows from a seedling to full maturity, changes occur in root behaviour and appearance. A critical stage of development occurs at the early fruiting stage (the first pick) when the plant carries its heaviest fruit load for the entire growth cycle. At this stage roots often cease growth and over ***50%*** may degenerate and die, and as a consequence there is reduced nutrient and water uptake. Under warm greenhouse conditions, the plant temporarily wilts and stops growth. This phenomenon is called ***'root death'*** and is known to occur in a number of plants with an indeterminate growth behaviour, eg cucumbers, whether grown in soil or solution. At this stage they are very susceptible to root diseases, eg *Pythium* spp., but in most instances active root growth resumes and plant recovers in a few weeks.

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Publications on Hydroponics (Vic Agnote)
Using Chlorine to Control Diseases of Hydroponic Crops (NSW Agfact)

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Australian Hydroponic Assoc. : Commercial Hydroponics in Australia : A Guide for Growers
Australian Hydroponics Conference Proc.
Hydroponics : Reference & Product Guide
Hydroponics International
Good Fruit & Vegetables
Growing Edge
GrowSearch (database Qld DPI)
Live Information Line for Hydroponic Advice (University NSW 1902 263 405)

Practical Hydroponics (book catalogue available from PO Box 225, Narrabeen NSW 2101)
State/Territory Associations
Tropical Hydroponics

Companies eg
Accent Hydroponics
Australian Hydroponics, Melbourne

See Soil N 82, Water N 92, Water plants N 94

Remember, always check for recent references

MANAGEMENT

Selection

Advantages of hydroponic systems includes no weeds, reduced disease and pests, conservation of water, better control of crop nutrition and the ability to grow crops anywhere, eg where no suitable soil exists or where soil is contaminated with disease. Culture is intensive so only a small space is required, reduced transportation costs to market, heavy work is reduced, yields are maximised and nutrients conserved, the environment is more easily controlled, root zone chemistry is easier to control, new plants easier to transport, reduced transplant shock. Many plants are propagated hydroponically before potting up for export (no soil adhering to roots, eg camellia). ***Disadvantages of hydroponic systems*** include the initial high cost, skill and knowledge needed. Diseases and pests can spread quickly through the system, beneficial soil microorganisms are normally absent, plants react quickly to both good and bad conditions, and available plant varieties are not always suitable.

Select the crop, seek advice, obtain references: Commercial crops grown hydroponically include ***ornamentals***, eg carnations, chrysanthemums, gypsophila, roses, ***fruit***, eg strawberries, ***vegetables***, eg cucumber, herbs, lettuce, tomatoes, zucchini. Many additional species can be grown by home gardeners (Mason 1990). Advisory services are available (Moody 1996).

Select the hydroponic system: The main techniques used include ***plants anchored*** in a range of solid media which also retains the nutrient solution between irrigation and ***plants which are suspended*** with their roots in a tank of water and oxygen from air is bubbled through the solution. These techniques have mainly been replaced by a third method whereby ***plants and their roots are supported*** in special channels set at an incline of about 1 in 50. A film of water less than 2 mm deep runs continuously down a channel to a sump from which it is pumped again to the upper end, known as nutrient film technique (NFT). Nutrient solutions may be ***recycled*** or ***non-recycled***.

Select the water/nutrient systems: Water used includes town or dam water, top up systems, recirculating, flood or drainage water. Depending on the source it may require treatment.

Select cultivars with some ***resistance*** to common problems and ensure that the planting material is ***disease-free.***

Establishment and Maintenance

Nursery hygiene: Follow a program of strict nursery hygiene which includes disease prevention measures. There are many leaflets available outlining procedures required. These include the use of ***disinfectants*** for water and substrate treatments and the observance of ***quarantine*** procedures to prevent the accidental introduction of soil or organic matter. ***Sanitation*** measures include removing all dead plant tissue to prevent diseases, eg grey mould (*Botrytis cinerea*), from growing on it, spreading to the living plants. ***Biological control*** programs can be used on hydroponic crops.

Pesticides: Generally pesticides are not registered specifically for use on hydroponic systems. Permits or work orders may have to be obtained.

Pest management programs can be prepared for a particular crop.

Postharvest

These are usually similar to those required for a conventionally grown crop. Some hydroponic crops, eg lettuce, are marketed with their roots attached so they may have a longer shelf life.

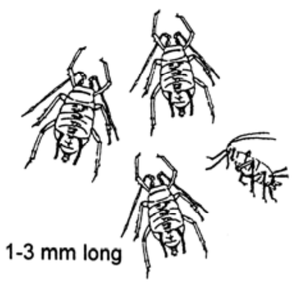

Fig. 422. The usual diseases and pests of a crop, eg aphids (Aphididae), may infest hydroponic systems.

Fig. 423. Nutrient deficiencies and toxicities are common. Dept. of Agric., NSW.

Fig. 424. Salt toxicity causes soft, brown leaf tips and edges. Dept. of Agric., NSW.

Interior plantscapes

PESTS AND DISEASES
Parasitic
Non-parasitic

PESTS AND DISEASES

Individual interior plantscape plants are subject to pests and diseases in the same way as their naturally grown counterparts outdoors, eg ***Aphelandra*** is very susceptible to aphid infestation. As a ***group***, interior plantscape plants are subject to the same pests and diseases as house plants. See House plants N 35, Greenhouses N 22. However, ***parasitic pests and diseases*** are being seen ***less often*** on interior plantscape plants, probably as a result of improved production techniques, and the good pest and disease research, which has been conducted in recent years on plants intended for use in indoor gardens. Soil-less media, tissue culture techniques designed to reduce the transfer of disease, new fungicides being used in nurseries producing indoor plants, plant spacing, irrigation and handling procedures in the nursery and the demands of the industry for quality material, have all played a part. The most ***serious problems*** affecting interior plantscapes are non-parasitic, followed by insect and mite pests.

Parasitic

Virus and virus-like diseases: Plants used in interior plantscaping are remarkably free from virus and virus-like diseases.
Bacterial diseases: Very occasionally ***bacterial soft rot*** (*Erwinia* spp.) occurs on soft fleshy plants. See Vegetables M 5.
Fungal diseases: ***Fungal leaf spots*** (various species), ***grey mould*** (*Botrytis cinerea*), ***powdery mildews, root, crown and stem rots,*** and ***wilts*** are uncommon on plants in commercial interior plantscapes. Plants are selected and grown in such a way as to minimise their development.
Insect and allied pests: ***Aphids*** (Aphididae), ***caterpillars*** (Lepidoptera), ***greenhouse thrips*** (*Heliothrips haemorrhoidalis*), ***greenhouse whitefly*** (*Trialeurodes vaporariorum*, ***longtailed mealybug*** (*Pseudococcus longispinus*), ***millipedes*** (Diplopoda), ***mites*** (Acarina), eg broad mite (*Polyphagotarsonemus latus*), cyclamen mite (*Phytonemus pallidus*) and twospotted mite (*Tetranychus urticae*), ***scales*** (Hemiptera), ***slaters*** (Porcellionidae) are more common than fungal diseases. If routine leaf and stem cleaning procedures do not provide satisfactory control, plants should be replaced.

See Greenhouses N 22, House plants N 35.

Non-parasitic

Compared with house plants, those used in interior plantscapes suffer additional non-parasitic problems.

Acclimatisation: Improper procedures may cause rapid deterioration of plants (Sams 1996).
Complaints: Employees working beside hired plants may feel that they 'own' the plants and complain when the plants look 'unwell'.
Containers may be damaged and need replacing. Despite being labelled by the plant hire company, they may be stolen.
Dust: Plants may become dusty if leaves are not regularly cleaned.
Environment: Plants are required for almost impossible situations and reliable information about the environmental tolerance and acclimatisation practices of the various species used indoors, is not always readily available. The indoor environment typically includes low lighting and overwatering. ***Light*** (artificial, natural or sunlight) is the major determinant of plant growth and development, influencing many plant processes, eg photosynthesis, chlorophyll synthesis, stomatal behaviour, pigment formation, etc. Light intensity can be measured and the recommended light intensities for maintenance of selected foliage plants followed. If a plant is maintaining its leaves, the light intensity is adequate. If it is too ***low***, leaves may yellow and drop and growth may be leggy. However, often light is stressful not because of the low intensity but because of the opposite. If too ***bright***, leaves may scorch. Light intensity guides are now available. ***Potting media*** may be highly aerated and well drained. This can lead to plant health problems, especially when the plants are ***watered*** sparingly and infrequently. Widespread drought stress and soluble salt toxicities develop because of heavy fertilisation in the nursery and subsequent drought stress indoors. ***Test water*** for pH, conductivity, concentration of disinfectants, nutrients, heavy metals and pesticides. ***Temperatures*** may be too hot or too cold (plants may be sun scorched). Sudden rises or falls in temperature due to sun coming in through windows or heating being turned off at weekends, causes problems. ***Watering*** is probably the major problem of indoor plants, eg too much or too little. The need to greatly lessen the water and nutritional content of soils in which interior plants are being maintained, is generally recognised. ***Humidities*** vary between too high or too low. See House plants N 36.
Nutrient deficiencies, toxicities are not so common today. Slow release fertilisers provide a more regular supply of the necessary nutrients. If necessary media tests, pH and tissue testing may be carried out.
People-pressure: Plants may be mechanically damaged by people, parties. Cigarette butts, tea leaves, food and other rubbish may be thrown on plants and coconut fibre. Branches may be broken and leaves pulled off.
Pesticide/chemical injury is not common. Materials recommended for cleaning leaves and controlling pests on plants in offices and other interior plantscapes at the present time, are of a low hazard to both humans and the plants themselves. Some ***cleaning agents*** may cause dead leaf tips and black leaf spots. If more effective chemical treatments are required plants are replaced. The ***atmosphere*** in buildings which may contain > 200 potentially volatile organic chemicals, especially in air-conditioned

offices, affect some species. Some indoor plants, eg Kentia palm and spathiphyllum, are susceptible. Air pollution tolerance index ***(APTI)*** may be measured by measuring basic leaf parameters, eg chlorophyll content, etc. Preliminary results indicate that this could be used as an early warning system for indoor air pollution (HRDC Research report 1994-95). Foliage plants are considered to have the ability to remove small particled substances from indoor air (Wood 1989).

Others: Plants in interior plantscapes are susceptible to the same problems as greenhouse and house plants. See House plants N 36, Greenhouses N 28.

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Landscape Contractors Association of NSW
NSW Nursery News
Queensland Interior Plantscape Assoc. (QIPA)

See Greenhouses N 28, House plants N 37, Nurseries N 56, Preface xii

Remember, always check for recent references

MANAGEMENT

Most commercial plant hire business have an indoor plant services manual which outlines the procedures for their particular business. Interior plantscape associations provide a range of information and services.

Selection

Horticultural requirements: ***Select plants*** with a ***proven performance indoors***. Plants must look good, survive indoors and fit a niche. They must be relatively easy and cheap to propagate, grow and maintain. Plants must be uniform in size, have good symmetry, be easily handled, transported and held in glasshouses prior to use. Leaves must be easily cleaned. Plants must be able to perform well in high or low light conditions and at air temperatures of 10^{o}C or above. Either select plants for the given light intensity and temperatures or change them to suit the plants chosen. Choose plants of different colours, textures and shapes with attractive hardy foliage. Tropical and subtropical herbaceous and woody foliage plants are the most important and predominant plant group used in interior landscaping. There must be provision for appropriate ***transport***, conditions must not be too cool or too hot. ***Specifications:*** Usually there are strict specifications for plants acceptable for particular indoor display contracts. For example, plants must have ***symmetry***, a good ***healthy appearance*** and ***high density***, they must be ***1-5 m in height***, with a good root to shoot equilibrium. Foliage must begin approximately ***150 mm above soil level***. Plants must have some degree of ***flexibility*** as they often have people bending them, walking or brushing against them. ***Spines, sharp point***s should be absent from the plant. ***Variegated foliage*** may be used for special effects. ***Flowering plants*** are generally often not suitable because spent flowers look messy and plants require more care than can be provided in a fortnightly visit. Plants must be disease and pest-free, of good shape and well balanced, and must be mulched with coconut fibre and the plastic pot hidden.

Exotic plants	**Australian native plants**
Chamaedorea elegans (parlour palm)	*Acmena brachyandra* (lilly-pilly)
Dieffenbachia spp.	*Alpina* sp. (native ginger)
Dracaena spp.	*Schefflera actinophylla* (umbrella tree)
Howea forsteriana (kentia palm)	*Caldcluvia paniculosa*
Monstera deliciosa	*Davidsonia pruriens* var. *jerseyana* (Davidson's plum)
Philodendron spp.	*Ficus benjamina* (weeping fig)
Rhapis spp. (lady palms)	*Giessios benthamii*
Spathiphyllum spp.	*Piper nova-hollandiae*
Scindapsus aureus (devil's ivy)	*Syzygium francisii*, *S. moorei* (lilly-pillies)

Resistant varieties: The main problems affecting interior plantscape plants are ***non-parasitic environmental problems***. Without question, most of the 'sick' plants noted in indoor gardens result from the complexities of cultural management. Indoor plants are not meant to 'grow', the aim is to maintain them in good health for as long as required. Root decline can be a common problem and is caused by the various stresses and imbalances brought on by suboptimal interior environments. Make a list of the relevant information for each species, eg cultural requirements (light, temperature, watering), any disease or pest problems, particular features, eg suitability for hostile sites. Only then will desired affects be achieved. The main method of pest and disease control in this industry is the selection of species and varieties which have some ***resistance to the common problems*** affecting such plants, eg low light, fluctuating temperatures, greenhouse thrips, mealybugs and twospotted mites. New varieties are constantly available for trial. ***Parlour palm*** (*Chamaedorea elegans*) is susceptible to twospotted mites and thrips. ***Lady palms*** (*Raphis* spp.) are relatively problem-free. As a rule of thumb, plants with light coloured foliage or variegation prefer high light areas, eg *Ficus,* and plants with dark colour foliage prefer low light areas, eg *Philodendron*.

Disease-free planting material: Most plants are purchased. Plants should be free from diseases and pests, eg aphids, mealybugs, scale, cobwebs, dust, and be of the required specifications. Some interior plantscapers propagate and recycle their own plants.

Direct sale to clients in offices: Advice on general care should be provided when the sale is made. It may also be necessary to provide design advice on arrangements of plants to achieve a desired effect.

Establishment

Train staff in their responsibilities, eg maintaining, arranging and changing displays and in public relations.

Acclimatisation: Indoor gardens are usually composed of large, container-grown plants that have been produced quickly by means of unlimited amounts of water and nutrients, high temperatures and optimal lighting. When brought indoors, these plants are often difficult to maintain in a healthy state, even those that have been 'conditioned' for a time by reducing the amount of light and the frequency of watering and fertilising. Good interior gardeners usually provide ***transitional environments and care programs*** for such plants, proper acclimatisation is still not widely practiced (Sams 1996).

Maintenance

Equipment required: Basic equipment includes 9 L watering can, 1 L spray bottle, garbage bag, feather duster, 5 L bucket, secateurs, diary, complete company uniform. ***Containers*** must have adequate drainage and be of appropriate material and size. Recommended ***media*** must be used. ***Planters*** must suit the needs of the plant and the environment and not be too expensive. They must be readily available, strong, durable and light in weight. Some indoor plants are grown ***hydroponically***.

Frequency: Fortnightly maintenance treatment is the usual regime.

Service: The ***time*** spent on each plant, eg salvaging or replacing, trying to eliminate pests and diseases, has to ***economically balanced*** with the need for maximum aesthetics. Service visits are aimed at preventing problems. ***Watering*** is the main reason for the fortnightly visit. If a plant is to remain for a long time, water as little as possible. Water plant in most jobs once per fortnight. ***Fertilising:*** It depends on the type of plant and the fertiliser used. Some fertilisers, eg Aquasol® or Thrive® , may need to be applied every fortnight slow release ones only every few months. ***Pruning*** is carried out at different stages in an indoor plant's life and for different reasons, eg acclimatisation, maintenance, natural target pruning and trimming. ***Leaf trimming*** is best avoided, it spoils the appearance of plants, wastes time and scissors may carry disease. Rather than trimming browned leaf tips or edges, the complete stalk should be removed. ***Staking*** may be necessary. ***Clean leaves*** with mild soap and water or other products, eg Clensel®. Wipe a few leaves on each plant on each visit. If the plant is kept clean in this way drastic action should not be necessary. Oils may clog the stomates and cut out one-third of the available light. ***Containers*** should be wiped clean if necessary, the appearance of the cleanest plant is spoiled by a dirty pot.

Unhealthy plants: Identify the problem. Commonly observed environmental maladies, eg tip browning, leaf yellowing, are often non-specific, possibly resulting from a variety of causes. See House plants N 40. Know and recognise problems associated with individual plants. ***Palms:*** It is difficult to avoid brown tips as they appear for varied reasons including their inability to adjust to lower humidity or wet soil. Removing the whole branch with the brown tip is often necessary. ***Ficus:*** Heavy leaf fall may occur due to a change in light intensity and rapid changes in temperature or twospotted mite and mealybug infestations. Maintenance of constant and correct temperature is essential; 25^{o}C favours rapid growth; *Ficus* will recover more quickly from being too dry than too wet. *Ficus* do not like dust on their foliage so regular cleaning is advised. Nutrient deficiency may also result in the fall of yellow leaves. ***Spathiphyllum:*** Leaf tips may brown due to the inability of lower leaves to acclimatise, or the plant is too wet. ***Pesticides:*** If leaves are kept clean by regular wiping, no other treatments ***in situ*** may be necessary. The only ones permitted for use on plants in offices are those ***registered for use on indoor plants***, eg soap, they should only be used if necessary. ***Replace plant*** if necessary. Eventually many healthy plants will need ***repotting***.

Postharvest

Plants which are beyond their life as an interior plant are either ***thrown out***, ***recycled for compost***, ***sold cheaply*** to the public, or ***trucked to nurseries*** for re-potting and regrowth.

Manure
(animal)

PESTS AND DISEASES
Parasitic
Non-parasitic
Contaminants
Flies
Nutrient deficiencies, toxicities
WEEDS

Manure is any substance produced by animals or plants that can be used as fertiliser. Most manure consists of ***animal waste*** mixed with straw or hay, though it may be pure animal waste. A special kind of ***green manure*** is obtained from plants (legumes) that are ploughed into the soil and allowed to decay.

PESTS AND DISEASES
Parasitic

Soil fungal diseases if present, eg *Fusarium* and *Rhizoctonia*, may invade manure on pasture and spread disease if collected. ***Nematode diseases*** may be spread in manure from animals feeding on infested plants, eg stock feeding on potatoes infested with root knot nematode (*Meloidogyne* spp.) spread it in their manure.

Non-parasitic

Contaminants: Animal manure may be contaminated with hormone fatteners, pesticides and other products used to treat animals and buildings. If manure is ***composted or stacked*** prior to use, these do not seem to be a problem. There are now restrictions on the use of certain hormones on some animals.

Flies (Diptera) are serious nuisances to humans and domestic animals and may breed continually or overwinter as pupae in manure from exotic animals. Nuisance flies include the common ***bush fly*** (*Musca vetustissima*) which settles on backs and faces, the ***house fly*** (*M. domestica*) which carries many diseases including typhoid and dysentery, and the ***stable fly*** (*Stomoxys calcitrans*) which bites horses, cattle, and humans to suck blood. Flies lay eggs in manure (and other decaying refuse) which hatch into maggots, which when fully grown pupate, adult flies finally emerging. The ***biological control*** of animal manure by dung beetles has been researched in Australia by CSIRO. Introduced dung beetles are used with varying degrees of success to bury manure of introduced animals. Manure may be ***pasteurised*** during composting. ***Insecticides*** are registered for control of some pests. See Compost N 17.

Nutrient deficiencies, toxicities

Nutrient value: Animal manures contain only small quantities of nitrogen, phosphorus and potassium which vary with the kind of animal, its diet and the amount of straw or litter mixed with it, and whether it is fresh, dried or partly decayed. In large amounts manures are excellent for improving the ***texture and structure of soils*** and improving its ability to absorb water.

Fresh manure: Generally manures should not be used fresh, but aged while moist for several months or composted. Otherwise roots, leaves and stems may be scorched due to its high pH or high nutrient content, eg ***fresh poultry manure*** has a very high nitrogen content.

Manure containing a lot of straw may cause a temporary ***nitrogen deficiency*** because bacteria decomposing the straw have first call and plants may suffer nitrogen deficiency. Extra nitrogen may be added, or a complete fertiliser containing at least 10% nitrogen plus some phosphorus and potassium. Seek advice if in doubt about what to do.

WEEDS

Manure in the field is easily contaminated with windblown ***seeds*** of annual and perennial weeds from surrounding areas. It may also be invaded by ***rhizomes*** of perennial weeds such as couch.

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Seedling Maggots (NSW Agfact)
Liming Materials (NSW Agfact)
Molybdenum Deficiency in Crops (NSW Agfact)
Organic Fertilisers : An Introduction (NSW Agfact)
Piggery Effluent as Fertiliser (Vic Agnote)
Vegetable Cropping with Fowl Manure (Vic Agnote)
Zinc Deficiency in Field Crops (NSW Agfact)

See Compost N 17, Potting mix N 65

Remember, always check for recent references

MANAGEMENT

Manure is not generally suitable for potting mixes, but may be used in composting and for including in soils. ***Fumigants*** are registered for treating manure for fungal diseases (damping off, *Fusarium* and *Rhizoctonia*, nematodes and fly maggots), ***insecticides*** are registered to control some insect pests. Effective ***pasteurisation*** is necessary to guarantee freedom from pests and diseases.

Mulches

PESTS AND DISEASES
Parasitic
Non-parasitic
- Aesthetics
- Leaves, prunings
- Nutrient deficiencies, toxicities
- Oxygen, irrigation
- Slopes
- Temperature
- Toxins

WEEDS

Mulches ***aid*** water retention and conservation. They ***increase*** soil microorganisms and nutrients, water filtration and aeration. They ***reduce*** soil water evaporation, soil temperature fluctuations, weeds, mud splash onto plants, compaction and erosion (ARK 1995). There is an Australian Standard (AS 95301) for mulches.

PESTS AND DISEASES
Parasitic

Most materials used as mulches do not spread or increase pest and disease problems, but there are some exceptions. ***Composted garden waste***, if improperly composted (cool areas of < 65°C on the surface), or ***contaminated chipped garden waste***, may spread diseases and pests. Whether they are a problem of not depends on the source of the composted or chipped material and where it is to be applied. Dutch elm disease has spread in the USA via chipped trees.

Bacterial and fungal diseases may be introduced when contaminated compost is used as a mulch, eg ***alternaria blight*** (*Alternaria*) of tomato, and ***soilborne diseases*** (*Fusarium, Rhizoctonia, Sclerotinia, Sclerotium*). Sclerotia of *Sclerotinia* and *Sclerotium* may be distributed with compost on to crops. When infected crop debris remains on the soil surface as a mulch, as in minimum tillage systems which are used to avoid soil erosion, diseases such as *Fusarium* and *Rhizoctonia* may increase on susceptible plants. *Armillaria* and some wood rot fungi, if present, and conditions favour their development, may grow on pine or eucalypt mulches.

Nematode diseases may be introduced to areas when contaminated compost is used, eg root knot nematodes (*Meloidogyne* spp.).

Parasitic plants, eg seeds of broomrape (*Orobanche* spp.) and dodder (*Cuscuta* spp.), may be introduced on straw when it is transported from one area to another for use as a mulch or feed.

Insects and allied pests: The buildup of natural organic mulches may provide an ideal environment for the development of some insect pests, eg ***garden weevil*** (*Phlyctinus callosus*), which can breed and hide during the day in surface organic mulches and emerge at night to feed on susceptible plant foliage. Pine chip*s* are attractive to ***termites***. ***Slaters*** breed and shelter under mulches.

Snails and slugs may become a major problem if susceptible ground cover plants are used as a living mulch. Coarse bark acts as a deterrent.

Non-parasitic

Aesthetics: Choose mulches to blend with the landscape and suitability for the site.

Leaves, prunings: Most leaves from deciduous trees may be used as a natural mulch ***in situ*** or composted, there are exceptions. Leaves from Australian plants, eg eucalypts and wattles, take longer to decompose. Disease-free prunings may be coarsely shredded and used as a mulch.

Nutrient deficiencies, toxicities

Decomposing mulches: Mulches of more succulent organic materials, eg turf clippings, animal manures, compost and hay, supply considerable nutrients as they decompose. ***Young plants*** to be mulched with woody organic materials, sawdust and pine bark often benefit from application of extra nitrogen to make up for the nitrogen used by microorganisms to decompose the mulch ***(nitrogen drawdown)***. ***Mature plants*** do not need any extra nitrogen, as a reduction in growth rate will hardly be noticed.

Mycorrhizae (symbiotic fungi) occur in soil under deep litter and are essential for adequate growth of some plants. See Trees K 18.

Nitrogen-fixing bacteria: There is more nitrogen fixed by free-living nitrogen-fixers in a soil under mulch than there is in the same soil when unmulched. See Trees K 18.

pH: Some mulches, eg mushroom compost, are quite alkaline.

Oxygen, irrigation: Mulches must have some means of allowing oxygen, rain or irrigation to reach the soil and the roots.

Mulches of sheet plastic must have holes in them or must cover part of an area only. An alternative is to use a woven material.

Organic mulches: Avoid organic mulches that mat down into a water-shedding layer preventing moisture, warmth and oxygen reaching plant roots, eg ***lawn clippings*** used before they have dried out. ***Paper*** mats down, reducing evaporation, it also becomes messy due to holes made in it to allow water to reach the soil. ***Sawdust*** mulches tend to rapidly decompose and compact. Mulches that do pack down may be mixed with a coarser material. Compaction can be reduced by occasional raking and then watering. Organic materials > 100 mm thick, reduce the effectiveness of rain or irrigation by absorbing most or all of the water before it reaches the roots. Wet the soil or mix before applying a mulch. ***In dry areas where plants will not be irrigated***, too thick a mulch could well lead to plant roots getting little of the rain that does fall. In such situations mulches should be only 20-60 mm thick at the most and relatively coarse in texture (Handreck 1994). ***In areas which experience seasonal dry periods***, mulches will help conserve water only if they are thin enough to allow even light rain to reach the soil, the finer the mulch the shallower its depth of application (Handreck 1994). Research suggests that optimum depths range from 20-30 mm for fine compost, 40-60 mm for chipped tree trimmings, to 80 mm for bark nuggets. Thicker mulches will not significantly reduce soil temperature or evaporation of water. ***In wet areas***, with plenty natural rainfall and little need to conserve water, mulches may prevent soil from drying out and organic mulches may reduce plant growth in soakage areas.

When to irrigate: When mulch is present there can be difficulty in knowing when to irrigate. Regularly check underneath.

Slopes: Mulches applied to the lower parts of sloping areas allow them to remain ***wetter*** than those higher up the slope. Plants in such areas may die from ***root rotting diseases***; small plants, eg bulbs, may gradually be ***submerged*** over a period of time. Certain types of mulches, eg large bark mulches, ***do not readily pack down***.

Temperature

Air temperatures: In colder areas ***organic mulches*** have a tendency to ***increase*** the negative effect of ***frost*** on nearby plants, ie they may increase frost damage.

Soil temperatures: ***Black plastic mulches*** on the soil surface can increase growth rates in early spring but in warmer weather high temperatures can lead to excessive transpiration and may later kill roots. Black plastic is not recommended as a mulch. ***Clear plastic mulches*** are used for solarisation to kill nematodes and fungi in the top centimetres of the soil. ***Organic materials*** make ideal ***summer mulches***, roots grow right up into the moist, cool surface layer of the soil, however, during late winter and early spring, because of lower soil temperatures, plants grow more slowly than do unmulched plants. Mulches > 80 mm do not significantly reduce soil temperature.

Toxins

Some mulches, eg fresh pine bark and some sawdusts, which contain phenols may inhibit the plant growth for a few weeks. If applying around newly planted trees and shrubs, they should be detoxified by ***moist ageing*** for a few weeks, otherwise wait until plants are well established. See Potting Mix N 65.

Pesticides: Do not use plants or other materials treated with herbicides or other pesticides for mulching, eg clippings from treated lawns or bark from areas treated with persistent herbicides, unless pesticide residues are no longer present.

Others: Phytotoxic materials and dog droppings spread in mulch, are potential health hazards.

WEEDS

Most mulches ***reduce*** the numbers of weeds growing in an area.

Weed seeds: Mulches are especially effective against ***annual weeds*** which only reproduce by ***seed***. Many weed seeds do not germinate under a mulch, or if they do, the seedlings die before they can reach the light. Those that do struggle through are weakened and easy to remove by hand or controlled by spot spraying with herbicides. When compost containing ***weed seeds*** (due to improper composting or aerial contamination) is used, there can be a large increase in weed populations. Some mulches, eg ***hay and straw***, may carry seeds of a range of weeds including those of parasitic plants, eg dodder (*Cuscuta* spp.).

Perennial weeds: Mulches are not so effective in controlling ***perennial weeds***, eg emerging shoots of nutgrass can pierce through many mulches including black plastic and continue to thrive in mulched areas. It can only be eliminated by herbicides. Where perennial weeds are a problem they are best eradicated ***prior to laying the mulch*** and consideration may be given to laying a weed mat under the proposed mulch. Any perennial weeds which persist can then be easily removed physically or with an appropriate herbicide. When ***compost*** containing bulbs, corms, rhizomes, tubers or cut up roots of perennial weeds is used as a mulch, there can be a large increase in weed populations.

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See Compost N 17, Soil N 80, Xeriscape N 95

Remember, always check for recent references

MANAGEMENT

Mulch is generally considered to be beneficial. There is a continually increasing range of mulching materials available, some of which are quite expensive. Select one that suits the situation, eg formal garden, rose bed, vegetable garden or container. The thickness of the mulch will depend on the material used. Consider the advantages and disadvantages of the particular mulch prior to purchase, if in doubt seek advice.

Nurseries

NURSERY HYGIENE

Management programs: All production nurseries, whether applying for nursery accreditation or quality assurance or not, should have in place nursery hygiene procedures. Nursery hygiene and nursery accreditation schemes (Anon. 1994a, Bodman and Forsberg 1992) contain management programs similar to those designed for managing any other group of plants or situation, eg hydroponic systems or roses (Kerruish 1990).

Losses from soilborne diseases in nursery stock was one of the main reasons for the development of nursery hygiene programs (Goss and Harrison 1979). Such diseases are spread in soil and water. Nursery stock is an ideal method of spreading pests, disease and weeds from place to place. The customer purchases it and takes the problems with them. Some schemes aim to control specific diseases. In WA, one of the aims of Nursery Industry Accreditation Scheme, Australia ***(NIASA)*** is to prevent *Phytophthora* spread.

Types of plants being grown: Although the pests, diseases and weeds in a nursery to some extent reflect the types of plants being grown, nearly all production nurseries are capable of spreading ***certain types of problems***, eg weeds in containers. ***Cactus nursery stock*** may also spread *Phytophthora*, scales, twospotted mites and possibly other problems. Nursery stock taken for ***display*** elsewhere may become infested and introduce pests when taken back to the nursery, eg ***African violets*** may become infested with cyclamen mite and ***lavender*** with carmine mite.

Diseases, pests and weeds: Diseases and pests affecting ***specific plants*** should be listed and described. ***General nursery*** diseases, pests and weeds which affect a wide range of nursery plants should also be listed and described (Mathias 1995a).

Pests and diseases of some plants in nurseries may only be serious on nursery stock. On planting out disease is minimal, eg rust on birches and grey mould on ferns.

1. LEGISLATION

- Horticultural stock and nurseries acts. The main provisions of these acts include registration of plant resellers, labelling of plants, and maintenance of records.
- Quarantine acts and plant diseases acts regulate the movement of plants into and within Australia and may stipulate control measures.
- Pesticide acts, chemical acts, hazardous substances acts, occupational health and safety acts, dangerous goods acts, duty of care and Australian standards regulate the handling, storage and use of pesticides.
- Clean water acts control pollution of waterways.
- Other acts and codes of ethics.

2. SITE AND LAYOUT

Choosing a site for the nursery: A new nursery should be sited in an area which is ***only slightly sloping***, appropriately drained and not subject to waterlogging or flooding during heavy rain, strong winds, temperature extremes and heavy weed contamination. An adequate supply of good quality water must be available. There must be an ability to ***recycle waste water*** eventually.

Design of nursery: Design should facilitate operations. Conveniently locate the various work areas, eg office, area for receiving and storage of bulk materials. ***To avoid cross contamination***, the area for potting mixes and fertilisers should be quite separate from the areas for treatment of potting mixes, storage of treated mixes and propagation and growing on areas. Parent stock plants should be ***isolated*** from cutting/seed propagation areas which should be separate from growing on and field production areas to ensure no casual transmission of pests and diseases (Goss and Harrison 1979). Areas should be located in such a way that there is an ***easy flow-on*** from one area to the next with access ways and drive-ways of adequate width for easy movement of equipment and to minimise spread of diseases, pests and weeds. ***Vehicle access*** in some nurseries is restricted to essential deliveries and loading areas located to minimise risk of contamination by outside soil.

Design of individual areas: Each area should be designed according to recommendations (Anon. 1994a). ***Field grown material*** should be planted to minimise pest and disease problems and facilitate easy maintenance and good disease, pest and weed control practices. ***Drainage*** should prevent waterlogging which would favour root rotting fungi. ***Continual production*** of similar plants in field areas should be avoided. Some form of crop rotation is beneficial and sufficient area should be allowed for this. Space plants to prevent physical damage due to crowding of roots and foliage and to minimise disease problems associated with high humidity and restricted air movement. Row spacing should allow easy access for disease, pest and weed control and ensure all plants can readily be inspected. Allow sufficient room for plants to grow without crowding later on.

3. STRUCTURES

Nursery structures should be ***suitable for the purpose intended*** and in ***good condition***. They should be capable of sustaining the growth of plants for the required period and reduce risk of introducing pests and diseases. The number and size of structures for plants is important for records and to assist in evaluating a nursery's level of production. Specialist nurseries require equipment and techniques appropriate to their operation.

Bench and floor surfaces: Pots should not be placed directly on soil. There should be good drainage beneath pots to ensure there is no buildup of drainage water which will assist the spread of disease from pot to pot. Do not use 2-tier benches as drainage from the upper level will contaminate the lower deck. If general hygiene is good and the nursery is free of soilborne pathogens, then drainage from pot to pot is of little importance. ***Suitable bench surfaces*** include wire mesh, eg aluminium, galvanised steel. Unsuitable bench surfaces include solid bench tops, wooden benches lined with plastic (where pots stand on a solid surface). Surfaces beneath benches should be concrete or screenings and drained to ensure no buildup of waste water. ***Suitable ground level container areas*** include galvanised welded mesh over concrete; 50-75 mm of blue metal, gravel or other types of screenings over soil; sloping (well drained) concrete or bitumen. Screenings should be free-draining and the sub-surface sloped to ensure all free water flows away from pots. ***Specially designed plastic decking*** (with bumps) to collect any run-off water and raise pots of the ground, can be laid over soil or other surfaces. It probably acts as a barrier for soilborne diseases present in degraded gravel, soil layers, etc, underneath. Irrigation run-off is not contaminated with soil. Roots are air-pruned when they grow out of drainage holes. ***Unsuitable ground level container areas*** include poorly drained concrete and bitumen floors; impervious weed mat (where pots stand on a solid surface) which allow drainage water to flow from diseased plants and be taken up by adjacent plants through drainage holes. ***Woven weed mat*** may not allow free drainage and may cause transfer of diseases as puddles of water build-up on the surface. Plant roots may grow out of the drainage holes and penetrate the mat contacting contaminated soil beneath. If water standing around pots is taken up by ***capillary action***, media remains wet and provides ideal conditions for soilborne diseases. Capillary matting is only acceptable if hygiene is of the highest standards and no soilborne or waterborne disease organisms are present. ***Black plastic*** is acceptable only if placed over a well graded, and compacted surface.

Shade cloth or plastic/glass structures must be in suitable condition and the degree of shade offered appropriate for the plants beneath.

Working areas: ***Cutting preparation areas*** should have impervious benches, eg of steel or laminex, which can be washed down regularly with disinfectants. Some disinfectants may damage steel top benches where they remain in contact for long periods. Suitable floor surfaces include concrete or bitumen. The floor of propagation areas should be suitable for frequent washing down with disinfectants, eg concrete or bitumen.

Cuttings growing areas include raised heated beds with concrete or screenings on the floor, ground level beds with screenings surface for standing cuttings, or wire mesh on concrete (drainage). The cutting-growing area should be set up to provide good drainage beneath raised beds or have a suitable drainage system beneath ground level beds. The comments above for cutting preparation areas should be considered for cuttings growing areas. The level of hygiene should be of the same high standard.

Transplanting or potting areas: The type and condition of benches and floor surfaces in transplanting areas should be as outlined above to ensure the same standards of hygiene and management as for propagation areas.

Storage areas: ***Clean and new containers*** should be stored in a clean dry area, to ensure they remain clean and free from disease and pest organisms that may be introduced by contact with soil, used potting media or used containers. ***Disinfect*** used containers, tools, secateurs, benches and floors.

4. GROWING MEDIA

Composition: The components in a potting mixture should allow for appropriate drainage (but still be capable of holding moisture) and nutrient balance. If the media or growing media ingredients are purchased from a reputable or accredited source, then no detailed assessment may be required. Ingredients must be appropriately mixed. ***Soil/media testing*** for nutrient compositions, etc, and diseases is considered necessary at some stage in the process. ***pH*** (acidity and alkalinity) and ***EC*** (electrical conductivity) measurements should be ongoing in the nursery.

Sterilising media: Media for potting must be pasteurised or be composed of ingredients that are guaranteed free from pests, diseases and weed seeds, ie obtained from an accredited reputable source. Some potting mixes are guaranteed to be weed-free. ***Sand and peat sometimes contain disease organisms***, eg ***peat***, may contain *Chalara* and *Pythium* and ***sand***, *Pythium* and *Rhizoctonia*. ***Soil and some compost components*** in mixes should be routinely treated either by pasteurisation, fumigants or fungicides. Other treatments include sterilisation by steam, electricity, microwave, solarisation (Anon. 1994a). ***Pasteurisation*** by heat (minimum 60^{o}C for a minimum of 45 minutes, all mix heated to 60^{o}C) is favoured because it mostly only kills disease organisms and does not create a 'biological vacuum'. ***Prevent recontamination*** of guaranteed disease, pest and weed-free mixes or of treated mixes. Avoid transferring ***contaminated growing media and soil*** between growing areas by cleaning and disinfecting tools, boots and machinery prior to their use at different locations. Avoid importing infested soil, clean up debris, eg leaves, avoid placing pots on bare soil, destroy infected plants, wash and clean equipment. Transport soil and roots in sealed containers and burn or dispose of in industrial waste collections. See Potting mixes N 64, Soil N 80.

Recycling of growing media: Used potting mix should not be re-used unless treated as above and stored to prevent recontamination.

Media storage: Mixes should not be stored for long periods before use; mixes incorporating slow release fertiliser should be used within 7 days of mixing. Store ***guaranteed pest-free*** media and treated media so that it remains free from contaminants.

***Suitable storage areas should*:**

- Be constructed for ease of regular cleaning, washing and disinfection between loads
- Be a concrete structure with a concrete floor and covered to prevent contamination. Metal or plastic bins, etc, may also be used. Use permeable covers as plastic covers prevent escape of gases from the mix and may contribute to excessive buildup of heat
- Separate from used media/containers
- Away from soil contamination
- Well drained and free from contamination by drainage water. The storage area should be raised or positioned to prevent drainage water from entering and contaminating media

Sterilising tools and equipment: Clean and disinfect regularly, eg by dipping in 70% methylated spirits or soaking in 2,500 - 5,000 ppm chlorine.

Sterilising footwear: Provide disinfectant footbaths at the entrance to all clean areas.

Signposting clean areas: Clean areas should be labelled and hygiene requirements displayed.

5. WATER

Irrigation water is a potential source of disease organisms. The ***plants*** being grown and the ***source of the water*** determine whether treatment is necessary. ***Mains supply and bore water*** (taken from below 3m) are usually free of disease organisms. ***Ground water*** from dams, creeks, soaks, streams, lakes or ***recycled waste water*** including nursery run-off (Mathias 1995b) must be treated to remove or destroy organisms such as *Phytophthora* and *Pythium*. Any techniques employed must be regularly ***tested*** for their effectiveness.

Treatments for contaminated water include: ***Chlorination*** (minimum of 2 ppm residual chlorine) and/or ***filtration*** to 5 microns (a pre-filter in the system may be an advantage). ***Ultraviolet light*** is also used to treat water. ***Slow sand filters*** are used overseas (Barth 1996) for treating recycled water. Where hoses are used for irrigation, nozzles should be kept off the floor at all times. ***Store*** treated water correctly to prevent recontamination.

Waste water may be ***contaminated*** with a wide range of soilborne and waterborne plant disease organisms and contain fertilisers and pesticides as well.

Irrigation patterns and wetting patterns achieved, should ensure consistent growth of plants and efficient use of water.

Water testing is included in accreditation assessment of an nursery. Iron precipitation, acidification and alkalisation of water is sometimes necessary.

See Water N 90.

6. LIGHT, TEMPERATURE AND WIND

Provide correct ***cultural conditions*** (light, temperature and moisture) to ensure optimum and continuous growth. Provide shelter from wind, temperature extremes (sun, frost) and humidity.

7. NUTRIENTS

Nutritional programs should be appropriate for the purpose (quantity, rate etc) to ensure continued growth and development beyond sale. ***Mycorrhizae*** should be added as recommended (Galea and Poli 1992, Handreck and Black 1994). See Trees K 18.

8. PROPAGATION MATERIAL

Plant quarantine: All plant material brought into the nursery should be isolated from healthy stock for at least 3 weeks and treated with suitable pesticides. Plants brought in from other nurseries either as rooted cuttings or stock plants may be a threat to a nursery's own stock. Even though they look healthy at purchase or reception, they may still be carrying disease.

Resistant varieties: Where practical, select cultivars with some resistance to major diseases and pests.

Parent stock plants must be ***true-to-type*** and have desirable ***horticultural qualities***. Some are certified to be of a certain quality. Repeated propagation from parent stock plants may deplete ***essential nutrients***. They are often only fertilised with NPK but may also need calcium, boron and other nutrients which are essential for root development in cuttings. The stock plant itself may not have dieback but the next generation of plants may suffer calcium or other deficiencies. There is thus potential for dieback even when calcium has been supplied in the potting mix. ***Nitrogen rich parent plants*** may inhibit rooting in cuttings taken from them. Plants continually raided for cuttings should be analysed (usually leaf analysis) once per year. The ***viability of seeds*** may diminish rapidly. Some ***plant provenances*** (place of origin of seed) may have superior resistance to diseases and pests. See Eucalypt K 65, Seedlings N 70, Trees K 19.

Disease-tested planting material: ***Parent plants may be a source of disease***. If ***certified pathogen-tested stocks*** are available they should be used. ***Certified seed and nursery stocks*** guaranteed true-to-type and free from specified pathogens are available for some plant species. If certified material is not available carefully select propagating material (seed, spores, corms, bulbs, rhizomes, cuttings) from disease/pest-free stock maintained in a healthy condition. Parent stock plants may be grown in containers where they can be kept protected by regular spraying for disease and pests and replaced on a regular basis to ensure that soilborne problems do not develop. It is difficult and sometimes impossible to maintain plants in the open ground in a completely clean condition. ***In WA***, 'Cuttings should only be taken from ***healthy plants***. Cuttings of susceptible host plants must not be taken from plants in areas where *Phytophthora cinnamomi* or other *Phytophthora* species are known to occur or are suspected of occurring. Cuttings should be taken, wherever possible, from at least one metre above ground level to minimise risk of splashed and dustborne disease organisms including *Phytophthora* spp.' (NIA of WA, 1990). Plant material which is free from disease on purchase can become contaminated if it is ***left on ground*** which people, vehicles or animals use. See Seeds N 74.

Treatment of propagation material: To take ***cuttings*** and other propagation material use clean disinfected secateurs, eg bacterial canker of stone fruit, is spread on secateurs. Cuttings may be treated with either a fungicide or sodium hypochlorite though for some plants, damage may occur. ***Seed*** may be treated with hot water or chemicals to eradicate internal and external diseases. Seeds are often treated prior to purchase with fungicides and insecticides to protect them against damping off diseases and soil insect pests after planting out (Kerruish 1990).

9. PESTS, DISEASES AND WEEDS

Pest status

Plants in the nursery must be maintained free from diseases, pests and weeds until sold to growers, retail garden centres or for export. Depending on the plants grown, different nurseries may be troubled with different pests and diseases. General pests and diseases are described by Mathias (1995a). Make a list of ***present*** and ***potential*** diseases, pests and weeds within your nursery and train staff to recognise them. ***Tomato spotted wilt (TSWV)*** may become an important greenhouse disease after the introduction of an important vector, western flower thrips (*Frankliniella occidentalis*). ***Thrips management*** would become important for virus control in greenhouses.

Bacterial diseases, eg crown gall, leaf spots, soft rots. See Vegetables M 5.

Fungal diseases: ***Soilborne*** diseases include *Phytophthora* (Fig. 425), *Pythium, Sclerotium, Sclerotinia, Fusarium, Rhizoctonia, Chalara*, *Cylindrocladium*. See Vegetables M 7. Downy and powdery mildews, rusts and grey mould (*Botrytis*) are also common.

Nematode diseases, eg ***foliar nematodes*** (*Aphelenchoides* spp.). See Vegetables M 10.

Insect and allied pests especially aphids, ***caterpillars***, eg lightbrown apple moth, corn earworm and native budworm, mealybugs, ***mites***, eg broad mite, twospotted mite, ***scales, thrips***, eg greenhouse thrips, plague thrips and western flower thrips, ***whiteflies***, eg greenhouse whitefly, poinsettia whitefly; ***soilborne insects***, eg black vine weevil (*Otiorhynchus sulcatus*), black fungus gnats or sciarid flies (Sciaridae).

Snails and slugs, eg common garden snail (*Helix aspersa*). See Seedlings N 70.

Non-parasitic problems, eg root bound stock, liverworts and mosses.

Weeds: All areas in the nursery should be as free as practicable of weeds. Propagating areas, standing areas, in-ground growing areas and saleable plants should be free from weeds and weed seeds. Weeds should be controlled when immature and certainly prior to seeding.

Monitoring

A system for ***monitoring*** diseases, pests and weeds must be in place. Their ***diagnosis*** must be confirmed. Decisions must be made regarding the availability and suitability of possible control methods. The results of any treatment must be ***assessed and recorded*** in terms of both its effectiveness and phytotoxicity.

Control

Pest management programs are available for some pests, eg for mealybug, twospotted mite.

Cultural methods: Plants should be free from any physical or nutritional disorder and be of consistent and even quality. Saleable plants should be well presented, correctly labelled and in suitable containers. Plants that have been treated with ***growth regulators*** should be capable of growing to full potential after sale.

Sanitation: Remove and destroy all diseased plants and dead plant material.

Resistant varieties may be the only practical method of control.

Biological control: Many agents are available, eg mealybugs, scales, twospotted mite.

Plant quarantine: As for propagation material; exporting nurseries must conform with Australian Quarantine Inspection Service ***(AQIS)*** guidelines and liaise with ***AQIS*** when for inspections.

Disease-free planting material: As for propagation material.

Physical and mechanical methods: Sticky yellow boards to trap whiteflies and monitor thrips, etc.

Pesticides: Storage, handling and use of pesticides must comply with ***Commonwealth and State/Territory legislation***, eg Agricultural & Veterinary Chemicals Act, State/Territory Pesticide Acts, Occupational Health and Safety Acts, etc.

Prepare a manual of safe procedures for the nursery (Anon. 1994b, Kerruish 1990). Operator(s) must be appropriately ***trained*** in legislation, read the label, pesticide absorption, protective clothing, environment, application, safe storage, handling and use of pesticides, effectiveness of pesticides, and initially be supervised by an experienced operator.

Spray equipment should be in good condition and set up for the intended purpose and appropriate for the size and layout of the nursery (knapsacks may be inefficient if large areas are to be sprayed). Sprayers for herbicides should not be used for insecticides and fungicides as risk of damage is great. There should be an adequate storage of equipment in a separate area.

Personal protective clothing should be appropriate to the hazard of the pesticide used. Showers and change areas must be provided. Protective clothing includes:

- Respirator, air-stream helmet etc.
- Face shield
- Overalls or waterproof clothing
- Rubber boots
- Impervious gloves suitable for spraying

Only registered pesticides are to be used. Some special permits are issued.

Requirements for storage areas include:

- Appropriate Hazchem labelling should be displayed on the pesticide store and throughout the nursery.
- Sufficient pesticide should only be purchased for use within 2 years.
- Containers should have an original undamaged label with purchase date. Material safety data sheets (MSDSs) should be accessible for all pesticides stored.
- Locked, well-ventilated, insulated, fire-resistant storage area.
- Facilities for weighing solid materials and measuring liquids with adequate ventilation preferably by an exhaust fan.

- Isolation from other buildings if substantial stocks are held.
- Protected from moisture and flooding.
- Large storage areas should have door sills (bunding) to retain spills.
- Other items include a fire extinguisher.

Withholding/re-entry: Minimum ventilation and re-entry times after ventilation, should be enforced before handling sprayed plants or working in treated greenhouses. If sprayed plants must be handled within these times then staff should wear the full protective clothing worn during the application. Depending on the pesticide used, it may be necessary for staff handling treated plants or media to wear protective gloves to prevent skin contamination for a longer period (Anon 1994b), ***First aid equipment*** should be available. A material safety data sheet (MSDS) for each chemical stored and used, must be available to staff. ***Disposal:*** Only mix sufficient for the job in hand. Washings from spray equipment may be recycled or disposed of in such a way that it cannot wash into waterways, creeks, etc. Pesticide containers should be recycled where possible, broken or crushed and buried, or taken to the local land-fill (if their regulations allow dumping of pesticide waste). ***Records*** of pesticides used, date of application, plants treated, quantity used, spray equipment, and weather conditions should be kept.

10. WASTES

Wastes include ***irrigation water*** and ***media*** which may be recycled, both need to be treated before re-use. ***Pesticide washings*** may be recycled and used for specified purposes. ***Containers*** may be re-used, the need for cleaning and disinfecting depends on the plants being grown. ***Dead and dying plants*** and cuttings etc. may be a source of infection to other plants, and should be removed and disposed of so that they do not contaminate either the nursery or other areas. Some fungi, eg *Botrytis,* may colonise and grow on dead plant material. Some root rot fungi are ***saprophytic***, ie they just grow on live plants when it suits. Remove dead plant material from areas between batches of plants. The best method is either burning or steaming to kill pathogens. Surplus healthy plants could be disposed of by composting or through normal rubbish disposal channels.

11. PERSONNEL

Disease organisms are readily spread on hands, feet and clothes of staff handling nursery stock, or on tools used. Careless handling by one member of the group can negate all the care taken in the early production phase. Personnel hygiene includes:

- Restricting access to propagation areas, chemical stores, machinery, etc. to authorised staff. Outside staff should be prevented from entering ***'clean areas'***. Staff should not step on disinfected areas.
- ***Provide appropriate*** facilities so that staff can wash hands before commencing propagation operations, after handling diseased or undipped materials and before touching treated materials. Handle healthy material ***before*** diseased material.
- Clean clothing should be worn by authorised nursery staff.
- Wash and disinfect tools or machinery used, especially before handling sterilised materials.
- Train staff on how diseases are spread and what should be done to avoid such problems.

12. NURSERY SURROUNDS

Specially constructed walkways or driveways of concrete or bitumen which are easily be kept clean are desirable. Bare ground walkways allow weed growth, dust (which can be contaminated with disease organisms) and even contamination of the holding areas by workers or the public carelessly stepping on beds. ***Weeds*** should be controlled in all parts of the nursery including fencelines, for they may carry diseases and pests and contaminate the nursery. ***Landscaping*** of the nursery is desirable; apart from assisting in preventing contamination of the nursery it gives the impression of a clean, neat and attractive nursery.

13. RETAIL GARDEN CENTRES

Healthy plants delivered to the selling outlets must be maintained in a healthy condition. The plants should be held in a well-lit, well maintained area and on benches which allow good circulation. Plants should be properly spaced, watered regularly and sprayed as necessary for disease and pest control. If sales are slow, fertiliser applications and even re-potting into larger containers may be necessary. See Garden Centres N 21.

14. RECORDS, MANAGEMENT

Records to be kept include deliveries, sources of media components, plant sources and sales, plant problems, pesticides stored and treatments. Financial business records also need to be kept.

NURSERY ACCREDITATION

National Industry Accreditation Scheme, Australia *(NIASA)*

The aim of ***NIASA*** is to unify the state schemes, promote the industry and improve consumer confidence, act in sympathy with environmental issues, motivate business to constantly upgrade the quality of their goods and services, and reward businesses which comply with the guidelines by recognising their efforts through accreditation (Anon 1994a). Accreditation is available for:

- The nursery industry
- Growing media and growing media ingredient suppliers

Accreditation schemes have to be administered and this will involve fees and other responsibilities. Various procedures will be prescribed, including:

- Parent stock plants
- Structures, tools

- Storage and handling procedures for treated media, transport of treated media
- Disinfestation of media
- Maintenance of beneficial organisms in media
- ***Sample and test*** water, growing media, growing media ingredients, soil and in-ground sites and plants for major plant pathogens (*Phytophthora, Pythium, Fusarium, Chalara, Cylindrocladium, Rhizoctonia, Sclerotinia, Sclerotium, Verticillium,* root knot nematodes, bacterial diseases), either by kit or laboratory testing, direct isolations and/or direct microscope examination, or baiting.
- Site inspections
- Access by vehicles and personnel
- Containers, in-ground production
- Waste management
- Compliance with legislation
- Cultural conditions of plant growth
- Newer systems of plant growing, including hydroponic systems will be assessed using different criteria as the need arises

While ***NIASA*** places a strong emphasis on ***hygiene***, the success of an applicant in gaining accreditation depends on him/her meeting ***a much wider range of criteria***. These include demonstrated competencies in irrigation management, nutritional management, correct disposal of waste water, safe and effective use of pesticides etc. New criteria will be ratified nationally in November and published next year, hopefully by February/March 1997 (Fig. 425).

State/Territory Nursery Accreditation

Various schemes operate/have operated (Bodman and Forsberg 1992). Generally they aim to:

- Improve the quality of nursery stock by setting standards of hygiene in production nurseries by inspection procedures
- Reduce the spread of plant diseases, pests and weeds.
- Assess the operational standards of production nurseries, and to determine their suitability as members of an elite group of accreditation nurseries that can display and advertise their status.
- All states abide by core requirements of NIASA guidelines but have add-ons of specific interest to them.
- Some state schemes are aimed at a particular disease on certain crops, eg *Phytophthora* on native species in WA (Fig. 425).

QUALITY ASSURANCE

The ***Australian Horticulture Quality Certification Scheme*** ***(AHQCS)*** is based on ***Quality Assurance (QA)*** requirements of the Australian/NZ standard (AS/NZS ISO 9002). ***QA*** is mainly based on ***human resources*** and will ***supplement*** existing and proposed nursery accreditation schemes which are mainly based on ***physical resources and inspection systems*** (Anon. 1994a, Lake 1995). ***QA*** includes systematic methods for the control of all processes, using education and training to develop a team of quality-aware and committed staff, improving efficiency and designing new products, services and processes (AHC, 1992b). ***QA*** systems are being prepared for media receival, rose production, seedlings,tulips, chrysanthemums, grafted tomatoes and flowering bedding plants (HRDC, Research Report 1994-95).

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Planning Wholesale Nurseries : A Checklist (Vic Agnote)
Plant Nurseries : Chlorinating Water for Disease Control (Qld Farmnote)
Suppliers of Materials, Fertilisers, Pesticides and Equipment (Vic Agnote)

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Australian Horticultural Corporation (AHC)
Horticultural Research & Development Corporation (HRDC) (Research Reports)
International Plant Propagators Soc. (IPPS)
Nursery Industry Association of Australia (NIAA)
Nursery Industry Trade Register (NIAA, Epping, NSW)
Nursery News (Nursery Assoc. of NSW)
Ornamentals Update
State Nursery Registers, eg Vic, SA, Tas.
The Australian Nurserymen's Fruit Improvement Co. Ltd (ANFIC)

Ornamentals Update for Qld Nurseries

Legislation

Commonwealth Export Control Act
Commonwealth and State Plant Quarantine Acts
State Horticultural Stock and Nurseries Acts which provide for registrations of nurserymen and resellers of certain stock eg fruit crops
State Plant Diseases Acts

State/Territory Accreditation Schemes eg

NA of Victoria Accreditation Scheme
NIA of NSW Nursery Accreditation Scheme (draft)
NIA of WA Nursery Hygiene Accreditation System
NIA of Tasmania (proposed scheme)
NT Nursery Clean Scheme
Nursery and Landscape Industry Assoc of SA (proposed scheme)
Qld NIA Voluntary Accreditation Scheme
Quality Assurance (AS/NZS ISO 9000 - 1994)
SGS International Certification Service

See Preface xii, Australian native plants N 9, Compost N 17, Garden centres N 21, Greenhouses N 28, Interior plantscapes N 47, Mulches N 50, Plant tissue culture N 59, Potting mixes N 65, Seedlings N 71, Seeds N 77, Soil N 82,

Remember, always check for recent references

Check list for excluding *Phytophthora* from nurseries includes:

- ☐ Seed taken from fruit harvested ***directly*** from the plant
- ☐ Potting mix allows ***air*** into 15% of pore space after watering
- ☐ Potting mix ***pasteurised*** with aerated steam
- ☐ Water ***disinfected***, eg chlorination
- ☐ Floors ***sealed*** with concrete
- ☐ ***Wire mesh*** bench tops at least 300 mm above the floor
- ☐ Tools, structures, equipment ***disinfected***
- ☐ ***Restricted entry*** for visitors and stray and pet animals
- ☐ ***Quarantine procedures*** for new purchases, soil deliveries etc
- ☐ ***Disinfectant footbaths***, eg copper, at all entrances
- ☐ Root systems should be examined and the nursery tested for ***disease*** regularly
- ☐ Contingency plans prepared for disinfesting the nursery when a ***disease outbreak*** occurs
- ☐ ***Staff trained*** in nursery hygiene procedures
- ☐ Keeping up to date with current ***nursery hygiene*** procedures and recommendations
- ☐ Special procedures for your ***particular type of nursery***
- ☐ Nursery ***accredited*** and ***quality assurance certified***

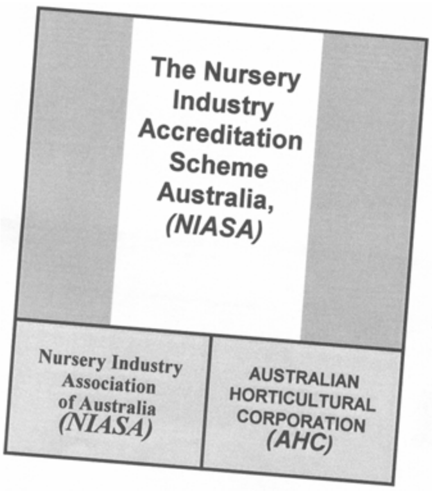

Fig. 425. ***Left :*** Checklist for excluding *Phytophthora* from nurseries. ***Right :*** Nursery Industry Accreditation Scheme, Australia *(NIASA)*.

Plant tissue culture

Plant tissue culture generally refers to the culture of all types of plant cells, tissues and organs under sterile conditions. The following information is based on data from Drew et al. (1991).

TYPES OF TISSUE CULTURE TECHNIQUES

Tissue culture techniques include ***meristem culture***, ie the removal of the terminal meristem and its subsequent culture on a defined medium, ***micropropagation***, ie the multiplication of desirable plants from various tissues (explants) such as buds, stem sections and leaves and ***embryo culture***, ie the removal of the embryo from the seed and growing it in culture until it can be transferred to the soil and grown naturally.

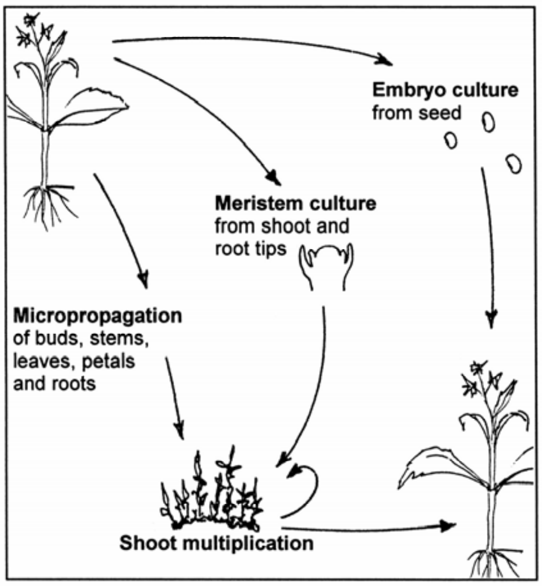

Fig. 426. Types of tissue culture techniques.

WHAT ARE TISSUE CULTURES USED FOR?

Elimination of diseases

(Meristem culture)

Many diseases (and occasionally pests) are carried ***in, on, or in association with***, vegetative propagation material (bulbs, corms, cuttings, budwood, rootstocks, scions). Diseases carried from one generation to the next by vegetative propagation may be eliminated by meristem culture and this is now used routinely in quarantine stations and nurseries. However, there is no guarantee that a plant is disease-free just because it has been meristem cultured. ***Techniques have been developed which test tissue culture materials*** for the presence of virus, bacterial and fungal diseases, eg ***sugar*** may be added to media to promote the growth of fungi; ***antibiotics*** may be added to media to prevent contamination. Meristem culture consists of removing the terminal meristematic region then culturing it on a defined growth medium. Meristems are disease-free, contaminants either do not easily invade or do not rapidly multiply in the younger meristematic tissue. Large numbers of disease-free plants may therefore be produced from meristematic explants.

Maintenance of parent stock

(In a disease-free condition for future multiplication or other purposes)

Parent stock must be ***tested*** by a plant pathologist to ensure its disease-freedom. Tissue culture is ***efficient and economic*** in these situations. In addition, many species can be maintained at low temperatures (4-5^{o}C) and only subcultured once or twice a year. Using ***conventional methods*** (plants in containers, etc) and maintaining stock in separate areas, to prevent the movement of disease-carrying insects is often difficult.

To store disease-free stock

(Micropropagation)

The space required for storage is small compared to that required for conventional stock. Micropropagation provides a means of ***cheaply storing disease-free stock***.

Plant quarantine

(Meristem culture)

Plant quarantine considers that ***plant tissue culture*** is an ideal way of importing (and exporting) cultivars. Large numbers of plants can be transported in small, light-weight containers and as plants are ***free of soil***, quarantine problems are minimised. However, because plants derived from tissue culture are not guaranteed free from diseases, the disease status of the plants from which the tissue cultures were derived must be known. ***Guidelines*** have been produced; although there is no restriction on numbers and no requirement for plant growth in quarantine, an import permit is still required and cultures are inspected in quarantine for the presence of any contamination. Cultures are ***tested*** for freedom from pathogens, and for the presence of antibiotic agents which might suppress pathogens. It is considered that ***anther smut*** (*Ustilago violacea*) of carnation may have been introduced on tissue cultured carnations.

Development of resistant varieties ***(Embryo culture)***

Embryo culture consists of removing the embryo from the seed and growing it in culture until it can be transferred to the soil and grown to maturity. It is mostly used to 'rescue' embryos during attempts at ***crossing distantly related plants***. The main reason for attempting these crosses is to transfer desired traits such as disease resistance from distantly related species, to existing cultivars. Another application has been to ***break dormancy*** in seeds, eg in iris, embryo culture breaks dormancy and ***shortens the breeding cycle*** by months, even years.

Integration of new varieties into pathogen-tested schemes

(Meristem culture followed by micropropagation)

By the use of selected clones this technique has resulted in a ***more rapid introduction*** of new varieties, improved yields and earlier cropping. These clones can been integrated into pathogen-tested schemes; resultant plants are ***free of diseases*** as well as being ***improved varieties***. ***Genetically-engineered cultivars*** may also be integrated into these schemes.

Rapid mass multiplication

(Micropropagation)

The aim is to multiply ***desirable strains*** of plants from various tissues (explants), eg buds, stem sections and leaves ***(this is called cloning)***. It is used for rapid clonal multiplication of rare, valuable or difficult to propagate species, or continuous production of planting material in commercial nurseries. Once disease-free plants have been produced by meristem culture they can be multiplied rapidly by micropropagation.

Save endangered species

Examples include the rare and endangered plant, *Olearia microdisca*, which has been vitro cultured as a means of rapid propagation to support a replanting program to boost the remnant population (Taji and Williams 1991, 1996).

DISEASES AND PESTS ASSOCIATED WITH TISSUE CULTURE

There are 2 main types of diseases and pests associated with tissue culture (Table 10). The 1st is ***the natural viral, bacterial and fungal diseases and insect and mite pests*** of the plant which are to be eliminated, eg the various virus diseases and other problems affecting ***carnation***. Insecticides will usually easily eliminate insect and mite pests. The 2nd type is ***tissue culture diseases*** which include ***external contaminants*** which are the greatest problem faced by commercial tissue culture laboratories. Many species are easily infected by bacteria, even in very clean environments. These problems result from contaminated air, media, tools, hands etc. Dodd et al. (1992) indicated that ***internal bacteria*** which do not cause disease in the field can cause diseases of plants in tissue culture.

Additional parasitic damping off diseases may occur. See Seedlings N 67. There may be problems associated with the ***culture***, eg temperature, etc. ***Genetic off-types*** occur more frequently with some species than with others, eg bromeliads, bananas. High production of off-types can delay acceptance of a species. Consider possible off-type production with the species chosen and how it can be minimised.

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State/Territory Departments of Agriculture/Primary Industry eg

Books about Tissue Culture (Vic Agnote)
Fundamentals of Plant Propagation by Tissue Culture (Vic Agnote)
Importing Ornamental Plants as Tissue Culture (Vic Agnote)
Plant Tissue Culture and Quarantine (AQIS, DPIE)
Tissue Culture Techniques and Procedures (Vic Agnote)

Associations, Journals etc.

Centre for Biological Management (Qld University of Technology)
GrowSearch (database Qld DPI)

Businesses eg

Biotech Plants
Calgene Pacific

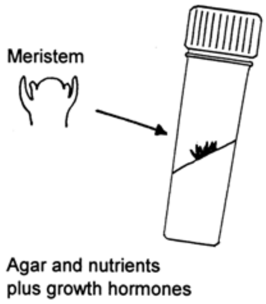
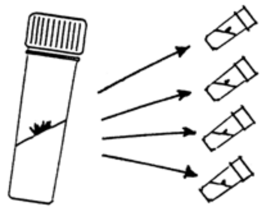
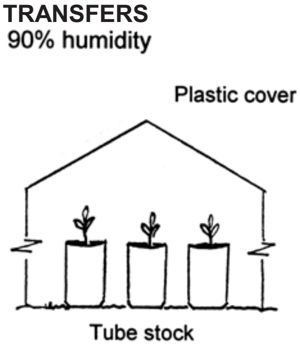
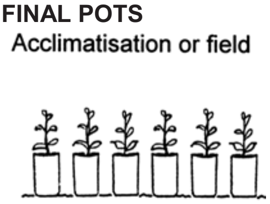
See Preface xii, Seedlings N 71

Remember, always check for recent references

MANAGEMENT

Commercially propagated species in Australia include ***Australian plants***, eg boronia, eriostemon, ***fruit***, eg banana, fig, pineapple, ***ornamentals***, eg African violet, bromeliads, carnivorous plants, ferns, gerbera, orchids. A brief outline of micropropagation in nurseries is presented by Coombs (1995). ***Obtain sound reference material and advice on procedures:*** Access recognised publications on tissue culture (Drew et al. 1991, Taji et al. 1993, Taji and Williams 1996), and visit/work in tissue culture laboratories to obtain first hand knowledge. ***Initially specialise and practice:*** The best results are usually achieved by nurseries which specialise in 1-2 species (Drew et al. 1991). The same tissue culture methods is not be suitable for all species. ***Staff training:*** Staff must be trained, skilled and reliable. Contamination may not show for 2 or more weeks and mistakes in media preparation can be disastrous. ***Sanitation:*** Comply with all recommended disinfection and management procedures. ***Pesticides:*** Disinfectants, antibiotics, plant growth regulators, fungicides and other pesticides and chemicals are used in plant tissue culture. ***Legislative requirements*** and ***recommended safety procedures must be adhered to***. ***Instruct customers*** on potting up procedures. Transfers often die as some nursery personnel do not know how to handle them.

Table 10. Disease and pest problems associated with tissue culture techniques. An example of a tissue culture system.

Process	Natural Diseases of the Plant	External Contaminants
1. ELIMINATION OF NATURAL DISEASES AND CONTAMINANTS BY MERISTEM CULTURE 	**NATURAL DISEASES** (systemic virus, bacterial and fungal diseases) **Parasitic diseases** It may be necessary to check that growth out from meristems are natural systemic diseases rather than contaminants. If ***bacterial and fungal*** diseases are a problem, nutrients may be added to encourage growth of any systemic bacteria and fungi that may be present. Antibiotics which suppress such growth should not be added (except to media). If ***virus*** diseases are a problem then meristem cultures must be tested for virus-freedom. **MAINTENANCE OF MERISTEM CULTURES** in a disease-free state. Once free of natural diseases, tissue cultured plants can be produced continuously.	**EXTERNAL CONTAMINANTS** (bacteria and fungi) originate from: ***Air*** ***Media*** ***Poor surface sterilisation*** of plant tissue or equipment. ***Hands***, hair, shoes, clothing of operator. ***Dust mites*** which may invade cultures and spread bacteria and fungal contaminants. ***Plant material*** which has not been properly disinfested. ***Other sources*** occasionally, eg endogenous organisms in internal cells and organs of plants; cleaning agents, eg soap, dilute methylated spirits or alcohol. **CULTURAL PROBLEMS**, eg temperature, light, excessive sterilisation. **GENETIC OFF-TYPES**, eg abnormal forms, sports.
2. MULTIPLICATION 	**MICROPROPAGATION** Parent stock should be free from systemic diseases (either naturally free, eg African violets, or eliminated by meristem culture, eg carnations), prior to large scale multiplication. Again nutrients are added but no antibiotics.	As above
3. TRANSFERS 	**DISEASES (AND PESTS)** **Parasitic diseases** Transfers should be free from systemic diseases. However, they are ***very susceptible*** to damping off ***(DO)*** diseases (to which they might normally be resistant) because of the humid environment of the transplants. **Non-parasitic diseases** Natural ones for the type of plant.	**DISEASES** **Parasitic diseases** Damping off diseases (probably additional fungi and bacteria may cause damping off because of the lack of an epidermis on the transplant cells etc.). **Non-parasitic diseases** Cultural problems may occur, eg Drying out Genetic off-types
4. FINAL POTS 	**DISEASES AND PESTS** Plants may become infected with diseases (systemic and other) to which they are naturally susceptible. Whether they become infected or not depends on the method of disease spread etc.	As above

Postharvest

Postharvest diseases of plant produce are those that develop during harvesting, grading, packing and transport to market, and during the various storage and handling operations until it reaches the consumer (Agrios 1988). Nearly all crops have a postharvest component which must be met for the customer to be satisfied. Crops include cut flowers, potted plants, green foliage, bare rooted nursery stock, seedlings, fruit and nuts, vegetables, seeds, stored foodstuffs, stored grain, turfgrasses, lucerne.

PESTS AND DISEASES
Parasitic
- Virus and virus-like diseases
- Bacterial diseases
- Fungal diseases
- Insects and allied pests
- Vertebrate pests

Non-parasitic
- Environment
- Ethylene
- Mechanical injury

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases are not really a postharvest problem. Occasionally ***flowers and foliage of potted plants*** may develop virus symptoms. Some ***imported cut flowers***, eg carnations, may be treated with herbicide, eg glyphosate, so that purchasers cannot propagate from them and introduce virus diseases of carnations into Australia. Some virus diseases are ***seedborne***.

BACTERIAL DISEASES

Bacterial soft rot (*Erwinia* spp.) may be a serious postharvest disease of fruit, nuts and vegetables. See Vegetables M 5.

FUNGAL DISEASES

Fungal diseases are serious postharvest diseases of ***cut flowers, fruit, nuts, vegetables*** and ***grain*** (Agrios 1988). Generally the more succulent the exterior of the product, and the greater the water content of the entire product, the more susceptible it is to injury and infection by fungi (and bacteria).

- Alternaria rot (*Alternaria* spp.)
- Anthracnose (*Colletotrichum* spp.)
- Black mould (*Aspergillus niger*) of onion
- Blue and green moulds (*Penicillium* spp.) (Fig. 427)
- Brown rot (*Sclerotinia* spp.) (Fig. 428)
- Fusarium rot (*Fusarium* spp.)
- Grey mould (*Botrytis cinerea*)
- Mucor rot (*Mucor* spp.)
- Rhizopus soft rot (*Rhizopus stolonifer*)
- Sclerotinia rot (*Sclerotinia sclerotiorum*) (Fig. 429)

See Annuals A 11, Fruit F 5, Vegetables M 6.

INSECTS AND ALLIED PESTS

Presence of insects may contravene export quarantine regulations for cut flowers, foliage, potted plants, stored grain, foodstuffs and seed.

Cut flowers, foliage and potted plants
- Insects on flowers, eg thrips (Thripidae) (Fig. 430)
- Twospotted mite (*Tetranychus urticae*)

Fruit, nuts and vegetables
- Fruit fly maggots (Tephritidae) (Fig. 431)
- Ferment flies (Drosophilidae)
- Scales (Hemiptera) on fruit

Grain, food products and seed
- Seed weevils (Bruchinae)

Turfgrasses
- Argentine stem weevil (*Listronotus bonariensis*)

VERTEBRATE PESTS

Mice and rats eat stored fruit, nuts, vegetables, seed, grain and foodstuffs. See Seeds N 77.

Non-parasitic

Environment: ***Water loss:*** Many harvested products are susceptible to drying out, eg cut flowers, bare rooted nursery stock, potted plants, fruit, vegetables and turf. ***Moisture:*** Postharvest bacterial and fungal diseases are favoured by moist conditions, eg plastic packaging. ***Temperature:*** ***Cooling*** (cool rooms and refrigeration) slows respiration and aging and is widely used to control postharvest diseases of cut flowers, vegetables and fruit. However, cooling may itself cause ***chilling injury***, eg orchid flowers, apple (watercore). ***Flouriness*** in apples is due to too long storage.

Ethylene: Ethylene is a ***naturally occurring odourless gas*** produced by fruits, vegetables and cut flowers to initiate their own ripening or maturing. Many cut flowers and foliage, pot plants and bulbs, fruit and vegetables may be ***injured by ethylene***. Storage areas must be adequately ventilated to prevent ethylene accumulation and should be free of ethylene-producing commodities such as pome and stone fruits. Cut flowers may be treated with ***anti-ethylene compounds***. Some fruits, eg bananas, are ***ripened*** by ethylene.

Mechanical injury: Some potted plants, eg African violet, are brittle and easily damaged during transport. Special packaging is required. Many cut flowers, fruit and vegetables are also easily damaged and require special packaging.

Others: Some cut flowers may be ***phototropic*** (bend towards light) or ***negatively geotropic*** (stems bend away from gravity) and must be specially packaged (Fig. 432). ***Miscellaneous*** live insects, snails and slugs, fungi, etc may contravene quarantine regulations.

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State/Territory Departments of Agriculture/Primary Industry eg
Cooling Cut Flowers & Foliage (WA Farmnote)
Chlorination in Postharvest Horticulture (WA Farmnote)
Cutflower Production in SA (SA Fact Sheet)
Drying Cut Flowers and Foliage
International Postharvest Science Conferences
Native Plants as Cut Flowers (NSW Agfact)
Postharvest Diseases, Injuries & Disorders of Vegetables (NSW Agfact)
Post-harvest Insect Disinfestation Treatments for Cut Flowers and Foliage (WA Farmnote)
Storage Conditions for Fruit & Vegetables (NSW Agfact)
Storage Conditions for Ornamental Crops (WA Farmnote)

Associations, Journals etc.
Good Fruit & Vegetables
GrowSearch (database Qld DPI)

See Annuals A 10, Australian native plants N 9, Fruit F 15, Vegetables M 19, Seeds N 77

Remember, always check for recent references

MANAGEMENT

International standards for fruit and vegetables defines the quality requirements to be supplied fresh to the consumer (OECD cur. edn). Long life flowers, eg carnation, are being genetically engineered (Bates 1996). Postharvest care starts before harvest as many crops grown under certain conditions may deteriorate quickly, not store or transport well or have a short shelf/vase life. Field diseases and pests may carry over into postharvest. ***Postharvest care may involve*** controlling the ***environment*** by minimising water loss and regulating humidity, temperature, light and gravity, providing for ***fruit ripening, flower opening and conditioning***, controlling ***gases***, eg limiting the oxygen supply and elevating levels of carbon dioxide to slow down the metabolic activity of the product and any microorganisms present, various treatments for ***diseases and pests***, eg fungicidal or insecticidal dips, waxes, and ***appropriate packaging***.

Harvest

Cultural methods: ***Harvest*** flowers, fruit and vegetables at the ***correct growth stage*** and by the ***correct method***. ***Maturity standards*** are available for most commodities. Harvest in cool temperatures; erect shades over field harvest trailers, over loading bays, etc. Check temperatures in transport vehicles. ***Water loss*** is minimised by various treatments, eg placing flowers immediately after picking in water, waxing fruit or maintaining a high relative humidity. ***Temperature*** is the most important postharvest factor affecting quality of ornamental crops. Lower produce temperature as quickly and as soon as possible after harvest (pre-cooling). ***Cooling*** cut flowers and foliage decreases respiration, reduces water loss, suppresses ethylene production, reduces sensitivity to ethylene and slows down development of bacteria and fungi.

Sanitation: Remove and destroy crop residues in packing sheds to reduce inoculum. Seeds, fruit and vegetables may need to be cleaned before marketing or storage.

Physical methods: Postharvest heat treatments, eg 5-10 minutes at 50-60^{o}C or shorter, control some disease organisms on the surface or within the few outer cell layers of fruit and vegetables. Such heat treatments of fresh fruit and vegetables can provide good control of the decay but do not yet provide the same protection of quality that postharvest fungicides do. Induced injury to produce and lack of residual protection are serious limitations. The best candidates for heat treatment are fruit and vegetables to be sold soon after harvest rather than stored. With the trend towards less reliance on chemicals, heat treatments warrant greater study.

Pesticides: Produce may need to be treated with fungicides or insecticides to satisfy quarantine regulations. Post-harvest ***insect disinfestation treatments*** are applied to cut flowers, foliage and fruit, for export. There may be special field treatments for diseases and pests which may invade produce postharvest.

Storage/Transport

Atmosphere: ***Ethylene*** is an odourless gas produced by cut flowers, ripening fruit and vegetables which may damage sensitive produce in different ways. Ethylene is used to ***ripen*** green fruit. Some growers treat cut flowers with anti-ethylene agents to reduce the effects of ethylene, eg silver thiosulphate (***STS***), which is environmentally damaging. ***Regulating other atmospheric gases*** extends postharvest quality of horticultural produce; oxygen levels are lowered in ***controlled atmosphere (CA)*** storage; in ***modified atmosphere (MA)*** storage, oxygen levels are also lowered but there is no active control over the atmospheric composition.

Nutrients may be necessary during storage and transport, eg sucrose keeps cut flowers growing.

Environment: Transport accounts for 90% of all postharvest costs. Develop a cold supply chain to reduce transport losses. ***Temperature:*** Most temperate crops can be stored at 0-2°C for long periods without significant loss of quality. Cooling may be in cool rooms, by ice or refrigeration, or by forced draft ventilation. Freezing must be avoided. Some crops are chill-sensitive and may be damaged by low temperatures, eg orchids, avocados, bananas, cucumbers, mangos, pawpaws; pineapples should not be stored at < 13°C. ***Water loss and relative humidity:*** Very short term storage recommendations (a few days) for many flower, foliage, fruit and vegetable crops of temperature origin are > 90% relative humidity at 1-2°C. Optimum storage temperature and relative humidity varies from product to product.

Sanitation: Storage and transport areas, benches, bins, bags and machinery must be cleaned and disinfected between each batch or season. All old produce must be removed and destroyed.

Pesticides: Fungicides and bactericides are used to prevent the development of ***bacterial and fungal postharvest diseases***, eg ***dips*** for fruit and vegetables, ***disinfectants*** in vase water for cut flowers, ***Chlorine*** is used in horticulture to control bacteria and fungi on vegetables and fruit and in cut flower vase solutions, ***insecticides*** sprays for quarantine requirements and ***growth regulators*** may be used in quarantine to prevent growers from propagating them. ***Irradiation*** is likely to be approved for wider use.

Packaging

Packaging is used to maintain ***relative humidity***, to prevent ***injury*** to produce, ***water loss***, ***ethylene buildup*** and ***insect and fungal attack***, and to control the ***atmosphere*** (ethylene, oxygen, carbon dioxide) during storage. ***Modified atmosphere packaging (MAP)*** controls gas exchange through the packaging, eg sealing inside a bag made from plastic that is somewhat permeable to gases. The respiration of the commodity uses up the oxygen in the bag but this is replaced by oxygen passing through the plastic just at a sufficient rate to supply the commodity's needs (Coombs 19950). ***Vacuum packaging (VP)*** withdraws part of the normal headspace, leaving an altered initial atmosphere. ***Some packaging*** has ***holes*** in it to prevent excessive relative humidity, others ***absorb ethylene*** (ethylene scrubbers) or ensure that ***produce is kept upright*** to prevent flower bending.

Shelf life/vase life

Fruit, vegetables and cut flowers will only have a useful shelf/vase life if harvest, storage, transport and packaging procedures have been properly carried out. ***Floral preservatives*** usually contain a ***disinfectant***, ***nutrients*** and an ***acidifier*** (see Annuals A 11). ***Growth regulators*** are occasionally added to extend vase life of cut flowers and stop sprouting in potato. ***Do not display*** produce ***sensitive to ethylene*** with that which ***produces lots of ethylene.*** Shelf and vase life varies depending on the product.

Fig. 427. Blue mould (*Penicillium* sp.) on injured citrus.

Fig. 428. Brown rot (*Sclerotinia fructicola*) on peach. Dept. of Agric., NSW.

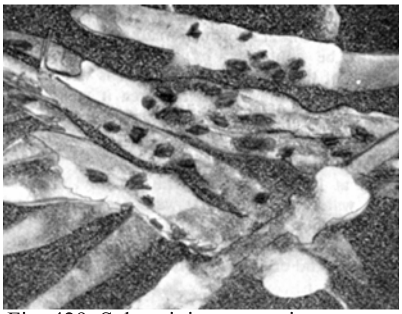

Fig. 429. Sclerotinia rot, nesting (*Sclerotinia sclerotiorum*) on beans. Dept. of Agric., NSW.

Fig. 430. Thrips (Thripididae) in flowers.

Fig. 431. Fruit fly maggots (Tephritidae) in nectarine.

Fig. 432. Negative geotropism on gladiolus flower.

Potting mixes

PESTS AND DISEASES
Parasitic

Soil and manures are not a common component of potting mixes, but if they are used then ***fungal diseases*** (and weeds) may be introduced. Pasteurisation of soil and manure or the final mix is necessary to guarantee freedom from pests and diseases. *Phytophthora* and *Pythium* are most active in rather wet conditions, *Rhizoctonia* and *Sclerotium* prefer a fluctuating soil moisture level. Therefore the most ***unfavourable mix*** for pathogens is an even, medium water content. ***Suppressive mixes:*** A potting mix should have no, or very few, disease-causing microbes, but a high level of beneficial microorganisms capable of suppressing the disease-causing bacteria and fungi by using them for food. Well matured compost is a source of such microorganisms, it is anticipated that these microorganisms will eventually become available commercially. Many ***soilborne insect pests***, eg ***black vine weevil*** (*Otiorhynchus sulcatus*), ***scarab grubs*** (Scarabaeidae), may occur in potting mixes. See Nurseries N 54, Soil N 80.

Non-parasitic

Algae, liverworts, mosses, fungi: ***Algae, liverworts and mosses*** may grow on the surface of overwet and highly nutritious potting mix in containers. See Greenhouses N 27. ***Mycorrhizae fungi*** may need to be added to potting mixes to ensure adequate growth. See Trees K 18. ***Projectile firing fungus*** (*Sphaerobolus stellatus*) produces tiny ***black fruiting bodies*** (2 mm across) which stick to plant surfaces causing minor disfigurement. Fruiting bodies are found on decayed wood, manure, greenhouse supplies, tools, etc. Potting mixes high in ***wood products*** may be invaded by the fungus. Fruiting bodies formed on the surface of potting media are forcibly discharged into the air and adhere strongly to surfaces contacted, eg ***azaleas leaves***. Avoid using wood, sawdust or manure mulches in or around the nursery, ensure wood materials used in potting mixes are thoroughly composted and do not use animal manures in potting mixes unless they have been thoroughly pasteurised or sterilised. ***Wood rot fungi*** may grow on wood or sawdust used in mixes and produce fruiting bodies (mushrooms or toadstools) on the surface of the mix in containers. Once the fungi have ***used up their nutrient source*** in the mix they will cease to grow.

Environment: Potting mixes must consist of the recommended ingredients (AS 3743 Potting mixes) to provide the correct physical conditions for plant growth. A few examples include ***porosity*** which is the space available within a mix for water, air or root growth. Small pores contribute to water retention whereas large pores promote aeration. ***Perlite*** increases aeration. ***Water-holding capacity:*** ***Peat*** has a variable water-holding capacity. ***Sand*** is used to vary the water-holding capacity of the mix, the larger the particle size the less water is held.
Soil, if used in proportions of > 30%, results in mixes which are often heavy and prone to waterlogging. The physical and chemical properties of soil can be variable. ***Vermiculite*** is porous and light and has a water-holding capacity 3-4 times its own weight. ***Drainage*** may be improved by adding polystyrene foam. ***Weight:*** Sand is used to increase weight, while perlite and polystyrene is used to decrease weight in potting mixes. The ***temperature*** of the potting mix can affect the uptake of nutrients and microorganism activity, roots may be killed at high temperatures in black plastic pots. Bottom heat is more efficient and evaporative cooling can reduce mix temperatures in containers.

Legionnaires' Disease (*Legionella longbeachae*) is an infectious bacterial respiratory illness that, in its most severe form, causes pneumonia and can be fatal. It afflicts people of any age, but occurs most frequently among elderly persons who have chronic long term illness and persons with a lower immunity to infection. The bacteria are associated with ***compost and potting mixes*** and appear to be part of the normal flora of composting organic material (Steele 1994). Users can become infected by ***inhaling*** the dust or contaminated air. ***All persons using potting mixes or composts*** (including home-made composts) should wear a recommended dust respirator/mask and wash their hands thoroughly after using these products. ***Avoid dusty working conditions***, moisten the potting mix to avoid breathing in the bacteria. ***Pasteurisation*** of potting media at the end of the manufacturing process kills many problem and beneficial organisms.

Nutrient deficiencies, toxicities: ***Animal manures*** are generally not suitable components of potting mixes as they are variable in mineral analysis. Fresh manure can burn plants. ***Fresh sawdust and pine bark*** in a potting mix can cause nitrogen deficiency in young plants because microorganisms are using the available nitrogen to break down the sawdust or bark ***(nitrogen drawdown)***. Both should be composted before use. ***Appropriate levels of fertiliser*** must be added to potting mixes. Sometimes ***excess nutrients*** are added to the extent that they almost inhibit growth. Identification of such problems is difficult, it may be necessary to undertake plant analyses to see if elements are present in the right quantities and proportions.

pH: Peats vary in pH, the pH of manures can be extremely high (alkaline), especially when the manure is fresh. Analyses of potting mixes nearly always includes a pH test.

Toxins: ***Fresh hardwood sawdust and pine bark*** (*Pinus radiata, P. pinaster*) produce phenols which are often toxic to roots of ***young plants***. Compost before using in potting mixes. Pine bark (*P. radiata, P. elliottii*) can be aged moist instead for at least 4-6 weeks. *P. pinaster* can be aged for 1 week (Handreck and Black 1994). ***Eucalypt wood chips*** (*Eucalyptus diversicolor, E. calophylla*) should be aged or composted before use as they may also contain toxins that stunt the growth of many plants.

WEEDS

Weed seeds and vegetative parts may be introduced in ***soil, sand or manure***. Potting mix ingredients can become contaminated ***after pasteurisation during storage***. All potting mix ingredients must be covered during storage to protect them from weed seed infestation.

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State/Territory Departments of Agriculture/Primary Industry eg
Brown Coal in Potting Mixes (Vic Agnote)
Chemical Sterilisation of Soils and Potting Mixtures (Vic Agnote)
Fertilisers and Chemicals for Nursery Potting Mixes (Vic Agnote)
Hardwood Sawdust in Potting Mixes (Vic Agnote)
Peanut Shells in Potting Mixes (Vic Agnote)
Pine Bark in Potting Mixes (Vic Agnote)
Potting Mixes (WA Farmnote)
Scoria in Potting Mixes (Vic Agnote)
Suppliers of Materials, Fertilisers, Pesticides and Equipment (Vic Agnote)
The Use of Heat to Sterilise Soils and Potting Mixtures (Vic Agnote)
Toxic Pinebark in Potting Mixes (Vic Agnote)

Associations, Journals etc.
Australian Horticulture (Research Features)
Australian Research & Development Corporation (HRDC)
GrowSearch (database Qld DPI)

See Compost N 17, Mulch N 50, Nurseries N 56, Soil N 82, Water N 92

Remember, always check for recent references

MANAGEMENT

Potting mixes should comply with the Australian Standard (AS 3743) and any recommendations for accreditation schemes. Choose a potting mix to suit the plants to be grown. For ***potting mix analysis*** follow instructions for collecting potting mix samples, eg take samples at the correct time, record details and send them off the same day. Most laboratories that offer analytical services for potting mixes use methods prescribed by the Australian Standard for potting mixes (Handreck and Black 1994). Tests for potting mixes include pH, salinity, ammonium and phosphorus toxicity, etc. Tests for air-filled porosity are worthwhile if plants susceptible to soilborne fungal diseases are being grown; good drainage can reduce the effects of these diseases.

Check list for a good potting mix

- ☐ It is well ***drained***
- ☐ It ***re-wets*** easily, some peat and bark media are difficult to re-wet if they dry out
- ☐ It does not ***shrink*** away from the side of the pot as it dries out
- ☐ It is the optimum ***weight***, not too heavy to lift, not so light as to blow away easily
- ☐ It has a ***pH*** between 5 and 6.5 which is satisfactory for most plants
- ☐ It is ***free from pests, diseases and weeds*** or, if not, it can be pasteurised without producing harmful by-products
- ☐ It can be ***stored*** for short periods without significant changes in physical or chemical properties.
- ☐ It is readily ***available*** or easy to prepare
- ☐ It is not ***expensive***
- ☐ It has desirable ***physical properties***, eg wood chips may be suitable for larger pots but too large for bedding plants
- ☐ It does not contain excessive levels of ***salt*** or ***nutrients***, eg peats or manures
- ☐ It does not contain any ***toxic chemicals***, eg copper chrome arsenate or boric acid from timber treatments, phenols from uncomposted pine bark or heavy metals from sewage sludge

Seedlings
Cuttings

Seedlings may be susceptible to the same pests and diseases as their larger counterparts, eg ***brassica*** seedlings may be affected by cabbage aphid, cabbage moth, cabbage white butterfly and snails and slugs. However, there are some ***general diseases, pests and weeds*** that are commonly associated with seedlings of many types of plants.

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

If a plant is susceptible to particular virus and virus-like diseases, infection may be obvious in seedlings or not apparent until plants are much older. Virus and virus-like diseases may be carried in ***vegetative propagation material*** (bulbs, corms, cuttings) or in association with ***seed***. Soil or water spread is not common. They may also be spread by ***insects*** (seedling infections can precede major crop infection) and on ***hands and secateurs*** so that viruses may be spread during harvesting and other activities.

BACTERIAL DISEASES

Some bacterial diseases may only be serious on young stock. ***Crown gall*** (*Agrobacterium* spp.) is only of economic importance on stone fruits < 1 year old. See Stone fruits F 125.

FUNGAL DISEASES

Damping off *(DO)*

Scientific name: Primarily soilborne fungi, eg

Eumycetes (water fungi): *Phytophthora* spp., *Pythium* spp., *Aphanomyces* sp..
Imperfect Fungi (produce conidia): ***Black root rot*** (*Thielaviopsis basicola*, *Chalara* spp.), ***charcoal rot*** (*Macrophomina phaseolina*), ***grey mould*** (*Botrytis* spp.), *Cylindrocladium* spp., *Fusarium* spp., *Helminthosporium* spp.
Imperfect Fungi (sterile fungi): *Rhizoctonia* spp., *Sclerotium* spp.

Bacteria may also be involved, especially in pre-emergence ***DO***.

Host range: Most ***DO*** fungi can infect a wide host range and most can also grow on undecomposed plant debris of all kinds of plants. Some ***DO*** fungi may also cause root, crown and stem diseases of more mature plants. ***Crown canker*** (*Cylindrocladium* sp.) infects rose cuttings and many trees and shrubs, eg *Verticordia*. ***Black root rot*** (*Thielaviopsis basicola*) may attack seedlings and roots of older plants. 2-year old established plants can normally tolerate ***Pythium***.

Symptoms: ***DO*** commonly occurs in patches throughout a planting. Seeds, seedlings, cuttings and young plants die. It may take several forms (Fig. 433). ***Pre-emergence DO*** occurs when seeds are attacked before or soon after germination causing them to rot before emerging (Fig. 433a). Bare areas and poor establishment occur (commonly caused by *Phytophthora*, *Pythium*, *Rhizoctonia*, occasionally by bacteria). ***Post-emergence DO*** occurs after plants have emerged and is first seen as yellowing, wilting and death of young seedlings particularly during hot weather. It may take several forms, eg stem rot, root rot or top ***DO*** (Fig. 433b-f). ***Diagnostic advice kits*** are available for ***some DO fungi*** enabling growers to test for a particular fungus. Otherwise a pathologist is needed to isolate the fungus.

Overwintering: Most species occur universally in soil and can survive for long periods in the absence of host crops. They may overwinter in infected plants, plant debris, water (*Pythium* spp. persist in water, especially stagnant water high in organic matter or in wet soil). *Rhizoctonia solani* lives in the soil and develops rapidly in the presence of undecomposed organic matter invading the soft tissues of young plants and damaged tissues of older plants. Some are seedborne, sometimes as resistant spores or as sclerotia, it depends which fungus is involved.

Spread: By movement of contaminated ***soil*** or ***crop debris***, on machinery, containers, tools or tyres. By movement of infected plants. Zoospores of *Phytophthora* and *Pythium* swim in water and may be spread by ***water***, eg rain, irrigation or drainage water, wash. Spores of some ***DO*** fungi, eg *Botrytis cinerea*, are spread by wind. Sometimes they can be distributed with ***seed***. Fungal threads of *Rhizoctonia* grow on organic matter through the soil. Seeds of some plants can become infected with *Rhizoctonia*. Spores may be washed downhill in surface water.

Conditions favouring: Those ***unfavourable for plant growth***, eg soil temperatures which are too low or too high for rapid germination. For rapid germination of turf seeds soak in water overnight with a small amount of wetting agent. ***Water splash from contaminated soil*** may infect shoots with *Cylindricladium*, causing blighting. ***Lack of crop rotation*** (causing a buildup of ***DO*** microorganisms in soil) may result in strains of ***DO*** developing. Also ***favoured*** by poor quality seed and incorrect sowing methods; seed damaged during harvesting and handling; poor light, soil aeration and air movement; seedbeds sown too thickly; excessive amounts of nitrogen fertilisers; acid soils with a pH of 5.2 or below; soils low in organic matter, ie low populations of microorganisms which might be antagonistic to ***DO*** organisms. Plant in the field at the same depth as grown in the nursery. Green stems are susceptible if rooted cuttings are planted too deeply. Soil-less and hydroponic mixtures are ***unfavourable*** to ***DO***.

Each ***DO*** fungus is favoured by particular conditions of temperature, moisture, etc. ***Phytophthora and Pythium*** are favoured by excessive moisture, wet soils with poor drainage during cool weather. ***Fusarium*** is favoured by warm dry soils and ***Rhizoctonia*** by cool moderately wet soils. ***Grey mould*** (*Botrytis*) by cool, humid conditions. See Vegetables M 7.

Control:

Cultural methods: ***DO*** can be so extensive that resowing is necessary. Sow healthy seed free from mechanical injury, at correct time and depth into moist well drained seedbeds when temperatures are favourable for rapid germination and seedling growth. Provide adequate ventilation and spacing. ***Avoid overwatering*** and watering soon after sowing, poorly drained sites, poor ventilation and overfertilising. Foliage should be kept as dry as possible (this is difficult in misting houses). If ground is too dry, pre-irrigate soil, let it dry for a few days before sowing. Delay spring sowing until the soil temperature is >15^{o}C at a depth of 50 mm. Do not plant into soil containing undecomposed plant trash.

Sanitation: ***Remove and destroy*** affected leaves and badly diseased seedlings and neighbouring plants to prevent further spread of disease and sources of further infection. ***Contaminated soil*** may be on tools, containers, benches, floors, and trolleys. A program of nursery hygiene for propagating areas (bench tops, floors etc) must be in place. Keep hose nozzles used for irrigation off the ground otherwise contamination can occur. Ensure ***strict hygiene*** in propagation areas and that irrigation water is free from disease organisms. Avoid recontaminating treated soil and water. Do not use tools that have been used in untreated soil or let water splash on to treated soil from untreated areas. Vegetation and animal manures must be well decomposed in soil before field plantings are made. See Nurseries N 51.

Biological control: Several bacteria and fungi have consistently provided control of ***DO*** diseases, eg *Pythium* and *Rhizoctonia solani* in the laboratory. They are not yet available commercially. See Greenhouses N 31 (Table 7), Trees K 6.

Resistant varieties: Nearly all seedlings are susceptible to ***DO*** diseases.

Plant quarantine: Isolate infected seedlings. Do not introduce infected plants.

Disease-free planting material: Always plant disease-free seeds and cuttings in disease-free or treated soil. Propagate from tip cuttings that have no contact with soil and which are free from mechanical injury. *Rhizoctonia* may be seedborne, so if it is a problem locally for particularly susceptible plants, eg beans and tomatoes, obtain disease-free seed or treat available seed with hot water, aerated steam or chemicals. Inspect new plants for symptoms before planting, burn any that are infected. Inspect cuttings before storage, discard any not healthy. Similarly discard and destroy any cuttings in the ground which develop the disease.

Physical and mechanical methods: Harvest seed to minimise damage. ***Soil pasteurisation*** is a pre-plant treatment suitable for container-grown plants, eg seedling or cutting trays, but not for field plantings. Standard treatment for propagation media is 60^{o}C for 30 minutes. This kills ***DO*** fungi. ***Hot water and aerated steam seed treatments:*** ***DO*** fungi may occur on or in seed. If this is suspected, advice should be sought regarding the procedures of treating seed as accurate control of temperature is essential. Seeds may be ***shrink-wrapped*** (Intellicoat®) to protect them against fungal attack in cold wet soil. Intellicoat® disintegrates when the weather improves or the soil warms up enough for the seeds to germinate (Sanders 1995). ***Water treatments*** are usually only necessary for ground run-off water, eg from streams, dams or recycling. Treatments include chlorination, filtration, heating, ozone, ultra-violet light. See Water N 90.

Pesticides: ***Identify*** the fungus causing ***DO***. Many seeds are coated with ***protectant fungicides*** (and insecticides) before being marketed to prevent them being attacked by ***DO*** fungi in soil. Some granular fungicides may be mixed with potting mixes. Many nurseries regularly soil drench for ***DO*** diseases either weekly or fortnightly, depending on the plant species. Because the species of fungus causing ***DO*** is often ***not known*** fungicides may be applied alternatively or as mixtures (Table 11). Fungi may develop ***resistance*** to systemic fungicides so it is important not to use the same fungicide continually. Only apply foliage and soil fungicides after affected plants have been removed. Dust healthy cuttings with fungicide before storage and again before planting. See Vegetables M 7.

PARASITIC PLANTS

Seed of ***broomrape*** (*Orobanche* spp.) and ***dodder*** (*Cuscuta* spp.) may contaminate host seed. When the host seed germinates so does the seed of the parasitic plant. Seed may also spread in hay and straw. See Trees K 9.

NEMATODE DISEASES

Nematode diseases, eg ***root knot nematode*** (*Meloidogyne* spp.) which can infest a wide range of plants, commonly attack seedlings. Nematode diseases may be ***spread*** in soil, water, seed and on vegetative propagation material (cuttings, bulbs, corms). See Vegetables M 10.

INSECTS AND ALLIED PESTS

Aphids (Aphididae, Hemiptera) may infest the soft growth of seedlings, some are host specific, eg ***chrysanthemum aphid*** (*Macrosiphoniella sanborni*) while others may attack a range of plants, eg ***green peach aphid*** (*Myzus persicae*). See Roses J 4.

Beetles, weevils (Coleoptera) may feed on newly planted seedlings and cuttings. ***African black beetle*** (*Heteronychus arator*) chew stems of newly planted seedlings in spring or autumn at ground level causing sudden wilting and death. Stems may look ragged. Beetles burrow into tubers making round, rough-edged gouges. The species normally inhabits grassland and considerable damage can be done to crops planted in land formerly under pasture. Beetles can also crawl into crops from adjacent grassland or in swarming flights. ***Susceptible crops*** should not be planted into ground where overwintering beetles are present. Beetle numbers may be reduced by growing legume crops (beans, peas, cowpeas, soybeans), which are not attacked by the beetles, or by a long clean fallow. Insecticides applied at planting in bands (baits, sprays or jetted into soil) along rows may protect seedlings. See Turfgrasses L 7. ***Others: Vegetable weevil*** (*Listrodes difficilis*), ***whitefringed weevil*** (*Graphognathus leucoloma*). See Vegetables M 17.

Caterpillars (Lepidoptera) may infest seedlings, some are host specific, eg ***cabbage white butterfly*** (*Pieris rapae*), while others may attack a wide range of plants, eg ***lightbrown apple moth*** (*Epiphyas postvittana*). See Annuals A 8.

Cutworms, armyworms

Scientific name: Noctuidae, Lepidoptera:
Common armyworm (*Leucania convecta*)
Dayfeeding armyworm (*Spodoptera exempta*)
Northern armyworm (*L. separata*)
Southern armyworm (*Persectania ewingii*)
Lawn armyworm (*S. mauritia*)
Black cutworm (*Agrotis ipsilon*)
Bogong moth, common cutworm (*A. infusa*)
Brown cutworm, pink cutworm (*A. munda*)

Host range: Wide range of plants. They are serious pests of pastures, forage crops, cereals and grasses, garden flowers, fruit (young grapevines), passionfruit, strawberry, most vegetables, cereal crops. Lawn armyworm is an important pest of pastures and lawns.

Description and damage: ***Moths*** are night-flying, mostly stout-bodied up to 40-50 mm across outspread wings and are black to brown, grey or fawn. ***Bogong moths*** may be seen in the semi-darkness hovering over crops or congregating at flowering plants, feeding on nectar. This nectar-feeding, especially by bogong moths on certain species of eucalypts, can at times seriously interfere with the yield of honey to beekeepers. They are attracted to lights, eg are often found indoors and at Parliament House in Canberra. They may shelter in foliage of citrus in bloom and irritate pickers. ***Caterpillars*** (cutworms) are up to 40 mm long, smooth bodied, dark grey to almost black, dark brown, olive green, light green, occasionally with a pinkish tint. They usually are the same colour all over but they occasionally have conspicuous stripes along their body. They are turgid, soft and when disturbed coil up like a watch spring and sham death (Fig. 435). ***Young plants***: Later stage ***armyworms*** when present in enormous numbers move army-like into uninfested crops and pastures consuming all palatable vegetation in their path. ***Cutworms*** feed on stems of newly germinated or young seedlings 'cutting' the stem and so that they fall over and die. Older plants may suffer partial or complete defoliation. Damage occurs in patches. They eat buds, shoots and sometimes green bark of cuttings, eg grapes. Cutworms shelter in the soil near recently damaged plants under clods or in old core holes by day and generally feed on stems of young plants in the late afternoon and at night or during the day in overcast weather. Damage is often attributed to other causes, eg wind or snails.

Pest cycle: Complete metamorphosis (egg, larva, pupa, adult) with several generations each year. Each female moth lays several hundred eggs, usually in clusters on stems and leaves of plants including weeds close to ground level or among leaf litter. When fully fed, caterpillars pupate 30-50 mm below the soil surface. When weeds are removed by cultivation, they feed on other young plants.

Overwintering: As pupae in the soil.

Spread: Moths are strong fliers and may be carried for long distances by wind and initiate infestations far from where they developed as caterpillars. Bogong moths may travel for many miles and shelter in huge numbers in summer in mountainous country, eg the Bogong High Plains.

Conditions favouring: Previous heavy weed growth. Plagues only occur when conditions are favourable for egg hatching, eg flooding or heavy rains followed by warm weather resulting in succulent weed growth. Prolonged cold or dry weather may defer the next hatching for months. Residual weed clumps shelter cutworms which move on to crop plants. Damage may be severe if crop growth following emergence is retarded by cold, wet weather.

Control: Early detection and treatment will prevent extensive damage. They are difficult to control if damage is occurring.

Cultural methods/sanitation: Sow in well-fallowed cultivated land where weeds have been controlled. Incorporate decomposed plant material and weeds to kill any cutworms present and to make the site less attractive for egg laying. Cutworm moths concentrate egg laying around occasional weeds which become a source of infestation. If only a few plants are involved (as in a home garden), collect cutworms at night with the aid of a torch. Back filling core holes help to prevent cutworm damage.

Biological control: Towards the end of a caterpillar plague, natural enemies kill many but not before economic damage has occurred. ***Various fly and wasp parasites, ground beetles*** and some predatory ***bugs*** prey upon them. In humid weather, many caterpillars are infected with a ***virus***, turn black and die; many remain suspended from plants heads downwards. This disease often brings about a rapid end to the infestation. Many ***birds***, eg magpies and crows, feed on cutworms. If birds suddenly fly into paddocks recently cultivated or sown, examine the soil to a depth of about 100 mm for cutworms.

Physical and mechanical methods: In a home garden, cardboard or tin collars may be placed around seedlings as they emerge through the soil or immediately after planting.

Pesticides: Sprays, dusts or baits may be applied before planting (if land is infested) or after planting. Baits should be spread in the early evening so that they are fresh and attractive when cutworms emerge to seek food at night and birds have retired. If cutworms are infesting a crop at the margins and are coming from surrounding weedy ground, strips of crops or weeds may be sprayed or baited heavily. Caterpillars should be treated when small as large caterpillars quickly do a lot of damage. ***Monitor*** emerging and establishing crops in the late afternoon or evening for caterpillars feeding on plants or crawling on the ground, especially after heavy rain or flooding, before applying an insecticide (Brough et al. 1994).

Flies (Diptera): ***Onion maggot*** (*Delia platura*, Anthomyiidae) enters the roots and stems of young seedlings (especially vegetable seedlings) below ground level and feeds inside (Fig. 436). Damaged seedlings may wilt and die. See Onion M 68. ***Seedling bean midge*** (*Smittia aterrima*, Chironomidae) maggots attack seedlings of French beans, other vegetables. See Beans (French) M 28.

Greenhouse whitefly (*Trialeurodes vaporariorum*) may heavily infest seedlings which may die. Occasionally the yield from established plants can be reduced if infestations continue unchecked throughout the growing season. However, whiteflies are often found feeding without causing any obvious damage and so, of course, require no control measures. See Greenhouses N 24.

Seedharvesting ants (*Pheidole*, Formicidae, Hymenoptera) may remove seed from newly sown areas. ***Roots of grasses*** may be damaged by ants working amongst them, this may cause abnormal drying and additional stress. Do not leave plant debris and other litter which is attractive to ants lying around. Lime coating or dusting seed being broadcast is known to minimise attack from ants as well as improve the speed of germination of the seed. If the area is being treated, water soil first. It is desirable to find the nest and destroy it. See Trees K 19, Turfgrasses L 8.

Wireworms, false wireworms

Scientific name: Coleoptera:

Wireworms, click beetles (Elateridae) eg
Potato wireworm (*Hapatesus hirtus*)
False wireworms (Tenebrionidae)
False wireworms (*Celibe* spp., *Gonocephalum* spp., *Isopteron punctatissimus*)
Striate false wireworm (*Pterohelaeus alternatus*)

Host range: Roots, bulbs and crowns of many plants, eg turfgrasses, vegetables. They are especially destructive to germinating seedlings.

Description and damage: ***Wireworms*** are the larvae of ***click beetles*** which vary widely in form, colour and size. Wireworms often have hard, smooth, brownish, round bodies and are 10-40 mm long when fully grown (Fig. 437). Some have soft, semi-flattened, smooth, yellow or white bodies with darker, wedge-shaped heads and forked tooth-edged tails. Legs are grouped near the head. ***Adults*** are about 10 mm long, dull and black. In red soils they become coated with the soil and appear a dull red-brown. ***Damage:*** Larvae chew into germinating seed or underground stems of seedlings and bore narrow holes deep into carrot roots, potato and sweet potato tubers and bulbs. Damage resembles that of ***cutworms***, in that seedlings are chewed but mostly below ground level and die as a result. Beetles will be found on the soil surface and the hard, slender cream larvae near the soil surface around affected plants.

Do not mistake wireworms with larvae of predatory ground beetles (Carabidae), which are slender and semi-flattened with large, dark heads and white or pale yellow, armour-plated bodies, with a prominent pair of spine-like, fleshy processes on the rear of the body. These larvae are beneficial insects which prey on eggs and larvae of soil-dwelling insects.

Pest cycle: Complete metamorphosis (egg, larvae, pupa, adult). Their life cycles can extend over 2 years and generations may overlap. Eggs are laid in the soil and pupae are found near the soil surface around affected plants.

Overwintering: As larvae and adults in the ground.

Spread: By adults flying and crawling. Larvae do not crawl far from plants through the soil.

Conditions favouring: Planting seedlings in land recently under pasture. Large numbers buildup in pasture over time. When pasture is ploughed up and crops sown in old grassland, these larvae turn to the crop for food, especially when germination is slow in cold, wet, low lying, poorly drained soil.

Control: Control is difficult and not often justified.

Cultural methods: Examine soil for larvae before sowing (they are usually in the upper 50 mm but may descend to 300 mm). Prevent infestation by a long fallow, with thorough working of the fallow before planting susceptible crops.

Pesticides: Controlling soilborne insects such as wireworms with insecticides is difficult to achieve. Take several samples to estimate larvae density before planting to decide whether insecticide needs to be applied before planting.

Others: ***Bugs*** (Hemiptera) may infest lush growth of seedlings. ***Leafhoppers*** (Cicadellidae) may cause leaf speckling. ***Mole crickets*** (Gryllotalpidae) may damage germinating seeds and very small plants of vegetables and ornamentals by tunnelling through the upper soil of seed and garden beds. They may also ringbark growing plants, cut the roots just below the soil surface or burrow around plant bases so that the soil and the roots dry out. Occasionally they chew into maturing potato tubers and root crops, eg carrots and turnips. ***Onion thrips***, cotton seedling thrips (*Thrips tabaci*) may attack some seedlings, eg cotton.

SNAILS AND SLUGS

Scientific name: Gastropoda, Mollusca eg
Black-keeled slug (*Milax gagates*)
Brown slug (*Deroceras caruanae*)
Common garden snail (*Helix aspersa*)
Green snail (WA) (*H. aperta*)
Reticulated slug (*D. reticulatum*)
Sand dune snail, white Italian snail (*Theba pisana*)
Vineyard snail, common white snail (*Cernuella virgata*)
White bradybaena snail (*Bradybaena similaris*)
All pest species are introduced.

Host range: Seedlings, cuttings, perennial herbaceous plants, ***ornamentals***, eg begonia, box, violet, ***fruit,*** eg citrus, grapevine, strawberry, ***vegetables***, eg pea, ***field crops***, eg cereals.

Description and damage: Damage is easily identified if pests are present on plants (Fig. 438) or if their shiny slime trails are visible. Snails and slugs mainly ***feed*** at night or during overcast weather. Their excrement is repulsive. Young snails may skeletonise new leaves, older snails eat holes (Fig. 19, Annuals A 3, Fig. 41 Gazania A 33). Tip growth may be destroyed. ***Young flower buds*** and ***flowers*** of daffodils, orchids and strawberries may be eaten, holes gnawed in ***ripe fruit*** may encourage moulds. Green bark of twigs, and stems of celery may be damaged. Damage may be confused with that caused by leafeating caterpillars, weevils and beetles. Up to 4,000 juvenile green snails/m^2 have been counted.

Overwintering: As adults and egg clusters in soil. Snails are inactive, in dry conditions they seal over the shell opening and seal themselves to some object.

Spread: By crawling, hitchhiking on vehicles, by the movement of plants, leafy vegetables, cut flowers, nursery stock, hay, pasture stock.

Conditions favouring: Prolonged wet weather during autumn, winter, spring, low damp sites. Sheltered shady areas. Weedy areas or adjacent weedy areas. Infestation usually starts by invasion from nearby weedy areas. Perennial ground cover.

Control:

Cultural methods: Use trickle irrigation instead of overhead systems to maintain unfavourable conditions and reduce the opportunity for them to breed.

Sanitation: Eliminate weedy areas, rubbish and rock piles where they may shelter and breed.

Biological control: 5-6 Khaki Campbell or Indian runner ***ducks***/ha control snails. ***Birds and rats*** kill many snails. ***Other natural controls*** include ***ground beetles*** (Carabidae), ***snail-killing flies*** (Sciomyzidae, Diptera), overseas ***parasitic protozoa***, ***carabid beetle*** (*Abax paralleepipedus*) (Sunderland 1991). In the UK; a ***nematode*** *Phasmarhabdites hermaphrodita* (Nemaslug®) controls ***reticulated slug*** (*Deroceras reticulatum*), ***garden slug*** (*Arion hortensis*) and ***keeled slug*** (*Milax budapestensis*). Nematodes enter slugs and release bacteria.

Plant quarantine: Some crops, eg cut flower crops in WA, must be inspected and certified free from green snails prior to export to the eastern states. The giant African snail occurs overseas (Com. of Aust. 1996).

Physical and mechanical methods: Remove snails by hand. Potting mixes with fibre and mulches of coarse woodchips and bark are unfavourable for snail movement. Deep barriers (20-30 mm) of wood ash or sand are effective for small plantings.

Pesticides: Monitor snails and slugs as even a few can breed in a crop and soon produce damaging populations (Brough et al. 1994). If necessary, apply snail bait or sprays before planting out seedlings towards evening during wet weather. Place it on the ground, not on the plants. If they are feeding in the foliage of trees baits are not effective, sprays can be applied. Where there are children and domestic pets use sprays or non-chemical control methods. Bordeaux mixture plus white oil repels older snails but kills young snails and slugs on citrus.

VERTEBRATE PESTS

Seedlings must be protected from ***grazing animals***, eg ***rabbits***, and ***birds***, eg blackbirds, sparrows, starlings, Indian mynas. See Fruit F 13.

Non-parasitic

Environment: Seedlings and other propagation materials require appropriate irrigation, soil temperature, light, fertilisers and protection from wind and sunscorch to promote rapid uninterrupted germination and growth. ***Inadequate light*** may cause elongated seedlings (Fig. 439).

Genetic problems: Saving seed from the same crop continually, may result in genetic problems, eg pea seedlings may lack chlorophyll.

Growing media (potting mix) must be free of salts, toxins, disease and pest organisms and weeds. It must have the correct ingredients, nutrients and be of the correct pH. See Potting mixes N 64.

Nutrient deficiencies, toxicities: Seedling mixes may be incorrectly prepared (wrong fertiliser or wrong rates) and deficiencies and toxicities may show up in seedlings. After planting out similar problems may also develop depending on the species.

Viability: Check the viability of seeds, cuttings and other propagation material. Ensure they are collected and stored appropriately.

Others: ***Algae, fungus gnats*** and ***springtails*** may infest seedlings in overwet soil/media. See Greenhouses N 27, N 28, Turfgrasses L 13, L 14.

WEEDS

Contamination of crop seed: If crop seed is contaminated then non-crop seeds may germinate at the same time as crop seed (Fig. 439).

Normal weeds which occur in a crop: ***Pre-plant*** cultural and/or herbicide treatments are essential to ensure weed-free seedbeds, cutting and crop beds. ***Post-plant*** treatments include cultural methods and/or pre-emergence or selective herbicides. ***Potting mixes*** must be weed-free, if necessary pasteurise media. Post-plant cultural methods or pre-emergence herbicides may be needed.

See Annuals A 9, Potting mixes N 65, Soil N 82.

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Cutworm Caterpillars (NSW Agfact)
Production of Kentia Palm Seedlings (NSW Agfact)
Propagation of Ornamental Plants from Stem Cuttings (NSW Agfact)
Seedling Maggots (NSW Agfact)
Seedling Production : Damping Off (Vic Agnote)
Vegetable Seedling Production (Vic Agnote)
Snails : Pests of Crops and Pastures in SA (SA FactSheet)
Snails and Slugs (NSW Agfact)
White Snails : A Pest in SA (SA FactSheet)
Wireworms (NSW Agfact)

See Greenhouses N 28, Nurseries N 56, Plant tissue culture N 59, Seeds N 77, Preface xii

MANAGEMENT

Remember, always check for recent references

Check list for seedlings

- ☐ Variety, colour, hardiness and other ***horticultural requirements*** correct. This may not be apparent until a plant flowers, eg pink flowering cherry instead of white Mt Fiji, and may be due to incorrect labelling of parent stock plants, propagation material or just mixed up nursery stock. See Nurseries N 53.
- ☐ ***Diseases and pests of the particular plants***, eg azalea lace bug and other planting material may be due to ***diseased parent stock plants***. Only use ***certified disease-free*** seed and other planting material, otherwise propagate from apparently disease and pest-free plants and treat with hot water and/or fungicides or insecticides. Many diseases are ***seedborne***, hot water or chemicals treatments may be necessary. ***Aerated steam*** has long been used by quarantine to eradicate seedborne diseases. Steam results in less uptake of water into the seed than standard hot water treatments, minimising the chance of damage which might reduce germination and vigour. Use ***resistant varieties or cultivars*** where practical.
- ☐ ***Damping off (DO):*** Untreated growing media or its components may be ***contaminated***, eg sand may be contaminated with *Pythium*. Treated media may be ***recontaminated***. There may be a lack of nursery hygiene, eg secateurs not sterilised. ***Hygiene*** in all stages of propagation is important (removal of dead plant material, personnel hygiene). Seed may be treated with fungicides and insecticides to protect against ***DO*** and soil insect pests. For ***some very susceptible species***, in addition to frequent inspections, hygiene and seed treatments, regular use of fungicide drenches may be essential to prevent disease problems. ***DO*** fungicides are suppressive only and are not permitted in some nurseries. ***Irrigation*** may be inappropriate, eg overwatering and poor drainage. ***Media*** may be inappropriate, eg may hold too much water, consist of wrong components, be too free draining or of the wrong pH. ***Upper leaves*** may need to be trimmed. Seedlings may be sown too thickly. Seeds may be sown when conditions are not ideal for germination of seed and growth, eg incorrect temperature. The longer seeds (or cuttings, etc.) take to root and grow, the longer they are susceptible to the ***DO*** diseases and insect pests, eg ***seedling maggot*** (*Delia platura*), that attack them. ***Growth regulators*** (rooting powders) used for cuttings when recommended can reduce susceptibility by speeding up rooting.
- ☐ ***Propagation material not viable:*** Some ***seeds*** can be dried and stored for years, others, eg lilly-pilly (*Syzygium* spp.), must be planted as soon as collected. ***Cuttings*** may have dried out, be of the wrong size, age and wood; it may be the wrong time of year; storage and propagation methods may be inappropriate. Cuttings dipped too long in rooting solutions which have alcohol as a solvent, may be damaged.
- ☐ ***Weeds:*** Contaminated media, or media components, eg sand contaminated with weed seeds. Weeds in media not controlled ***prior to planting***. Weed-free or treated media ***recontaminated*** with airborne seeds. Ensure source of propagation material is not contaminated with ***weeds***.
- ☐ ***Others:*** ***Nutritional deficiencies or toxicities*** may develop due to incorrect fertilisers or rates of application. ***Light, temperature*** or other environmental requirements faulty. ***Faulty equipment***, eg sensors may fail, valves may stick, mist jets blocked, faulty switches. ***Air pollution***, eg toxic air from in-house heaters (effluent gases are not directly ducted to outside). ***Phytotoxic disinfectants*** which have not been rinsed off or given enough time to evaporate. ***Phytotoxic pesticides*** used to control diseases and pests especially in greenhouses.
- ☐ ***Postharvest:*** Seedlings and other nursery stock must be disease, pest and weed free, correctly labelled and marketed in good condition during the appropriate planting season.

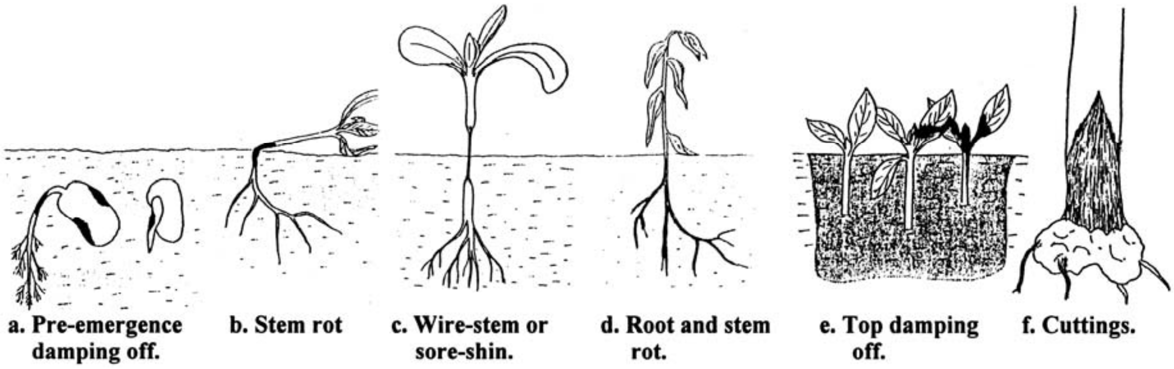

Fig. 433. a. ***Pre-emergence damping off.***

b. ***Stem rot*** near the soil surface causes seedling to fall over. This is the most common form of damping off and is usually caused by *Phytophthora*, *Pythium* and *Rhizoctonia*.

c. ***Wire-stem or sore-shin:*** Some seedlings, such as cabbages, have rather woody stems and the fungus kills the tissues at ground level but the plants remain standing. Commonly caused by *Rhizoctonia*.

d. ***Root and stem rot:*** Rootlets rot and the rot then progresses up into the stem. Usually caused by *Cylindrocladium*, *Phytophthora* and *Pythium*.

e. ***Top damping off:*** Under damp conditions, fungi may spread from leaf to leaf or from stem to stem via the tops of the seedlings which rot down to soil level often leaving the crown and roots uninjured. Depending on the fungus, infection may be airborne or originate from the soil, spreading up the first few plants and then remaining aerial. Often caused by *Botrytis*, *Phytophthora* and *Rhizoctonia.*

f. ***Cuttings*** may rot progressively from the cut end, from the root bases, from wounds made by the removal of buds or leaves, and from dead leaf bases. Dept. of Agric., NSW.

g. ***Damping off*** in a seedling tray. See below.

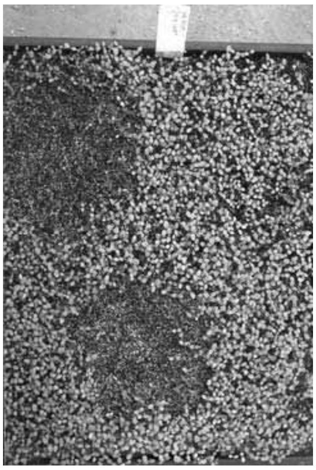

Fig. 433. g. Damping off in a seedling tray.

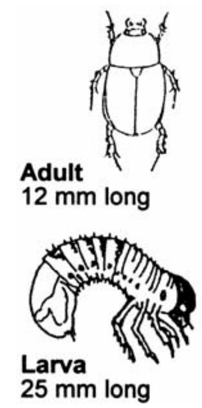

Fig. 434. African black beetle(*Heteronychus arator*) and larva.

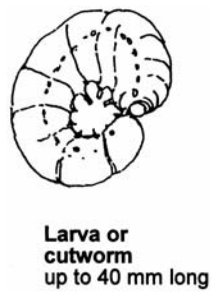

Fig. 435. Cutworm (*Agrotis* sp.).

Fig. 436. Onion maggot (*Delia platura*). Dept. of Agric., NSW.

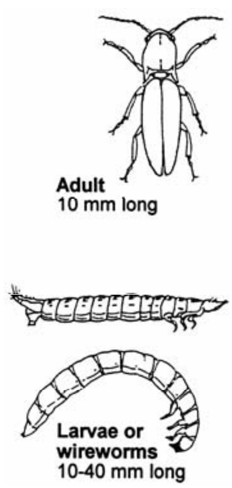

Fig. 437. Wireworms (Elateridae).

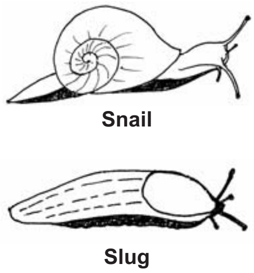

Fig. 438. Snails and slugs.

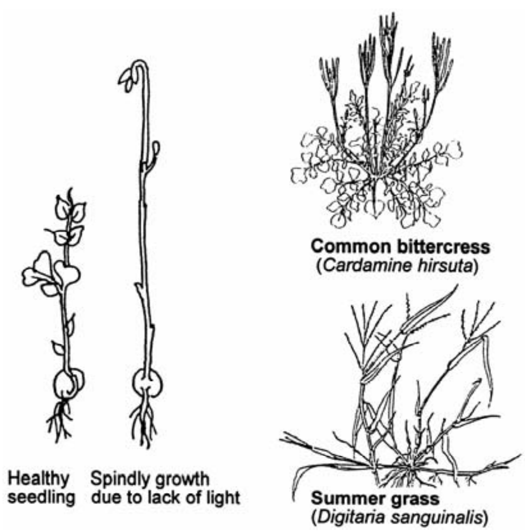

Fig. 439. ***Left :*** Etiolation due to lack of light. ***Right :*** Annuals weeds in seedbeds.

Table 11. A guide to some damping off fungicides.

This table is not a substitute for reading and following instructions on the label of a currently registered product.

TRADE NAME *Activity group*[a] Chemical group	ACTIVE CONSTITUENT	CROPS[b], SITES[b] TREATED Examples only	FUNGI[b] EFFECTIVE AGAINST Main examples only	COMMENTS[b]
Previcur *Group Y - multisite activity* Carbamate	propamocarb	Ornamentals, containers, seedlings, vegetables.	**Water moulds**, eg *Pythium*, *Phytophthora*.	**Systemic**. Persists 6-8 weeks. Preventative treatment.
Fongarid *Group D - phenylamide* Acylalanine	furalaxyl	Seedbeds, soil treatments.	**Water moulds**, eg *Pythium*, *Phytophthora.*	**Systemic**. Persists 2-3 months. Do not use in greenhouses.
Ridomil as for Fongarid	metalaxyl	Fruit, field crops, vegetables.	**Water moulds**, eg *Pythium*, *Phytophthora,* downy mildews	**Systemic**.
Terrazole *Group X - unspecified* Thiadiazole	etridiazole	Ornamentals, potting mix, roots, trees, turf.	**Water moulds**, eg *Pythium*, *Phytophthora.*	Non-systemic. Persistent. Only use outdoors.
Benlate *Group A - benzimadazole* Benzimadazole	benomyl	Ornamentals, fruit, field crops, turf, vegetables.	*Botrytis, Fusarium, Rhizoctonia.* **Not Water moulds.**	**Systemic**.
Ronilan *Group B - dicarboximide* Dicarboximide	vinclozolin	Ornamentals, fruit, turf, vegetables.	*Botrytis, Sclerotinia.* **Not Water moulds.**	**Non-systemic**, local systemic activity.
Rovral as for Ronilan	iprodione	Ornamentals, turf, fruit, vegetables.	*Botrytis, fungal leaf spots.* **Not Water moulds.**	**Non-systemic**, Irritating to eyes.
Terraclor (PCNB) *Group Y - multisite activity* Chlorophenyl	quintozene	Some ornamentals, fruit, turf and vegetables.	*Rhizoctonia, Sclerotium.* **Not Water moulds.**	**Non-systemic**. Often used pre-plant. Persistent. Only use outdoors.
Thiram *Group Y - multisite activity* Dithiocarbamate	thiram	Ornamentals, fruit, vegetables, turf, seedbeds.	**Wide range**, but not as effective against some fungi as other fungicides.	**Non-systemic**. Seedbeds. Seed treatments.
FUMIGANTS **Basamid** Sub D aromatic	dazomet	**Pre-planting**, seedbeds, soil treatments.	**Soil fumigant,** fungi, nematodes, insects, weeds.	**Pre-plant only.** Granular.
Metham **Vapam** Carbamate	metham-sodium	**Pre-planting**, seedbeds, fields, potting mix, turf.	**Soil fumigant,** bacteria, fungi nematodes, insects, weeds.	**Pre-plant only.**
Various	methyl bromide + chloropicrin	**Pre-planting**, soil, compost, manure, commodities, non-crop, space, quarantine.	**Soil fumigant**, bacteria, most fungi, insects, weeds, rodents.	**Pre-plant only.** Chloropicrin is also a warning agent. **METHYL BROMIDE IS BEING PHASED OUT.**

[a] Avcare. 1995. *Fungicide Activity Group List*. Avcare, North Sydney.

[b] ***Read the label*** of a ***currently registered product*** for directions for use, rates, and safety directions. Damping off fungicides may be applied by many methods, including pre-plant treatments, seed treatments and soil drenching. Soil drenches may be applied at spray rates as high as 2L spray per square meter. Make sure that the mix is moist before soil drenching. *Botrytis* causes aerial damping off and spraying is therefore more effective than soil drenching. Although it is necessary for a fungicide to persist for short periods of time to provide effective control, some soil fungicides persist for too long for use in greenhouses.

Seeds

PESTS AND DISEASES
Field diseases, pests and weeds
Seedborne diseases, pests and weeds
Stored seed

FIELD DISEASES, PESTS AND WEEDS

Seed production may be affected by:

Killing the plant prior to seed production. Rabbits and wallabies may eat plants before seed is set. Weeds or drought may kill young plants.

Reducing plant vigour so that quality and quantity of seed produced is impaired. Virus, bacterial and fungal diseases, insects and allied pests, nutrient deficiencies and drought may reduce plant vigour. Heat waves can affect seed ripening and seed drop in species like wattles. In a good seed year quality is better and harvesting easier.

Seed destruction: ***Fungal diseases*** may cause seed to be replaced by spores or spore-producing structures. ***Ergot diseases*** (*Claviceps* spp.) of paspalum, rye and other grasses replace seed with ergots (Fig. 440) which may be poisonous to stock. See Turfgrasses L 7. ***Smut*** of couch, and some ***smut diseases*** of cereals (Fig. 441) replace seed with spores. See Turfgrasses L 7. ***Nematode diseases***, eg ***annual ryegrass toxicity (ARG)***, develops when annual or Wimmera ryegrass (*Lolium rigidum*) is infected with a seed nematode (*Anguina funesta*) and an associated bacteria (*Clavibacter* sp.). Toxic galls formed in place of the seeds can kill animals grazing on infected ryegrass pasture. ***Insects*** may attack maturing seeds, causing serious losses, eg ***lucerne seed wasp*** (*Bruchophagus roddi*). ***Vertebrate pests***, eg mice, may eat sunflower seed on the plant (Fig. 442). ***Non-parasitic:*** Mechanical injury by machinery, dropped seed (nail head in bean) and overmaturity.

SEEDBORNE DISEASES, PESTS AND WEEDS

The term 'seedborne' means that pest or disease organisms or weeds are carried on, in or in association with, the seed. Crops produced from such seed will be infested or diseased.

Diseases

Virus and virus-like diseases: More than 20% of these diseases are seedborne, but often only on particular hosts and not all seed from that plant may carry the virus. Tomato spotted wilt is seedborne only on beans, cucumber mosaic virus only on some hosts.

Bacterial diseases are commonly seedborne, eg bacterial leaf spots of primula and zinnia, bacterial blight of pea.

Fungal diseases which are seedborne include rusts, smuts and fungal leaf spots. ***Grey mould*** (*Botrytis cinerea*) does not infect seed but may be spread with seed contaminated with sclerotia the size of the seed or with bits of plant debris infected with the fungus (Agrios 1988).

Control: ***Seed disinfection*** is the eradication of diseases and pests within the seed by hot water treatments, steam-air (Mebalds, 1995) or the use of systemic chemicals. ***Seed disinfestation*** is the eradication of infestation from the surface of seed. ***Seed protectant fungicides*** applied to the outside of seeds (Kerruish 1990) are sometimes required to serve as seed disinfestants as well as protectants against soil diseases and pests. Many seeds (ornamentals, carrot, bean, pea, sweetcorn, turfgrass) are treated with fungicide to prevent ***damping off (DO)*** diseases and damage by soil insects. Only plant ***certified disease-free seeds.*** Some disease organisms may die out in seeds before the ***viability*** of the seed reaches uneconomically low levels, eg *Septoria* leaf spot.

Insects and allied pests

Flies (Diptera): ***Sorghum midge*** (*Contarinia sorghicola*) is a ***major field pest*** of grain sorghum and also infests sweet sorghum, broom millet, Johnson grass, Sudan grass and native pasture grasses. The midge is a fragile fly, smaller than a mosquito, with a bright orange abdomen. ***Maggots*** feed on and destroy developing grain and pupate in tiny pupal cases attached to the tops of many of the florets.

Moths (Noctuidae, Lepidoptera): ***Corn earworm*** (*Helicoverpa armigera*) may ***seriously damage*** developing seeds of maize, linseed and lucerne in particular. See Sweetcorn M 89. ***Pink bollworm*** (*Pectinophora gossypiella*) is a ***serious pest*** of cotton. Larvae feed preferably on the kernel of the seed and resting stage larvae may be found on seed for up to 2 years if conditions are unfavourable. Infested cotton seed is usually heat treated (65^{o}C for 30 sec.) or fumigated. ***Others: Clover casebearer*** (*Coleophora alcyonipennella,* Coleophoridae) damages seed of white, strawberry and red clovers. Young caterpillars feed inside seed, older caterpillars cause cavities in them. Cased larvae, which are the overwintering forms, and the pupae are about the same size as rye grass seed and they are commonly found in seed harvested from infested pasture. Also ***Macadamia nutborer*** (*Cryptophlebia ombrodelta*, Tortricidae), ***dryandra moth*** (*Carthaea saturnioides*, Carthaeidae).

Seed chalcids or chalcid wasps (Eurytomidae, Hymenoptera) are mostly beneficial insects which are parasitic on many insect pests but a few attack seeds. ***Lucerne seed wasp*** (*Bruchophagus roddi*) destroys seeds of lucerne, some clovers and medics. Eggs are laid in partly developed seeds, ***larvae*** eat the contents of the seed, pupate in the seed, and adult wasps chew their way through the seed coat and the pod, leaving a hole in each. The winter is spent as full grown larvae within the hollowed out seed coats and these infested seeds are the source of infestation for the new season. Control measures are partly based on destroying as many of these larva-bearing seeds as possible, including careful cleaning. ***Parsnip seed wasp*** (*Systole* sp.) has been recorded as emerging from severely damaged parsnip seed. See Parsnip M 71. ***Wattle apple-gall wasp*** (*Trichilogaster acaciaelongifoliae*) causes flower galls on wattle.

Seed weevils, bruchid beetles (Bruchinae, Chrysomelidae) are ***serious pests***; larvae live mostly in the seeds of Fabaceae and Palmae. ***Bean weevil*** (*Acanthoscelides obtectus*), which attacks bean seeds of various types (Fig. 443), and ***cowpea weevils*** (*Callosobruchus* spp.), are both mainly storage pests which may first infest seed in the field. Infested seed usually germinate but resultant plants are poor, less vigorous and lower yielding than those from pest-free seed. ***Pea weevil*** (*Bruchus pisorum*) and ***broadbean weevil*** (*B. rufimanus*) are mainly pests of green crops but many survive in dry seeds for considerable periods. See Bean (broad) M 24, Beans (French) M 31, Pea M 74 ***Prickly acacia seed beetle*** (*Bruchidius sahlbergi*).

Other weevils (Curculionidae, Coleoptera): ***Argentine stem weevil*** (*Listronotus bonariensis*), a pest of turf and pasture grasses, is also found in ryegrass seed. ***Mango seed weevil*** (*Sternochaetus mangiferae*), ***palm seedborer*** (*Coccotrypes dactyliperda*) and ***kurrajong weevil*** (*Axionicus insignis*) burrow into seeds.

Others: ***Seedharvesting ants*** (*Pheidole* spp.) may remove newly planted seed for food from turf areas (see Turfgrasses L 8), also ***seed mite*** (*Tyrophagus longior*), ***seed bugs*** (Lygaeidae).

Snails and slugs (Gastropoda) may contaminate seed, eg ***vineyard snail*** (*Cernuella virgata*), ***sand dune snail*** or ***white Italian snail*** (*Theba pisana*), may damage cereal crops and contaminate grain. See Seedlings N 70.

Weed seeds, other crop seeds and seeds of some ***parasitic plants***, eg ***broomrape*** (*Orobanche*) and ***dodder*** (*Cuscuta*), may contaminate crop seed (Fig. 444). ***Vegetative propagative material*** may also be contaminated with weeds, eg couch stolons may contaminate gladiolus corms.

STORED SEED

Diseases: ***Saprophytic fungi*** (and occasionally bacteria) can grow on seeds and grain during storage, but are usually only a problem if the stored material contains excessive moisture (> 12% relative humidity).

Insects and allied pests

The main problems associated with stored seeds and grain are caused by ***insects***, eg ***beetles*** (Coleoptera), ***moths*** (Lepidoptera) and ***mites*** (Acarina). Despite the importance of field pests, the damage caused by insects and mites to harvested seeds (and grain) in storage is much more serious. Some pests (and diseases) which attack plants in the field can carry over into storage. Various stages of some of these insects may survive in seeds and may require treatment.

Description and damage:

1. Feeding damage

Primary pests attack and destroy sound unbroken seeds (Fig. 445). Except for the lesser grain borer, larvae of primary pests are not capable of a free existence outside the kernel, they live entirely within the kernel where they feed unseen and often unsuspected. The entire larval and pupal stages are passed inside the grain. Seed may be infested in the field. Primary pests cannot be removed by ordinary cleaning machinery and must be controlled by other means. There are 5 major primary pests:

Angoumois grain moth (*Sitrotroga cerealella*)
Granary weevils (*Sitophilus* spp.)
Lesser grain borer, Australian wheat weevil (*Rhyzopertha dominica*, Bostrichidae)
Maize weevil (*S. zeamais*)
Rice weevil (*S. oryzae*) (Fig. 445)

Secondary pests are mostly surface feeders in both adult and larval stages (Fig. 446), eating damaged, moist and out-of-condition grain and stored food products:

Cadelle (*Tenebriodes mauritanicus*)
Confused flour beetle (*Trilobium confusum*)
Driedfruit beetle (*Carpophilus hemipterus*)
Flour beetles (*Trilobium* spp.)
Indian meal moth (*Plodia interpunctella*)
Khapra beetle (*Trogoderma granarium*) (Fig. 446)
Mediterranean flour moth (*Ephestia kuehniella*)
Rust-red flour beetle (*Trilobium castaneum*)
Sawtoothed grain beetle (*Oryzaephilus* spp.
Warehouse beetle (*Trogoderma variabile*)
Warehouse moths (*Ephestia* spp.)

If grain is not damaged by primary pests, it is unlikely that any other insect will damage it appreciably in commercial storage or shipment, except possibly the ***khapra beetle*** (*Trogoderma granarium*). Caterpillars of the ***Indian meal moth*** and ***dried fruit moth*** make large amounts of webbing which may buildup into unsightly films over the surfaces of bagged seed or on top of the seed in bulk store. Some seed-infesting insects chew holes through fabric, film and paper containers. Secondary pests can largely be removed by seed or grain cleaning operations. ***Mites*** (Tyrglyphidae) are common pests of seeds in store especially in ill-ventilated damp, unclean warehouses. ***Flour mite*** (*Acarus siro*) attacks many stored products including grain and seeds.

2. Contamination: Although there is considerable loss from direct feeding, fragments and faeces of insects contaminate foodstuffs.

3. ***Heat and moisture generation*** can lead to further spoilage, seed germination and further insect and fungal infestation. Heat is generated by respiration of grain, fungi and insects.

Overwintering: ***Stored seed:*** Most insect infestation originates after the seed is placed in storage and involve insects which are widely distributed, abundant and feed on a variety of stored products. In addition, many of the insects are strong fliers and can move into storage structures to start infestations if preventative measures are not carried out. ***Used bags*** can also be a source of infestation if they are not cleaned thoroughly or fumigated before refilling. ***Bagged or packaged seeds*** carried over from one season to the next provide an infestation hazard. Adult beetles or moths lay their eggs near or on packages, the tiny newly hatched larvae crawl in through minute openings. The first external evidence of trouble may be when the mature insects cut holes in the package to emerge. By this time extensive damage has occurred. ***Reserve stocks of seeds*** are another source of difficulty. The longer storage period provides time for the development of more generations of insects and possibly a large increase in numbers. Older seeds may also become more susceptible to attack if storage conditions have not been suitable. ***Seeds may become infested in the field*** before harvest, eg maize seed by the rice weevil and the Angoumois grain moth, and legume seed by bruchid beetles. These insects can complete their development and continue to reproduce after seed is put into storage.

Spread: Adult insects may fly, seed may be infested in the field and be transferred to storage during harvesting. Bags and machinery may spread infestations.

Conditions favouring: High temperatures > 15^{o}C especially if relative humidity is > 12% (exact temperatures and humidities vary with the species). Grain heat is indicative of grain deterioration and comes from respiration of grain, fungi and insects.

Control: To ***prevent*** infestation of seed, control must start at the point of harvesting and be continued until the seed is utilised. Minimise damage from field infestation by prompt harvesting and proper handling which may include drying, fumigation or other chemical treatment, or all three. Insect control in warehouses may vary depending on whether the seed is stored in bulk or in bags and according to the type of storage structure. However, the basic principles are the same in all cases. The most important being the ***cleaning*** of seed and storage areas and ***monitoring*** of storage temperatures and grain moisture content. Fumigants and other insecticides may be required.

Sanitation: ***Seed cleaning*** will not remove primary pests which develop ***inside the seeds***, but will remove most or all of the external forms of secondary pests. It is difficult for infestation to get started in clean seed. The more thoroughly seed is cleaned the less hazard there will be of insect infestation, eg a concentration of 0.5% dust/broken grain, etc, may be critical at seed moisture content of 9-10%, while a smaller amount is critical at 12% moisture or higher. In filling bulk bins this material tends to concentrate in dense layers or columns, which, in association with moisture and fungal activity, creates a mass that is hard to fumigate or cool by forced air. ***Clean storage areas*** inside and out before bringing in new seed. Destroy or treat spilled seed, grain or animal feed, bags and stored grain from previous seasons. Do not stack new seed near older seed. Old stocks of these materials that may be infested should be removed or treated. Clean machinery.

Biological control: The presence of parasites and predators indicates pests are present. ***Parasitic wasps*** (*Anisopteromalus* spp.) swarm over seed. Wasps lay eggs in larvae of beetles and moths. ***Pseudoscorpion*** (*Allochernes wideri*) preys on mites, insect eggs and small larvae. A ***predatory bug*** (*Xylocoris* sp.) sucks juices from insect eggs and small insect larvae. ***Hay itch mites*** (Acarina) are external parasites of various insect larvae, eg Angoumois grain moth, grain weevils.

Resistant varieties: Peas resistant to weevils which eat peas in store are being developed. The digestion of starch in the weevils stomach is blocked so that they starve to death.

Plant quarantine: A number of other species occur overseas and could be introduced into Australia, eg ***greater grain borer*** (*Prostephanus truncatus*).

Physical and mechanical methods: ***Moisture content:*** Measuring the moisture content of seeds is most important but not always easily achieved. An average sample of seeds must be obtained to determine moisture content. Because there may be differences of 2-7% between different locations in a large bulk a knowledge of the variation is important in assessing storage risks. Seed that is harvested dry, or dried soon after harvest, and is free from insects may remain sound and in good condition and of high germination capacity for many years. Seeds stored at uniform and high moisture content may not remain so, especially in bulk storage. Moist surface grain may be invaded rapidly and spoiled by storage fungi and may even germinate. Moisture migration is of minor importance in small quantities of seed or bagged seed. The upper limit of moisture content that seeds can tolerate varies with the kind of seed, temperature and duration of storage. ***Moisture requirements of various storage insects differ***, eg grain weevils do not develop in seeds that contain < 8% moisture and do not grow well when the moisture is < 11% unless the temperature is 30-33^{o}C. On the other hand the saw-toothed grain beetle and flour beetle can live on food almost devoid of moisture if the temperature is favourable. The upper limits generally considered safe for long storage under average conditions are 13% for beans, peas and cereal grains including corn; 10% for flax seed. Seed stocks of most of these stocks are stored at lower levels than those indicated. ***Temperature:*** Cool storage of seed is important because of the relationship between temperature and moisture in their effect on the development of insects. The optimum temperature for most seed infesting insects is 27-30^{o}C. Temperatures > 35^{o}C are not favourable, temperatures of 49-52^{o}C are fatal; this is employed sometimes in treating infested seed. Development is retarded at < 21^{o}C. Most of the stored product insects cease feeding and become inactive from 4.4-10^{o}C. Some species and mites will reproduce at 4.4^{o}C and even lower but only if the moisture content of the seed is > 12%. Some large storages have temperature measuring equipment which is valuable in detecting rises in temperature caused by insects. ***Refrigeration is impractical or too expensive*** for protecting most seeds and is only justified for small quantities of valuable seed stock or if the infestation hazard is unusually high. Even in cold storage moisture content must be kept down to avoid damage to germination. Upon removal from cold storage, ***condensation may occur***. Seed with a high moisture content removed from cold storage and subjected to high summer temperatures will deteriorate rapidly. ***Barriers:*** Insect resistant packaging is useful for protecting seed during storage and until it is planted. ***Inert dusts***, eg diatomaceous earth, dehydrate insects but contaminate grain. ***Gamma irradiation:*** The exposure of grain and grain products to an irradiation source has been used successfully overseas for large or continuous supplies of grain. There is no residue from irradiation sources when used for grain, but ***technically competent staff*** must handle such materials.

Pesticides: ***Protectant*** fungicides and insecticides applied to seeds prevent damage by insects and damping off fungi after planting. The fungicides provide little or no protection against storage fungi but insecticides may be effective in preventing infestation during storage before planting. Often ***residual sprays*** are applied after cleaning and before new seed is stored. The application of a protectant as seed goes into storage may be desirable if the storage period is to be more than a few weeks. The periodic application of residual sprays over the surface of stocks of bagged seed may be desirable as a preventative measure. The seed must of course be free from infestation when stacked. ***Space treatments*** may be used against moths but their value is limited. ***Seed that is infested at harvest must be treated*** before, during or immediately after it is placed in storage. ***Fumigation*** is the most effective corrective measure to apply if infestation develops in storage when preventative steps have been lacking or inadequate. ***Methyl bromide*** is being phased out as it accounts for between 5-10% of ozone depletion worldwide. ***Phosphine*** is becoming less effective as resistance builds up in insects. Possible alternative fumigants being tested include ***carbonyl sulphide*** (a common waste product of burning and rotting plant matter and fossil fuels) and ***carbon dioxide***. During storage, insecticides may be applied to seeds as surface dusts, sprays or other treatments to protect against damage. Some major insect pests have developed ***resistance*** to insecticides. ***Pheromone lures*** have been developed for moths and beetles and enable the precise identification of moth and beetle pests and enable ***monitoring*** before and after control treatments (Macquillan 1994).

Vertebrate pests: Mice, rats, possums, etc, may eat seed on the plant or in store. ***Seed in store*** is not only eaten but also contaminated with faeces.

Non-parasitic: The ***containers*** used for storage, ***type of shelving*** and ***storage conditions*** affect the length of time seed should be stored and seed viability. Seed varies in ***genetic quality***, depending on the crop, continued collection of seed from crops for resowing can lead to albinism, poor germination, transfer of disease, etc. ***Pesticide residues*** in seed limit its use. Tolerances have been established for insecticides to permit their use on seed grains and food. Surplus or reserve seed stocks treated with these materials therefore may be diverted for use as animal feed or human food if tolerance level has not been exceeded. Seed treated for planting may not later be used for human or animal consumption and it should not be used for feed, food or oil.

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Control of Stored Food Insects (WA Farmnote)
Control Seed-borne Diseases with a Hot-water Bath (Vic Agnote)
Grain Insect Control : The Clean Pipeline (WA Farmnote)
Grain Silo Failures (NSW Agfact)
Guide to Seed Certification (NSW Agfact)
Indian Meal Moth (NSW Agfact)
Insect Pests of Stored Foodstuffs (NSW Agfact)
Insect Pests of Stored Grain (NSW Agfact)
Insects of Stored Grain (CSIRO poster)
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Loose Smut of Wheat and Barley (NSW Agfact)
Oat Smut (NSW Agfact)
Pasture Seed Certification (Tas Service Sheet)
Pea Weevil (NSW Agfact, SA Fact Sheet))
Practical Seed Storage (NSW Agfact)
Quality Seed : The Basis of all Agriculture (NSW Agfact)
Seeds Acts (Most states/territories)
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Seed Certification No.2. Responsibilities of the Grower and Cleaner (Qld Farmnote)
Seed Cleaning of Mungbean Contaminated with Cowpea (NT Technote)
Some Facts about Seed (NSW Agfact)

Sources of Registered Seed of Field Crops, 1986 (Vic Agnote)
Storage & Sale of Bulk Certified Seed (NSW Agfact)
Seed Sampling (NSW Agfact)
Seed Storage and Particle Board (NT Technote)
The NSW Seeds Act 1982, Explained (NSW Agfact)
The Tasmanian Seeds Act 1985 Explained (Tas Farmnote)
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Associations, Journals etc.
Grains Council of Australia (GCA)
Horticulture Australia
International Seed Testing Assoc. (STA)
Seeds Industry Association of Australia (SIAA)
State Certification Authorities
State/Industry Seed Testing Laboratories
Stored Grain Research Laboratory, CSIRO (Insects of Stored Grain (poster))

See Bean (broad) M 24, Beans (French) M 31, Pea M 75, Seedlings N 71, Preface xii

Remember, always check for recent references

MANAGEMENT

An overview of the seeds industry in Australia is outlined by Coombs (1995). The seeds industry is regulated by both federal and state legislation via various seeds acts.

Field diseases, pests and weeds

Where field diseases, pests and weeds are a problem, examine crop samples for their presence and accurately identify them. Treat where appropriate. Identify common major weeds and their seeds and factors leading to crop seed contamination. Understand sources of weed seed infestation of crops.

Seedborne diseases, pests and weeds

Be aware of legislation, statutory and voluntary schemes relating to weed seeds.

Seed certification in general seeks to produce seeds which are true-to-type, free from declared and prohibited weeds and other seeds and free from prohibited pests and diseases. Hence, seed certification schemes enable the maintenance, production and identification of quality seeds (RIDC 1993). A seed certification scheme is maintained by each state government of Australia and the nature, operations, rules and fees are fully documented in literature from each state department of agriculture. The development of a single industry-based incorporated association (SEEDCERT) to progressively assume responsibility for all seed certification schemes in Australia has been recommended. Alternative schemes have be suggested. ***Seed certification schemes*** include pre-sowing, seedling and spring inspections, seed cleaning, pest control varietal purity tests and administration of the scheme itself.

Resistant varieties: Some types of stored seed are very susceptible to damage in storage. The pea weevil may reduce yield by 30%. ***Gene surgery*** is being researched to transplant genes from the French bean (*Phaseolus vulgaris*) into peas (*Pisum* spp.) to inhibit an enzyme which pea weevils need to digest its food.

Disease-free planting material: Where seedborne diseases are a problem, only plant certified disease, pest and weed-free seed supplied by a registered grower or treat seed as recommended before planting. ***Recognise field pests*** which affect the storage of particular crop seeds and methods of controlling them, eg eelworm wool, insect contamination of harvested seed, pests and their damage to stored seed, seedling pests and their damage. Understand how ***seed treatments*** control seedborne diseases and pests. ***Identify*** common major weeds and their seeds and factors leading to crop seed contamination. French bean seed certification schemes operate which supply seed free from specified weed seeds, diseases and pests. ***Seed disinfection*** is the eradication of pests or diseases from within the seed by hot water or air-steam treatments or by systemic chemicals. Some pathogens may die out in seeds before seed viability reaches uneconomically low level, eg *Septoria* leaf spot. ***Seed disinfestation*** is the eradication of infestation on the surface of seed by chemicals or air-steam treatments. ***Seed protectants***, applied to the outsides of seeds (ornamentals, pea, bean, carrot, grass) to preventing infection and damage to seed by soil microorganisms, are sometimes required to serve as ***seed disinfestants*** as well. Overseas seeds may be shrink-wrapped to protect them from soilborne fungi (Sanders 1995). See Seedlings N 67.

Pesticides: Understand the problems associated with applying insecticides to seeds and the legislation relevant to them. Some seeds, eg sweetcorn seeds, may be treated with fungicide and insecticides to protect them from damping off fungi and soil insects. Do not use such seed for feed, food or oil.

Stored seed

Wherever seed is stored there is a need to prevent or control infestations by insects, especially during warm conditions. Potential pests must be ***identified*** and ***monitored***.

Harvest at the correct time when seed is ripe. In a 'seed year' seed quality is better and harvesting easier. Heat waves can affect ripening and cause seed drop in some species, eg wattles. Seed must be adequately ***labelled***. Examine samples of seeds for presence of pests and diseases. ***Sanitation:*** Harvested seed must be ***cleaned*** prior to storing but this may be difficult. Clean by sieving through wire mesh, winnowing or use an air stream to remove impurities from the seed. Bags, containers, packing and storage areas must be cleaned. Before storing seed check that surface is dry and each seedlot free from insects. ***Insecticide*** dust of a low hazard may be recommended if seeds are to be stored > 1 year. Seal in an air tight nearly full container. For bulk storage, monitor grain moisture content and temperature. Understand the problems associated with the application of fumigants and insecticides to seed, ie seed treated for planting cannot necessarily be diverted for food or feed. For certain types of seed there may be special treatments. ***Plant quarantine risks and precautions:*** All produce of plant origin is carefully controlled through permits and inspections. This, combined with the cooperation of shippers and importers and the public, prevents the accidental importation of pests from overseas or spread of some diseases, pests or weeds within Australia.

Fig. 440. Ergot (*Claviceps* spp.).
Left : Ergot on wheat.
Upper right : Wheat ergots.
Lower right : Tall fescue ergots.
Dept. of Agric. NSW.

Fig. 441. Loose smut of (*Ustilago avenae*). Dept. of Agric. NSW.

Fig. 442. Mice eat sunflower seed. Dept. of Agric. NSW.

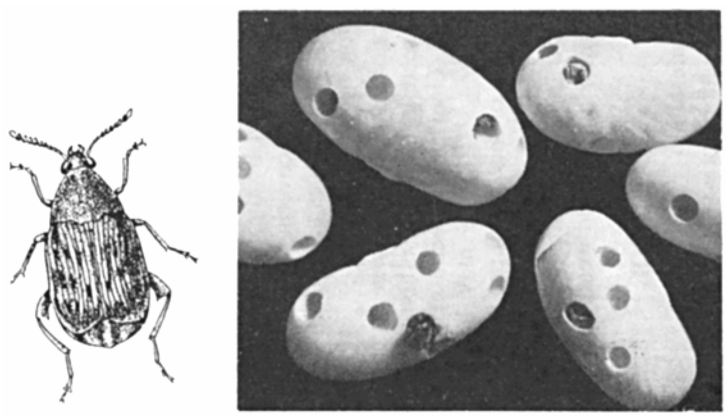

Fig. 443. Bean weevil (*Acanthoscelides obtectus*).
Left : Bean weevil (3-4 mm long).
Right : Exit holes of adult weevil. Dept. of Agric. NSW.

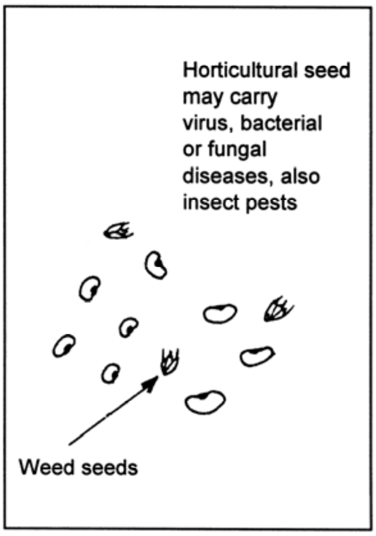

Fig. 444. Weed seed in desired seed.

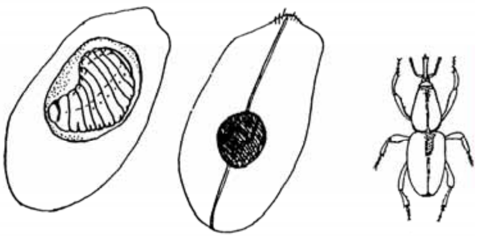

Fig. 445. **STORED SEED - Primary pests,** eg Rice weevil (*Sitophilus oryzae*).
Left : Legless larva (up to 4 mm long) in seed.
Centre : Exit hole of adult weevil.
Right : Adult weevil (about 3 mm long).

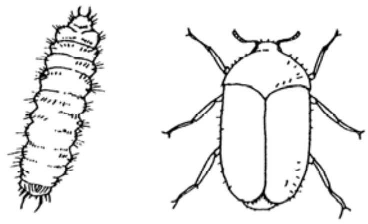

Fig. 446. **STORED SEED - Secondary pests,** eg Khapra beetle (*Trogoderma granarium*).
Left : Larva (up to 5 mm long).
Right : Adult (2-3 mm long).

Soil

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Fungal diseases
Parasitic plants
Nematode diseases
Insects and allied pests
Snails and slugs
Vertebrate pests
Non-parasitic
Beneficial animals and plants
Environment
Pest animals and plants
Pollution
Soil characteristics
WEEDS

PESTS AND DISEASES
Parasitic

Many pests and diseases spend part of their life cycle in the soil. Some of these soil pests and diseases may attack a wide range of plants while others may be host specific and only attack a genus, species or variety. Conservation tillage practices bring many benefits, but their adoption in recent years appears to have increased the incidence of insect damage to summer and winter crop seedlings. Retained stubble provides food and shelter for insect larvae and adults and favours the survival of ants, wireworms, false wireworms and earwigs. Many other factors affect buildup of insect numbers and it is difficult to predict accurately when high pest populations will occur. Whether a particular crop is affected or not depends on what it is **susceptible** to, the **presence** of the disease, pest or weed in sufficient numbers and the **environmental conditions** favourable to the pest, disease or weed (Fig. 447).

Susceptible host plant

∆

Presence of pest, disease or weed   **Favourable environment**

Fig. 447. The disease triangle.

VIRUS AND VIRUS-LIKE DISEASES

It is unusual for virus diseases to be **soilborne.**

Lettuce big vein virus is spread by a soil/water-borne fungus (*Olpidium brassicae*).
Tobacco mosaic virus, which infects orchids, is spread by mechanical inoculation, by grafting, by contact between plants, by seed, by infected crop debris.

BACTERIAL DISEASES

Many bacterial diseases of plants are **soilborne**, eg

Bacterial soft rot (*Pseudomonas carotovora*)
Black rot (of stock) (*Xanthomonas campestris* pv. *incanae*)
Crown gall (*Agrobacterium* spp.) (Fig. 448)

FUNGAL DISEASES

Many fungal diseases of plants are **soilborne**, eg

Armillaria root rot (*Armillaria* spp.)
Damping off (*Pythium* spp., *Phytophthora* spp.)
Fusarium root and crown rots (*Fusarium* spp.)
Grey mould (*Botrytis cinerea*)
Phytophthora diseases (*Phytophthora* spp.)
Rhizoctonia diseases (*Rhizoctonia* spp.)
Sclerotium stem rot (*Sclerotium rolfsii*)
Sclerotinia rots (*Sclerotinia* spp.) (Fig. 449)
Take-all disease (*Gaeumannomyces graminis*)
Wilts (*Fusarium oxysporum, Verticillium dahliae*)

Some herbicides may favour the development of some soil fungal diseases. Some fungal diseases which attack the **foliage**, eg fungal leaf spots or sclerotinia rots, may survive from season to season in crop debris on or in the soil.

PARASITIC PLANTS

Seed from **broomrape** (*Orobanche* spp.), **dodder** (*Cuscuta* spp.) and **devil's twine** (*Cassytha* spp.) may be present in soil. See Trees K 9.

NEMATODE DISEASES

Most nematodes spend some part of their life cycle in the **soil** including:

Cyst forming nematodes (Nematoda)
Dagger nematodes (*Xiphinema* spp.)
Foliar nematodes (*Aphelenchoides* spp.)
Pin nematodes (*Paratylenchus* spp.)
Root knot nematodes (*Meloidogyne* spp.) (Fig. 450)
Root lesion nematodes (*Pratylenchus* spp.)
Stem and bulb nematodes (*Ditylenchus* spp.)
Stunt nematodes (*Tylenchorhynchus* spp.)

See Vegetables M 10.

INSECTS AND ALLIED PESTS

Most insects (representatives of many insect orders) spend **some of their life cycle in the soil**. It is often ***difficult to find*** soil insects, and ***identification of larvae*** can be difficult. Many insects ***pupate*** in the soil even though adults fly and larvae feed on or in plants.

Ants (Formicidae) nest in soil.
Aphids (Aphididae) may feed on roots (Fig. 452).
Beetles (Coleoptera): Larvae (Fig. 451) of ***scarab beetles*** (Scarabaeidae), eg ***African black beetle*** (*Heteronychus arator*), ***white grubs*** (*Rhopaea* spp.) may feed on roots, burrowing up to 1.5 m, ***vegetable***

beetle (*Gonocephalum elderi*). Larvae of many ***weevils***, eg ***Fuller's rose weevil*** (*Asynonychus cervinus*), ***garden weevil*** (*Phlyctinus callosus*), ***spotted vegetable weevil*** (*Desiantha diverpes*) ***vegetable weevil*** (*Listroderes difficilis*) and ***whitefringed weevil*** (*Graphognathus leucoloma*), feed on roots.

Caterpillars (Lepidoptera) may live in the soil, eg ***armyworms and cutworms*** (Noctuidae) (Fig. 451) lay eggs and hide in soil, many insects pupate in the soil, eg ***grapevine moth*** (*Phalaenoides glycinae*), ***oriental fruit moth*** (*Grapholita molesta*).

Crickets, grasshoppers, locusts (Orthoptera) lay eggs in soil (Fig. 451).

Earwigs (Dermaptera) lay eggs in soil.

Fruit flies (Tephritidae) pupate in the soil.

Mealybugs (Pseudococcidae) may feed on roots (Fig. 452).

Sawflies (Hymenoptera), eg ***steelblue sawfly,*** pupates in soil (Fig. 451).

Springtails (Collembola) and ***symphylids*** (Symphyla) live and breed in wet soil (Fig. 452).

Thrips (Thripidae) may pupate in soil (Fig. 451).

Millipedes (Diplopoda), eg ***black Portuguese millipede*** (*Ommatoiulus moreletii*).

Termites (Isoptera) may nest in soil (Fig. 452).

Wireworms (Elateridae) and false wireworms live in soil and feed on roots and runners (Fig. 451).

SNAILS AND SLUGS

Most ***snails and slugs*** lay eggs in ***soil***, eg ***common garden snail*** (*Helix aspersa*). See Seedlings N 70.

VERTEBRATE PESTS

Many vertebrate pests such as ***rabbits*** (Fig. 453) and ***other rodents*** which feed on plants have burrows in ***soil***. ***Wombats***, which are part of the native fauna, live in burrows in the soil.

Non-parasitic

Beneficial animals and plants

Algae are present naturally in soil and only become a problem if conditions are overwet. See Water N 91.

Amoeba in soil may attack and feed on a wide range of soil fungi. Many genera occur in Australian soils and possibly could be useful for controlling soil fungal diseases, eg ***Phytophthora cinnamomi.***

Bacteria, eg ***nitrogen-fixing bacteria*** (*Rhizobium* spp.), are also present in soils (Fig. 454).

Earthworms improve soils by many means, eg turning over soil, increasing the rate of decomposition, availability of nutrients to plants and the amount of water held by soils.

Fungi: Slime moulds and many other fungi in soil assist in the breakdown of organic matter. ***Antagonistic fungi***, eg *Trichoderma* spp., colonise roots of some plants and are antagonistic to certain soilborne diseases (*Armillaria*, *Botrytis*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, *Sclerotium*, *Chondrostereum*, *Penicillium, Phomopsis*). ***Edible fungi*** also occur. ***Mycorrhizae*** are common in soil (Fig. 454). See Trees K 18.

Lichens (symbiotic algae and fungi) assist in breakdown of dead wood and rocks. See Trees K 18.

Nematodes (Nematoda), eg predatory species, feed on fungi and other nematodes. Nematodes breakdown organic matter. See Vegetables M 10.

Insects and allied pests (Arthropoda), eg ***springtails*** (Collembola), are important as soil builders. Fly ***maggots*** breakdown organic matter (Fig. 454).

Protozoa feed on bacteria, fungi, other protozoa and nematodes.

Snails and slugs, eg ***predatory slugs***, feed on pest species.

Environment: Erosion may occur due to lack of soil cover, tree clearing, overgrazing, water, wind. ***Conservation tillage*** (the killing of weeds and old crops by the application of herbicides rather than by cultivation), assists in preventing erosion and has a mulching effect; but the ***remaining debris*** may increase soil pests and diseases ***if they are a problem*** for that crop. See Soil N 80.

Pest animals and plants:

Many insects and allied pests nest or breed in ***soil***, eg ***ants*** (Formicidae), ***flies*** (Diptera), ***fungus gnats*** (Diptera), ***mosquitoes*** (Culicidae), ***spiders*** (Araneida) and ***wasps*** (Hymenoptera).

Bacterial diseases of humans: Legionnaire's disease (*Legionella longbeachea*) is associated with potting mixes and causes respiratory disease mainly in older people. See Potting mix N 64. ***Melioidosis***, Knightcliff gardeners' disease (*Burkholderia pseudomallei*) is found in soil in tropical regions and symptoms range from skin ulcers, abscesses, fevers, etc. It is recommended that waterproof gloves and shoes are worn when prolonged contact with the soil is likely to occur in the wet season. ***Tetanus***, lockjaw (*Tetanus bacilli*) thrives in dust and dirt and gets into the body through breaks in the skin. Children are immunised against infection.

Pollution

Fertilisers in excess may cause salinity problems. Human and animal sewage pollution may cause nitrogen and phosphorus toxicity problems.

Industrial waste may cause pollution with heavy metals.

Pesticides which have ***undue persistence*** may accumulate in soil. Examples include ***persistent fungicides***, eg copper, ***residual herbicides***, eg diuron, and ***persistent insecticides***, eg chlorpyrifos.

Petroleum products, eg diesel fuel, may persist for months in soil.

Soil characteristics

Chemical properties, eg nutrient status. Soils may be ***naturally deficient*** in nutrients and trace elements or may have a ***surplus***. ***Salinity*** may be a problem.

Physical properties, eg colour, pH, temperature, water-holding capacity,wettability. ***Soil temperature*** is more important than air temperature for ***growth of the host***, eg seed germination, and ***disease and pest development***, eg damping off.

Soil analyses are recommended prior to planting a commercial crop (Fig. 455).

WEEDS

Weed seeds, rhizomes and ***root pieces*** are common in soil (Fig. 456), so that a weed management plan for both pre-plant and post-plant control of annual and perennial weeds, grass and broadleaved weeds, must be prepared and implemented. ***It may involve*** cultivation, removal by hand or machinery, mowing, ground covers, mulches, biological control agents, pre-emergence and post-emergence herbicides, selective and non-selective herbicides.

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Earthworms for Gardeners and Fishermen
Food for Plants
Organic Matter and Soil
Potting Mixes and Care of Plants Growing in Them
Soils : An Outline of their Properties and Management
Soil : Australia's Greatest Resource
What's Wrong with My Soil?
When Should I Water?
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NSW Agfacts
Herbicide Behaviour in Soil
Identifying Deficiencies in Crops
Know Your Fertilisers
Liming Problem Acid Soils
Nutritional Deficiencies in Crops
Nutritional Deficiencies in Plants
Soil Acidity and Liming
Soil Salinity and How to Recognise It
Vic Agnotes
How to Take Soil Samples for Analysis
Properties of Soils
Sampling Soils and Plant Materials for Examination of Nematodes
Soil Fumigation
For the New Farmer : Soil and Topography of the Melbourne District
Soil Solarisation : Disease and Weed Control
The Use of Heat to Sterilise Soils and Potting Mixtures
What is Soil?
Chemical Sterilisation of Soils and Potting Mixtures
WA Farmnotes
Chemical Disinfection of Soil
Identifying Soil Insect Pests : Beetles
Soil Moisture Monitoring Equipment
Tensiometers : Preparations and Installation
Qld Farmnotes
Crop Establishment and Soil Insect Pests
Mycorrhizae : Soil Fungi Improve Phosphorus and Zinc Nutrition
CSIRO videos
Borne Again Soil
Continent in Crisis
Down to Earth
Saline Soil
Salinity and Water Penetration in Australian Soils
Soils of Australia
Soil Animals (poster)
The Living Soil
Associations, Journals etc.
Australian Jl. of Soil Research
Australian Soil Conservation Conference Proceedings
Earthworms in Australia. NSW
GrowSearch (database Qld DPI)
Horticultural Stock & Nurseries Act
Soil Testing Laboratories/Businesses
Soils and Their Management

See Compost N 17, Mulch N 50, Nurseries N 56, Potting mix N 65, Turfgrasses L 16

Remember, always check for recent references

MANAGEMENT

Selection

Soil standards have been proposed (Lake 1994). Usually soil for particular situations, eg playing fields, have prescribed specifications.

Soil analysis (Fig. 455) determines ***chemical composition***, eg pH and total soluble salt content, phosphorus and potassium levels, major and minor element analysis and water analysis, ***physical characteristics***, eg particle size distribution, texture, drainage and compaction, profile wettability and ***biological analysis***, eg root system evaluation, germination tests, disease diagnosis, insect and weed identification, presence of beneficial organisms. ***Select*** areas for sampling, the depths of the samples; for subsurface samples, eg for nematodes, sample when soil is damp (moist, not wet); for ***trees*** lift clumps of soil containing feeder roots and place in a moisture proof container. ***Take samples*** at the correct time, label adequately, record details of sample areas and send them off the same day. ***Follow instructions*** on how to collect representative soil samples.

Plant analysis: Follow instructions for collecting plant samples, eg take samples of the correct plant part, eg leaves, at the correct time; record details and send them off the same day.

***Resistant varieties*:** If contaminated soil is to be planted, preferably select species with some resistance to any pests and diseases present in the soil, eg *Fusarium*-resistant carnations or tomatoes. Some plant species may also be resistant to drought.

Plant quarantine: Soil is full of potential pests, diseases and weeds and is therefore a ***prohibited import*** into Australia and between ***designated regions*** within Australia. Quarantine legislation regulates the movement of soil. ***Soil deliveries*** or soil on equipment or in pots, may introduce soilborne problems to areas where they do not occur.

Disease-free planting material: To avoid introducing diseases and pests to healthy areas, it is essential to only plant disease-free planting material (cuttings, nursery stock, seed). Plant into disease, pest and weed-free soil or media, or treat soil or media prior to planting. Use weed-free mixes, soil-less mixes. ***Seed or plant treatments:*** Seed may be treated with fungicides and insecticides to protect it against damping off fungi and soil insect pests. See Nurseries N 53.

Establishment and maintenance

When dealing with small amounts of soil, eg for seedbed, potting mixes, turf areas it is possible to control soilborne pests, diseases and weeds but once a field area is contaminated with certain organisms it is almost impossible to eradicate them, eg bush blocks infected with *Phytophthora*.

Cultural methods*:** Susceptible plants only become damaged if the ***soil environment is favourable to pest development (Fig. 447). ***Pest and disease numbers can be reduced*** by practicing crop rotation (the pest or disease must only have narrow host range for this to be successful). ***Trap plants*** (*Tagetes* spp.) may be grown for one season to reduce root knot nematodes (*Meloidogyne* spp.) sufficiently for susceptible crops to be grown the following season. Provide a root environment which is ***favourable for the host***, eg optimum growing conditions (good drainage, correct pH, nutrients, phosphorus improves resistance to disease) but ***unfavourable for the pest or disease***. ***Soil conditioners*** improve the physical, chemical and biological properties of soil. ***Wetting agents*** added to soil may damage some plants.

Sanitation*:** Practice ***nursery hygiene, eg clean soil from tools and equipment, destroy contaminated crop debris by deep burying, etc, to ***reduce pest numbers and inoculum***. See Nurseries N 51, N 55.

Biological control of soilborne pests and diseases is difficult. A ***bacteria*** (Nogall®) will control crown gall. Roots of *Prunus* nursery stock may be dipped in Nogall® prior to planting. Suppressive mixes and soils have been identified (soils high in organic matter). A ***nematode*** (Otinem®) will control the black vine weevil. ***Mycorrhizae soil fungi*** improve uptake of phosphorus and other nutrients. When soil is moist, it is a favourable medium for the application of biological control agents, eg bacteria and fungi, to control soil diseases, eg *Phytophthora* and pests, eg scarab grubs. Hopefully, these may become available commercially in the near future.

Physical and mechanical methods/Pesticides: ***Pre-plant soil treatments*** include soil pasteurisation, solarisation, fumigation, pesticide applications (fungicide, nematicides, insecticide baits) which are suitable only for small areas. ***Post-plant treatments*** include pesticide applications. ***Soil fungicides*** are often only ***suppressive***, so their use may not be permitted in nurseries where certain diseases exist, eg *Phytophthora,* as it will be spread to new areas when pots are sold.

Storage

Treated soil (or media) for later use in potting mixes or seed beds must be stored in such a way that it cannot become ***re-contaminated*** with pests, diseases and weeds.

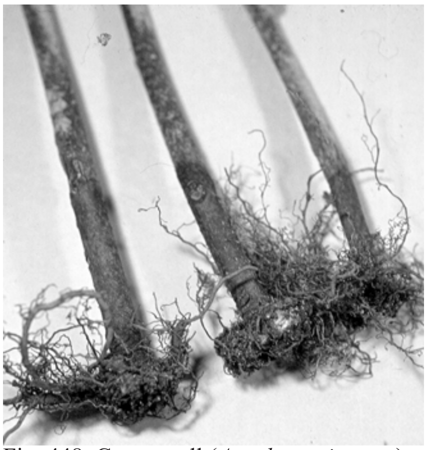

Fig. 448. Crown gall (*Agrobacterium* sp.) on loganberry (*Rubus* sp.).

Fig. 449. Sclerotinia rot (*Sclerotinia sclerotiorum*). ***Left :*** Sclerotia on carrot. ***Right :*** Trumpet-shaped apothecia (spore-producing structures) produced by sclerotia in soil. Dept. of Agric., NSW.

Fig. 450. Root knot nematode (*Meloidogyne* spp.) on tomato, parsnip.

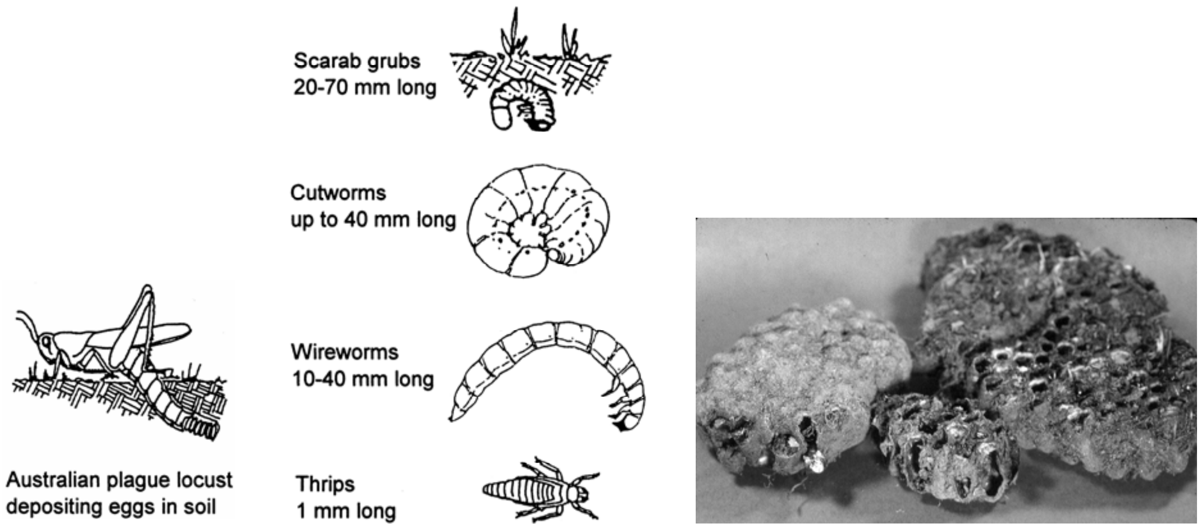

Fig. 451. Eggs and immature stages of insects and other pests commonly found in soil.
Left : Australian plague locust depositing eggs in soil.
Centre : Larvae of scarab grubs, cutworms, wireworms; nymphs of thrips.
Right: Pupae of steelblue sawfly.

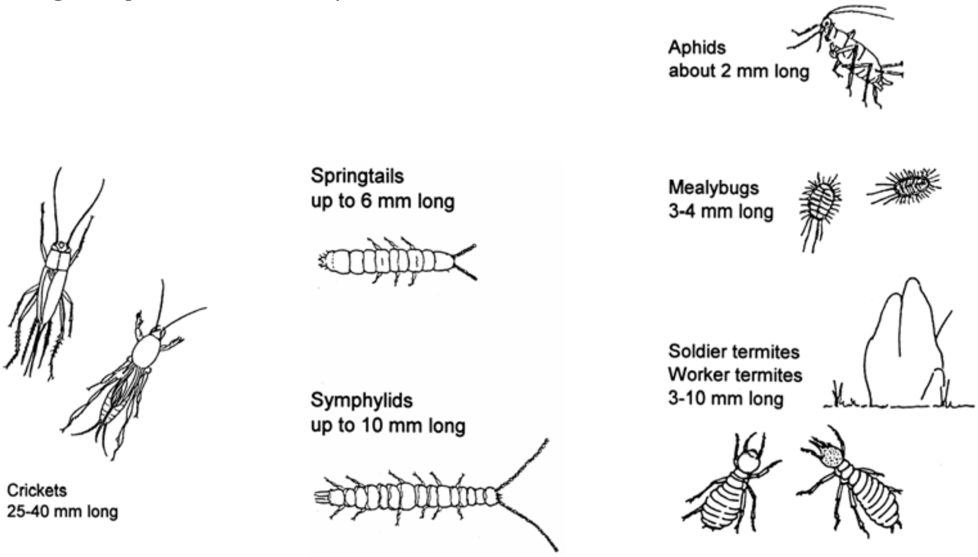

Fig. 452. Adult insects and allied pests commonly found in soil.

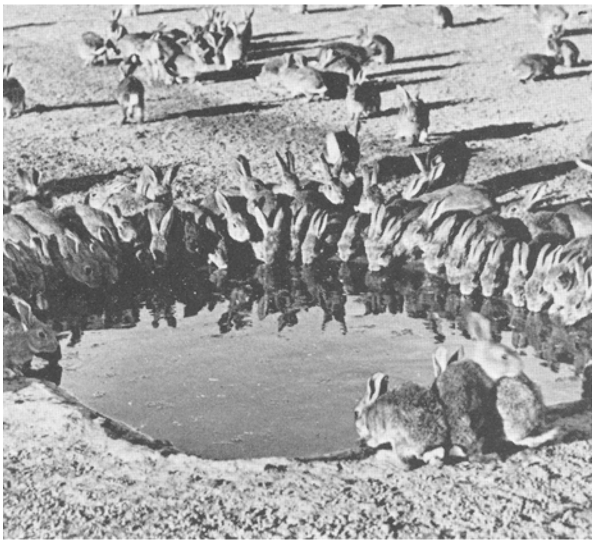

Fig. 453. Rabbits round a waterhole. CSIRO·

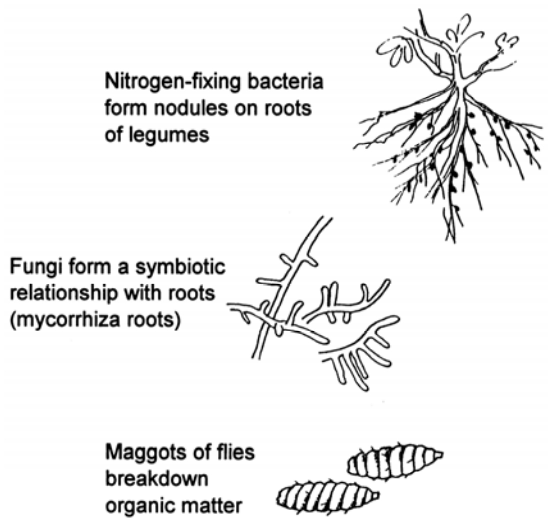

Fig. 454. Beneficial animals and plants in the soil.

Soil Analysis

CHEMICAL PROPERTIES

Nutrients (macro and micro),
pH, salinity, herbicides, water analysis

PHYSICAL PROPERTIES

Texture, particle size,
drainage, water holding capacity,
wettability, compaction

BIOLOGICAL ANALYSIS

Beneficial and pest species,
bacteria, fungi, nematodes, insects, weeds,
root systems, germination tests

Fig. 455. ***Left :*** Soil analysis (performed before planting). ***Right :*** Iron deficiency on hydrangea. Dept. of Agric., NSW

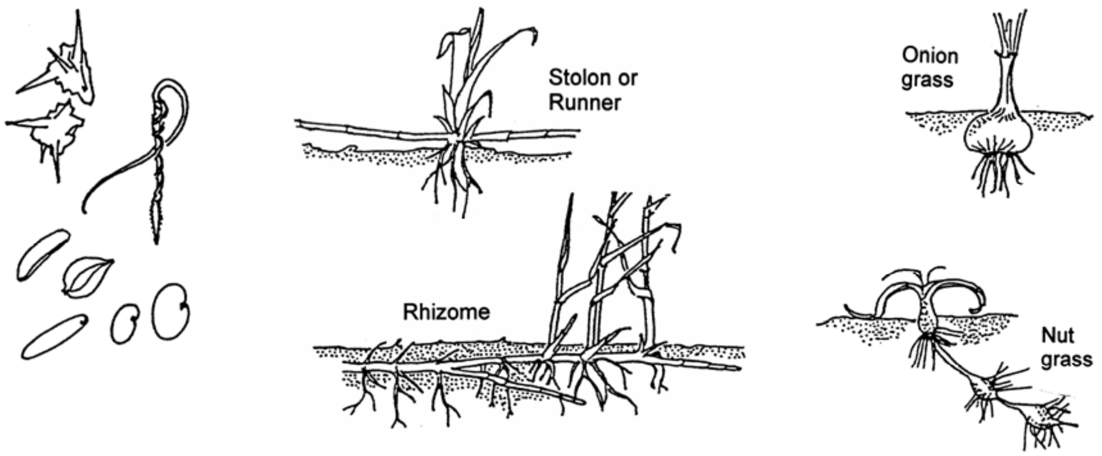

Fig. 456. Annual and perennial weed reproductive structures in soil. ***Left :*** Seeds of annual and perennial weeds are abundant. ***Centre :*** Rhizomes and stolons of perennial weeds grow above and below the soil surface. ***Right :*** Bulbs, corms and tubers of perennial weeds, also cut up pieces of stolons and tap roots, suckers.

Urban bushland

PESTS AND DISEASES **Parasitic** **Non-parasitic** **WEEDS**

PESTS AND DISEASES

Parasitic

Virus and virus-like diseases: Viruses introduced with exotic orchids may spread to native species.
Fungal diseases: ***Exotic fungal diseases***, eg ***Phytophthora root rot***, is a major disease of jarrah and other native plants. See Trees K 6. ***Australian diseases***, eg armillaria root rot (*Armillaria* spp.), may spread in bush areas. See Trees K 4.
Parasitic plants, eg devil's twine, mistletoe and native cherry, may spread in bushland. See Trees K 9.
Insects and allied pests: ***Exotic insect pests***, eg various scales, may infest native plants, eg eriostemon. ***Australian insects***, eg leaf beetles, may only be minor pests of eucalypts in their natural habitat, but may be serious pests when species are grown out of their natural habitat.
Snails may hitch rides on containers and vehicles.
Vertebrate pests: ***Exotic animals***, eg starlings, eat fruit; rabbits may eat small plants; mice and rats eat seed and crops. ***Australian animals***, eg cockatoos, may destroy crops in local areas.

Non-parasitic

Environment: Natural drought and fire affect the biological condition and appearance of bushland.
Fungi, insects, vertebrate pests: ***Fungi:*** Several Basidiomycetes, eg death cap (*Amanita phalloides*), which are extremely poisonous, have been introduced into Australia with deciduous exotic trees, eg oak, beech. ***Insects:*** The bush fly (*Musca vetustissima*) is a common nuisance. See Compost N 17, Manure N 48. ***Vertebrate pests:*** Domestic and feral cats may feed on native birds. Feral pigs dig up the bush. The cane toad was introduced as a biological control agent, and camels were introduced for transport. Carp are a serious pest of waterways.
People-pressure problems: ***Animal dumping*** before school holidays. ***Fire***, eg fire trails and breaks, altered fire regimes. ***Pollution:*** Some native plants are used as indicators of ***air pollution*** (ozone, carbon from wood fires, etc); ***water pollution*** may be caused by increased run off, fertilisers and pesticides; ***soil pollution*** by fertilisers and residual herbicides; ***noise pollution*** by aeroplanes. The use of some ***soil residual herbicides*** in bush areas is considered to affect soil microflora. ***Removal*** of plants, rocks and soil. ***Rubbish dumping*** (garden rubbish, soil, old car engines) in bush areas. ***Soil erosion,*** degradation, salination of waterways from previous clearing and misuse of land especially in marginal areas due to agriculture, mining and forestry. ***Trail bikes, 4-wheel drive vehicles*** cause soil compaction and erosion. ***Trampling of bush*** by bush walkers. ***Urban services:*** Power lines, sewage, water, gas, drains, roads, parking areas, expressways. ***Vandalism:*** Removal of trees, signs, etc, trees may be damaged.

WEEDS

Exotic weeds may colonise bush areas. Many were ***introduced deliberately*** for ***agricultural crops***, ***ornamental purposes***, eg briar rose, or for ***soil conservation***, eg bitou bush. Often these are the most obvious plants in urban bushland. Some were ***introduced accidentally,*** eg skeleton weed. ***Australian native weeds*** are native species which have become weeds in certain environmental circumstances, eg Cootamundra wattle, hardenbergia. ***Noxious weeds*** are those weeds which are declared noxious in certain areas of Australia. ***Weeds*** may be introduced to ***bushland*** in soil in containers, and via garden waste dumped in bush areas. ***Potential weed species*** can now be identified using ***computer modelling*** based on plant family, area of origin, and other information. This could be used to limit future introductions and sales of plants in certain regions of Australia. ***Weeds in urban bushland*** may be ***controlled*** in small areas by diligently ***digging out*** or by spot spraying or stem injecting ***herbicides***. On a very large scale the only possible or practical control is to develop some form of ***biological control*** as has been done for prickly pear. The ***plant quarantine*** trend is to free up introductions of food, new cultivars and other plant materials for trade reasons. This will inevitably increase the accidental introduction of exotic weeds, and diseases and pests. Only plant ***weed-free planting material*** (seed, runners, etc) in bush areas. ***Weed control acts*** are the responsibility of local shires or governments, ie control of weeds is on a regional basis, a plant may be a weed in one place but not in another. Proposed ***codes of practice*** for weed control could avoid soil disturbance or large scale clearing, and encourage the use of mulches, removal by hand, cutting down, mowing or stem injection. ***A national weed strategy*** is also being developed. Nurseries, landscapers, councils and gardeners must accept some responsibility locally and cease recommending, selling and planting species which some local authorities are trying to control, eg cotoneaster.

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Effective Rabbit Control (NSW Agfact)
Feral Pigs : Identifying the Problem (NSW Agfact)
Foxes and Their Control (NSW Agfact)
Noxious Animal Control (NSW Agfact)

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Australian Weeds Committee
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Greening Australia, Landcare
Landscape Australia
National Weeds Strategy (DPIE)
Reclaiming Land (video CSIRO)
Royal Australian Institute of Parks and Recreation
State/Territory Forestry Commissions, Shires, Councils
Towards Ecologically Sound Australian Landscapes

See Soils N 82, Trees K 22, Urban landscape N 88

Remember, always check for recent references

MANAGEMENT

Commonwealth/State management: Departments of lands and environments, national parks and wildlife, heritage commissions, special committees, trusts, shires, etc. are responsible for problems that transcend state boundaries. Some of these responsibilities may be regulated by legislation, eg protection of native flora and fauna, noxious weeds. ***Nursery accreditation schemes*** attempt to prevent spread of weeds, diseases and pests via plants and media in containers. ***Plant quarantine*** regulates plant, soil and other introductions. Bird traps across the Nullarbor stop starlings reaching WA. Fruit flies are monitored in northern Australia. ***Biological control*** programs are the only possible way of controlling many weeds and animals, eg blackberry, rabbits. ***Shires or local governments*** are responsible for tree preservation orders, other codes of practice for tree clearing, care of local plants, animals and weed control. ***Community groups***, eg Greening Australia, Landcare, Parkcare, etc. have ongoing commitments.

Selecting the purpose: What does the local community want? Because there are few areas in Australia with undisturbed bush in urban areas the ***intent of urban bush care schemes*** must be clear, eg

- What is the ***value*** of the bush to the local community, eg aesthetic, recreational, education, scenic?
- Is the ***intent*** to eradicate ***all exotic and non-local Australian plants,*** or only ***exotic plants?***
- Is the intent to eradicate ***all exotic*** and ***non-local Australian animals***?
- Is the intent to ***replant*** naturally occurring plants and ***re-introduce*** naturally occurring animals?
- Is the intent to ***reduce soil erosion*** and other ***physical disturbances***, eg vehicle use, or just ***clean up***?

Is the purpose of the activity possible to achieve? Prepare an inventory to assess the present situation by checking legal land status, codes of practice, mapping the physical and biological features, erosion, water run off, drainage, present ***flora*** (plants, fungi, etc.) and ***fauna*** (vertebrates, insects, etc.) of the area and their diseases and pests. ***Finalise a plan of what is possible to achieve***, eg soil and drainage management, fire control, pollution control (air, noise and water), wind reduction, site preparation, design, picnic areas, planting, fencing, tree guards, fertilisers, watering, disease, pest and weed control, natural regeneration, replanting native species, seed/nursery stock (grow own or purchase), costs and labour, ***preparation of codes of practice*** for plant sales from local nurseries, ***prohibitions*** (trail bikes, 4-wheel drives, rubbish dumping, removal of plants, soil and rocks, unauthorised roads and paths, driving off designated roads, soil disturbance).

Monitor progress and future maintenance needs.

Review of project after a period of time.

Urban landscape

PESTS AND DISEASES
Parasitic
Non-parasitic
WEEDS

PESTS AND DISEASES
Parasitic

Individual urban plants are susceptible to their own pests and diseases. For example ***eucalypts*** may be affected by Christmas beetles, lerp insects, longicorn borers, sawflies, scale, etc. ***Hebe*** may be affected by fungal leaf spots or powdery mildew. ***Radiata pine*** may be affected by needle cast fungi, pine aphids, sirex wood wasp, drought or nutrient deficiencies.

Monitor existing diseases and pests, eg elm leaf beetle in Melbourne, to see if they are becoming more serious. ***Monitor possible future*** pests and diseases, eg Dutch elm disease, which is not known to occur in Australia. ***Management plans*** can then be prepared to alleviate existing problems and for dealing with new problems.

Pest management programs need to be set in place for amenity turf, playing fields, flower displays, rose gardens, school grounds. ***Some diseases and insect pests***, eg codling moth and fruit fly, may be regulated by quarantine and plant disease acts.

Non-parasitic

Environment: ***Light:*** Plant shade-tolerant plants in areas shaded by buildings. ***Temperature:*** In some landscapes, eg courtyards, temperatures may be higher or lower than in surrounding areas and the diseases and pests may vary from the norm. ***Water:*** Poor drainage or lack of water affects tree survival. In some seasons lack of natural rainfall can result in high percentages of new plants dying. Replacement trees may have a higher rate of failure. In irrigated areas water may be expensive. Water recycling, eg the use of grey water, is being increasingly experimented with, recommended, and may be compulsory in some areas. ***Wind*** can blow over trees with shallow roots or close to leaking irrigation systems (waterlogging).

Fungi, insects, animals: ***Fungi:*** Poisonous fungi, eg ***fly agaric*** (*Amanita muscari*) and ***death cap*** (*A. phalloides*), have been introduced in association with exotic trees. ***Insect pests:*** The exotic ***European wasp*** (*Vespula germanica*) commonly nests in the ground, or less often, in buildings or palm trees. ***Honey bees*** and ***mosquitoes*** can sting. ***Ants*** may invade houses and lawns. ***Vertebrate pests:*** Cats and dogs mess lawns, dogs may bite humans, kill cats and chickens, possums may invade houses and eat fruit. Birds may nest on, and dirty, buildings.

People-pressure problems: ***Buildings:*** Trees may be planted too close to buildings and may lean away. Tree roots may invade foundations. ***Construction sites:*** Foundations, drains and underground cables, may sever tree roots. Runoff from construction sites may contaminate waterways. ***Hostile sites:*** Trees are often placed in pavement areas, in bitumen car parks. ***Pesticide use:*** There are special restrictions on the use of pesticides in public areas, eg schools. Pesticides may drain into waterways during weed control operations. ***Pollution***: ***Air*** pollution may result from cars, factories, fires, smog, etc., ***waterways*** may become polluted with fertilisers or pesticides, algae of various types may grow in water. See Water N 91. ***Landscapes*** may be polluted by the dumping of rubbish, noise, light, dogs, etc. ***Soil erosion:*** Parks may be damaged by unauthorised traffic over sloping land, road cuttings erode. ***Soil compaction:*** Car parking, traffic and people walking may compact soil. ***Vandalism:*** Thefts of plants including flower displays, bulbs, theft of playing field goal posts, burning playground equipment, breaking the tops off young trees, setting fire to leaves on the ground and burning trees. Sometimes trees are ***poisoned*** because they block a view.

WEEDS

Weeds are a major pest of urban landscapes and need to be ***monitored*** and ***controlled*** for various reasons, eg aesthetics, fire danger and to prevent damage to bitumen and other paving.

Weed management programs need to set in place, arrangements for amenity turf, fence lines around houses, rose gardens, road edges, schools, native areas, playing fields, flower displays. Woody urban weeds, eg *Pyracantha*, and noxious weeds, eg blackberries, sweet briar, also need to be managed. ***Control measures*** may involve the use of ground covers or mulches, physical removal, the use of pre-emergence, post-emergence and soil residual herbicides. They may be carried out by government employees or by contractors (ACT Parks and Conservation, Neal 1992). Volunteer groups may also have responsibilities.

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State/Territory Departments of Agriculture/Primary Industry eg

European and Papernest Wasps (NSW Agfact)
Street Tree Directories (State/Territory)

Association, Journals etc.

Australian Horticulture (Landscape Features)
Golf Course Management, NZ Turf Management
Journal of Arboriculture
Institute of Horticulture
Landscape Australia, Landscape Australia Directory
Landscape Management
Parks and Gardens News
Brooklyn Botanic Gardens Gardening Guides
California Landscaping

See Trees K 22, Turf L 16, Urban Bushland N 86

Remember, always check for recent references

MANAGEMENT

Most cities and towns have a procedures manual for the management of urban landscapes. Procedures must comply with ***legislation***, eg land planning and environment acts, pesticides acts, occupational health and safety acts, noxious weeds acts, ***Australian standards*** (DR 92100 Trees : Amenity Valuation), tree preservation orders, heritage requirements and ***responsibilities*** for maintenance.

Selection

Design plantings to suit the ***site***, eg schools, street trees, playgrounds, parks, waterways, hostile sites, power lines, playing fields, annual beds, prestige areas, mounds. Plantings may be required to ***delineate*** pathways, ***protect*** danger zones, eg holes, ***screen*** unsightly views, eg rubbish bin sites, ***provide shade*** in car parks, ***protect*** sloping areas from erosion, ***provide shelter*** for birds, ***be aesthetic***, eg provide year round interest (flowering, fruiting, leaf colour, bark texture). Plantings should ***match the landscape***, eg bowling greens are very formal and the landscaping should reflect this formality. The ***purpose*** of the planting must not be forgotten. ***Landscape design*** should minimise general maintenance and difficult weed control situations, eg naturalistic plantings are visually less disrupted by weeds (Hitchmough 1995). ***Evaluate*** landscape design and plant selection. Plants must be ***proven*** for the site and climate and be ***available*** in suitable numbers at appropriate cost. ***Consider need*** for irrigation, maintenance, eg removal of leaf and tree litter, pruning, fertilising, etc.

Maintenance: ***Avoid high maintenance*** street trees, turf areas (irrigation, mowing) or herbaceous perennial borders, where possible. Restrict intensively managed plantings to a small percentage of the total, eg for prestige areas. ***Avoid plants with undesirable features***, eg shedding bark. ***Proposed maintenance programs*** should match the money available, number of staff and level of training.

Resistant varieties: Plants must have sufficient resistance to local pests and diseases (and drought, lack of irrigation, frost and pollution) so that there is no need for the application of insecticides and fungicides.

Plant Quarantine: ***Potential problems*** may be those which invade an area from overseas or from other areas within Australian. Elm leaf beetle, already within Australia, threatens existing large plantings of elms in Australia, and Dutch elm disease, already in NZ, may eventually arrive in Australia. ***Avoid large plantings of plants susceptible*** to potential serous diseases and pests. ***Computer modelling*** may be used to predict the immediate and long term possible effects of potential diseases and pests.

Disease-free planting material: Purchase disease and pest-free plants growing in disease, pests and weed-free media from proven reliable suppliers, eg accredited nurseries. Plants may need to be ***hardened***.

Need for pesticides: If plant species are selected appropriately, there should be no need for spray applications of insecticides and fungicides, there are exceptions. Landscape design should minimise potential weed problems requiring herbicide applications.

Establishment and maintenance

Cultural methods: ***Do not plant up hostile sites, or those contaminated*** with armillaria root rot, phytophthora root and collar rots, nematodes, and other diseases and pests, with ***susceptible plants***. Only plant during the recommended ***season***. ***Provide recommended*** irrigation, tree guards, weed control, formative pruning, etc. Comply with stand specifications (if any). Provide fencing if required.

Biological control programs for major insect pests and noxious weeds may be put in place by organisations such as CSIRO.

Pesticides: The need for ***herbicides*** is difficult to avoid given the desire of the public for floral displays, formal parks, fire protection, reduced costs, etc. Herbicides are used to ***control roots and suckers***. The use of herbicides may be increasing. ***Growth regulators*** may be used to control hedge height under power lines and on turf. Emphasis should be placed on ***non-chemical methods*** of diseases, pest and weed control where practical and possible. Where pesticides of any type are used, ***only low hazard products*** should be selected. Consider possible persistence, pollution and other effects on the ***environment***.

Maintenance programs change as trees age. ***Tree surgery requirements*** will vary depending on the site, eg under power lines, street trees, home gardens. ***Weed control practices***, eg herbiciding around newly planted trees, will eventually not be required, as older trees provide shade which inhibits weeds. ***Continued herbicide application*** on slopes may eventually result in soil erosion problems, roots may be exposed.

Monitoring pest and diseases of existing plantings of trees, playing fields, fruit trees, etc. and weed problems improves future plant selection and maintenance programs.

Evaluation of establishment and maintenance programs: ***Considerations include:*** Are they satisfactory or too costly? Which designs, plantings or species are cost effective? Are tree root control and pruning programs effective? Are safety procedures for herbicide selection and use adequate?

Water

PESTS AND DISEASES
Parasitic
Virus and virus-like diseases
Bacterial diseases
Fungal diseases
Nematode diseases
Insects and allied pests
Snails and slugs
Non-parasitic
Exotic fish
Insects (midges, mosquitoes, springtails)
Pollution
Water characteristics
WEEDS
Aquatic weeds

PESTS AND DISEASES
Parasitic

VIRUS AND VIRUS-LIKE DISEASES

Virus diseases are not commonly spread in water, one important exception is lettuce big vein virus spread by the water mould fungus (*Olpidium brassicae*). See Hydroponic systems N 41.

BACTERIAL DISEASES

No spores are produced by bacteria which infect plants. Bacteria have ***flagella*** which enable them to swim and spread in water. Bacterial diseases of plants spread by water include ***bacterial leaf and flower blight*** (*Pseudomonas andropogonis*) of carnation.

FUNGAL DISEASES

Soilborne fungal diseases: ***Spores*** are spread by wind, water splash and in water currents. ***Water mould fungi***, eg *Aphanomyces, Phytophthora* and *Pythium,* produce ***zoospores*** which have ***flagella*** enabling them to swim in water. ***Other fungi:*** *Botrytis, Fusarium* and *Thielaviopsis* (*Chalara*) produce ***spores*** and ***resting spores*** (chlamydospores); *Sclerotinia* produces ***ascospores*** and ***sclerotia***, *Verticillium* produces ***spores*** and ***microsclerotia***. *Rhizoctonia and Sclerotium* mostly do not produce spores and are not so readily spread by water; both produce ***sclerotia*** which can be washed downhill.

Spread: ***Water supplies*** can introduce soilborne fungal disease into nurseries. Diseases may be washed downhill to contaminate new sites. These soilborne diseases may also be spread by movement of ***contaminated soil*** on vehicles, machinery, tools, footwear; by the introduction of ***infected planting material***. See Vegetables M 7.

Conditions favouring: ***Recycling*** of irrigation water or nutrient solutions in hydroponic systems. ***Drainage*** or surface washings from nurseries into dams which are subsequently used for irrigation.

Control in water sources:

Water source: ***Most town water supplies*** (which are usually chlorinated) and ***bore water or roof run-off water*** are usually free from disease organisms. These water sources do not need treatment. All ***surface water*** pumped from dams and streams and run off water, being ***reused*** or ***recycled***, must be assumed to be contaminated. Water from dams, soaks, streams, rivers, lakes or recycled water must be treated to remove or destroy possible *Phytophthora* and *Pythium* fungi depending on the plants grown. ***Nursery accreditation schemes*** usually include specified water treatments for water from certain sources. ***Water storage tanks*** must be cleaned. ***Wire bench tops*** prevent splash of fungal spores and nematodes from pot to pot.

Water treatments: Common treatments for contaminated water include ***chlorination or a combination of filtration and chlorination***. Tanks used for holding treated water, including liquid feeds, must be covered to prevent recontamination. ***Chlorination*** is cheap, effective and simple with chlorine gas but sodium hypochlorite can be used in smaller nurseries. It is recommended that water should be treated with at least 2mg/L free chlorine and held for at least 20 minutes (Anon. 1994). Main sources of chlorine used are calcium hypochlorite, sodium hypochlorite and chlorine gas. ***Chlorination*** is ***hazardous***, improper use of chemicals and higher than recommended concentrations may corrode the irrigation system, damage soil and plants. Active chlorine solutions are ***dangerous*** to humans and animals. Avoid contact with skin and eyes, and do not swallow solutions (Rolfe et al. 1994). Prior to chlorination, water analyses must be carried out to determine the required dosage rate and the need for settlement tanks to remove any organic matter or the need to precipitate suspended mineral impurities (Rolfe et al. 1994). ***Bromination*** is also effective. ***Filtration:*** To retain ***disease organisms,*** a filter with a ***mesh size*** of 0.1-0.2 microns is required but is often not practical (Rolfe et al. 1994). Effective filters must be no greater than 5 microns (a microbiological standard). Inclusion of a prefilter in the system may be an advantage (Handreck and Black 1994). ***Others: Chlorine dioxide*** is effective at high pHs and is being researched (Mebalds et al. 1996). ***Heating*** to 65^{o}C for 30 minutes. See Nurseries N 53. ***Slow sand filters*** are being researched in Australia with some success (Barth 1996). Another alternative is to use ***ozone (O_3)*** which is generated by passing very clean air through an electrical discharge. The air containing the ozone is mixed vigorously with water being treated (Mebalds et al. 1997). Both these techniques are still in the developmental stage. ***Ultra violet (UV) light*** is available to sterilise water by flowing the water around a UV tube. The UV machines must be calibrated to produce the dose required to kill off all damping off fungi. All particles > 5 µm must first be removed. Radiation intensity must be at least 80 000 mws/cm^2 to ensure a complete kill of *Phytophthora* spp. (Handreck and Black 1994).

NEMATODE DISEASES

Wire mesh bench tops prevent nematodes from swimming from pot to pot. Do not put pots on ***soil*** or on a ***holding surface*** where water may accumulate in pools. See Vegetables M 10.

INSECTS AND ALLIED PESTS

Most maggots of ***hover flies*** (Syrphidae, Diptera) live in stagnant, polluted water including the rat-tailed larvae (*Eristalis* spp.) which have long tails for obtaining air from the surface.

SNAILS AND SLUGS

Aquatic snails (*Physastra* spp.) attack rice while it is establishing and at tillering. See Seedlings N 70.

Non-parasitic

Exotic fish if present in sufficient numbers may cause irreversible damage to waterways. ***Carp*** although used as food, destroy eggs and breeding places of more valuable fish. They muddy water.

Insects: ***Midges*** (Chironomidae, Diptera) are mostly minute flies, superficially resembling mosquitoes which fly in the evening in large numbers near still water. ***Flies*** vary from black, brown to greenish, reddish and yellowish. They often form mating swarms at sundown and can occur in such large numbers as to cause considerable annoyance around lights on warm evenings. ***Maggots*** are with few exceptions ***aquatic***, living in or on bottom debris, free on vegetation, many of the former construct and live enclosed in a gelatinous tube coated with particles of debris. Tube-dwellers include the 'bloodworms' (*Chironomus* spp.) whose colour is due to haemoglobin. The ***rice bloodworm*** (*C. tepperi*) damages rice seedlings in NSW principally through physical disturbance of the roots (Currey 1984). ***Mosquitoes*** (Culicidae, Diptera) have elongated mouthparts to pierce human and other animal skin. Males are not blood suckers but females require a ***blood meal*** before their eggs can mature. There is considerable host specificity and not all will attack humans. Some species have been/are important ***vectors of human disease*** in Australia, eg ***malaria*** by *Anopheles farauti,* ***myxomatosis*** of rabbits by various species of mosquito, ***filariasis*** by *Culex fatigans,* ***dengue fever*** by *Aedes aegypti,* ***Ross River fever*** by *A. vigilax* and *C. annulirostris*. Some species are just ***nuisance pests.*** *A. notoscriptus* is widespread and breeds in containers. ***Maggots*** are aquatic. ***Control*** is usually aimed at preventing ***maggots*** developing in water; kerosene is applied to the surface to stop them breathing. Mozkill® (*Bacillus thuringiensis*) has to be eaten by the maggot for it to be effective. Insecticides are registered to control the ***adults***. ***Springtails*** (Collembola) spread in water.

Pollution

There are 3 chief sources of water pollution.

Agricultural chemicals and wastes: ***Chlorination*** of drinking and swimming water is common. Swimming pool water contains high concentrations of sodium and chloride ions from chlorinating chemicals and acid to lower the pH. Never use these waters to irrigate plants. Chlorination forms residual products and is considered to be an environmental hazard. Most ***insecticides***, including the low hazard ones of pyrethrin and rotenone, are ***acutely toxic*** to fish and should not be used on aquatic plants or on plants close to water features (Brown 1978). ***Herbicides*** may be detrimental to some water plants and animals. ***Herbicides*** applied to control weeds on land may become an environmental hazard as they often end up in storm water drains and water systems. They affect organisms in water during direct treatment and later in the water system, lakes, etc. If ***recycling*** nursery water, avoid using ***persistent*** herbicides, eg oryzalin, oxyfluorfen, simazine. Some ***fungicides*** are persistent, eg copper. Copper sulphate (Bluestone®) is dangerous to fish. ***Additives***, eg ***surfactants***, in some formulations of herbicides, may affect some aquatic animals, eg frogs. ***Fertilisers***, eg ***nutrients*** in recycled nursery water, may be toxic to plants (Beardsell et al. 1996). ***Rainwater*** flowing from urban areas and farmland (feed lots) carries chemicals, fertiliser (nitrogen, phosphorus), manures and pesticides. Nutrients and organic matter in the water stimulate increased growth of bacteria and other microorganisms, eg algae.

Industrial waste: Various types of pollutants may be released into the ***air*** (causing acid rain, ozone-reducing compounds) and heavy metals may be released into ***waterways***, eg mercury. Heated effluent may destroy animals and plant life in adjacent regions (Kerruish 1990). Flood water may carry contaminants away from storage sites.

Sewage consists of ***human and animal wastes,*** which contain bacteria and other disease-causing microorganisms, general waste and water that has been used for laundering and bathing. Most of this is treated before it is discharged into waterways; these sewage-treatment plants are a major source of nitrogen and phosphorus. Use phosphorous-free products.

Different types of ***algae*** may develop in water.

Blue green algae (*Anabaena*, *Anacystis*, *Microcystis*, *Noctularia*, other species) may form water blooms and appear as thick green scum on fresh, clear, still waters during the warmer months of the year. They create ***serious water quality problems*** causing river channels to be choked by an ***overabundance of water plants.*** They can be ***toxic*** to humans and animals (birds, cattle, dogs, poultry, sheep) if swallowed, and can cause skin irritation if body contact occurs (National Health and Medical Research Council 1994). Affected animals may die within hours or after a prolonged time with the appearance of ***jaundice*** (yellows) and ***photo-sensitisation*** (sunburn). Boiling the water does not destroy the toxins. Fish and other life forms in water are starved of oxygen by excessive amounts of decomposing plants and algae. ***Blooms are caused*** by the interaction between ***turbidity*** (turbid water means less light reaches the algae so it grows more slowly), ***mixing*** (of water-moved algae from the surface to lower areas, if mixing is slow then algae is exposed to light more and so grows more quickly), levels of various ***nutrients*** especially phosphorus and nitrogen which are present in fertilisers, water softeners and dirt dissolvers in laundry detergents and cleaning agents, ***reduced water flow*** due to irrigation, drought, increased industry and domestic use, disturbance of the natural food web (exotic fish, draining of wetlands or the destruction of water plants by carp and cattle). ***In dry conditions*** most nutrients come from point sources, eg sewage-treatment works and ***in wet conditions***, especially during floods, from agricultural lands or forests (Creagh 1992).

Green algae (*Cladophora*, *Euglena*, other species) do not produce toxins and so are mainly a **nuisance** in that they clog nozzles and make storage areas and holding areas unsightly. Chemicals can be used for their control (Rolfe et al. 1994) but if they are a regular problem try to determine the cause. Bales of barley straw in small pools or ponds produce a chemical which inhibits algal growth (Lake 1996).

Legislation: Clean waters acts and other laws regulate discharge into waterways, ***monitor*** their effectiveness. **Scanning of waterways** (for algae, muddiness, temperature) by aircraft predicts when blooms are likely to occur. Rivers can then be flushed out to stir up the mud, speed up the flow and mix the water to stop blooms forming. **Toxicity assays** and algal counts may be necessary. **Biological controls**, eg virus and bacterial diseases, predatory micro-crustaceans (plankton graziers, eg *Daphnia* spp.), etc are being researched (Creagh 1992). **Algacides** are used in greenhouses to control algae that grow on floors and walls. Water is chlorinated to kill microorganisms for domestic use and prior to disposal or recycling for drinking, laundering, bathing. There are **different water qualities**, eg one suitable for ***drinking***, another for ***gardening***, etc ***(grey water)***.

Water characteristics have to be determined and **monitored regularly**, eg pH, salinity, turbidity, electric conductivity (EC), hardness. **Recycled water** must also be monitored (Bearsdell et al. 1996).

WEEDS

Aquatic weeds: Some aquatic weeds are ***declared noxious weeds*** in some regions of Australia, eg alligator weed, salvinia. **Aquatic** and other weeds may occur in crops, eg rice, and along edges of waterways, drains, water channels etc. These weeds should be treated as aquatic because of their association with water. Aquatic weeds may be **submerged** (bulk of the plant is under the surface of the water, eg pond weed), **free-floating** (float free on the water surface, eg salvinia), **emergent** (rooted in the silt and the major portion of the plant is above water, eg cumbungi, bulrush), and **bank-anchored weeds**, eg water couch.

Identify the weed: A herbicide is only registered for a specific weed in a specific situation, so it is necessary to identify the weed, its growth habit, ie whether it is an algae, free-floating, emergent, or submerged weed, and how it reproduces, spreads and its life cycle. **Spread:** *Elodea* during the growing season tends to promote spread of ***stem segments*** and should be avoided where possible. ***Weed seeds*** of various types, not just aquatic weeds, may be spread by irrigation water, waterways etc.

Initial responsibility for **controlling noxious plants** on private lands rests with the owner or occupier of the land. Create **cultural conditions** unfavourable to growth of water weeds. Pondweed (*Potamogeton*) may be controlled by regularly drying, **cleaning** and renovating irrigation channels. Many aquatic weeds, eg alligator weed, salvinia and water hyacinth have been **biologically controlled** by CSIRO. There are many exotic aquatic weeds not at present in Australia and **quarantine** attempts to prevent their entry. If the water is used for human or animal consumption or for the irrigation of gardens or crops, chemical control is often not desirable or possible. The **physical removal** of plant material from the water removes substantial amounts of nutrients, slows regrowth and avoids the depletion of oxygen due to the breakdown of vegetation following a chemical treatment, avoiding fish death. Type of ***mechanical treatment*** depends on the weed species. Scoop nets may be used to remove floating weeds, eg salvinia and azollis. Dragging systems may be used for submerged plants, eg ribbon weed. Some weeds, eg cumbungi, can be cut below the waterline in autumn. Bank-anchored weeds may be mown. **Herbicides** are registered for commercial use on weeds in, or in association with, aquatic areas, eg drains and channels, margins of dams, lakes and streams. There may be a reduction in effectiveness if ***more than one quarter*** of the above ground portion of the weed is submerged at treatment. If most of the weed grows below the water, herbicide control is difficult, some also have a waxy coating. Most applications require **approval** from the relevant body, eg a lake management working group. Some ***herbicides*** are hazardous to use and need permits, others require the chemical to be applied by a licensed operator. Chemical control is only suitable if infestation is small and the water is not to be used for stock or domestic purposes or for watering gardens and crops. Using **pest management** (several different methods) to control water weeds generally is more effective, eg controlling aquatic weeds in a small dam might involve initially ***mechanically removing*** plants, ***spot treating*** any remnants with herbicides, ***dredging*** to deepen the dam, ***diverting*** cattle yard effluent on a permanent basis and taking action to minimise further ***siltation***. Trees could be planted to shade the dam and appropriate biological control agents released.

Others: **Willows** are a ***major pest*** of water ways. See Willow K 140.

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State/Territory Departments of Agriculture/Primary Industry eg

Aquatic Weed Control in Small Dams (NSW Agfact)
Aquatic Plant Control (NSW Agric)
Australian Water Weeds Kit (Australian Water Resources Council)
Clearing Muddy Water 1 : Amounts of Clearing Chemicals to Add (Vic Agnote)
Clean Clean Water (CSIRO video)
Clearing Muddy Water 2 : Add Clearing Chemicals/ Tanks/Dams (Vic Agnote)
Controlling Weed Growth in Community Drains (Rural Water Com of Vic)
Controlling Weed Growth in Farm Channels (Rural Water Com of Vic)
Filtration of Microject/Mini-sprinkler/Trickle Systems (Vic Agnote)
Farm Water Quality and Treatment (NSW Agfact)
Fish in Farm Dams (NSW Agfact)
Groundwater (Vic Agnote)
Arrowhead (Vic Rural Water Corp)
Handling Calibration (Rural Water Com Vic)
Glyphosate in Aquatic Situations (Rural Water Com Vic)
How to Take Water Samples for Analysis (Vic Agnote)
Installing Test-wells (Vic Agnote)
Maintaining Water Quality In Farm Dams (SA Fact Sheet)
Mangroves (NSW Agfact)
Monitoring Soil Water (SA Fact Sheet)
Tolerance of Plants to Salty Water (WA Farmnote)
Weed Control in Irrigation Channels & Drains (Vic Agnote)

Associations, Journals etc.

Australian Horticulture (Water Management Features especially April 1995)
Australian Water Resources Council, ACT
Greenhouse Grower
Hort. Research & Development Corporation (HRDC)
International Erosion Control Assoc.
Irrigation Assoc of Australia
Nursery Industry Associations and Conferences
Rural Water Corporation, Vic
State/Territory Authorities, City Water
Stormwater Industry Assocs.
Water Testing Laboratories/Businesses
Water Quality Management Seminar 1995 CIT/ATRI, ACT

**See Nurseries N 56, Water plants N 94, Willow K 140,
Xeriscape N 96, Preface xii**

Remember, always check for recent references

MANAGEMENT

Water management programs must be put in place. Be familiar with ***regulations and legislation*** which apply to water use and disposal/run-off. ***What is the water to be used for?*** Bathing, drinking, fertigation, irrigation in nurseries, recycling or enclosed systems. ***What is the source of water?*** Bore, dam, drainage, rain, recycled water or grey water; town water must be identified. ***Storage areas,*** if applicable must be cleaned**.** Where is the water to be ***drained to?*** Water must be ***analysed*** at regular intervals. The most useful analyses include electrical conductivity, pH, total hardness, cations (calcium, magnesium, sodium), boron, chloride, sulfate and bicarbonate. They may also be analysed for nitrate and ammonium and other nutrients, also for herbicides. Tests to detect ***disease organisms*** may sometimes be required (Handreck and Black 1994, James 1995b). Follow instructions for ***collecting water samples***, eg take samples at the correct time and depth, record details, take the correct number of samples and send them off the same day. Know what the water is to be ***tested for***, eg electric conductivity (EC), hardness, pH, salinity, turbidity, ***when*** it is to be tested and ***where*** to send it to. ***Conditions of sampling*** include taking samples when the pump has been running for some time. Samples should represent the whole depth of water in dams and deep storage facilities. Label samples clearly, record details of the collection. Collect about 500 ml in a plastic or glass bottle, fill to top and refrigerate. It must reach the testing laboratory within a few days after collection. ***Water treatments*** include chlorination and/or filtration (Rolfe et al. 1994). See Water N 90.

Water plants

PESTS AND DISEASES
Parasitic
Non-parasitic
Pesticide toxicity
Weed potential

Water features must comply with ***local legislation***.

PESTS AND DISEASES
Parasitic

Water plants are generally free from major diseases and pests, but individual species may be subject to pests and diseases in the same way that land grown plants are, each genus or species being susceptible to specific problems. ***Waterlily*** (*Nymphaea* spp.) may be affected by ***fungal leaf spots*** (*Cercospora nymphaeacae*, *Gloeosporium* sp.), ***pythium root rots*** (*Pythium* spp.) and the ***waterlily aphid*** (*Rhopalosiphum nymphaeae*). In northern Australia, ***larvae of a beetle*** (*Donacia* spp., Chrysomelidae, Coleoptera) pierce the roots of waterlilies to obtain air. However, there are some problems which are generally common on a range of water plants. ***Aquatic snails*** may be added to water features to feed on undesirable algae, but if there are too many, they may also attack desired plants. Field crops such as ***rice*** may be attacked by aquatic snails (*Physastra* spp.).

Non-parasitic

Pesticide toxicity: Some pesticides are ***registered*** for use on some aquatic crops. Herbicides are ***registered*** for drains, etc. Some pesticides applied to control diseases and pests and weeds of aquatic plants, will inevitably enter the water. Depending on the amount that enters water and the intended use of that water, the ***quality*** may be severely affected.

Most insecticides, including low hazard ones, eg pyrethrin and rotenone (Derris® Dust), are toxic to fish, and should not be used on water plants or plants close to water features or swimming pools. Soap solutions and other insecticides may disfigure flowers.
Herbicides may kill desirable plants. See Water N 92.
Fungicides are used in hydroponic systems, and fungicide dusts are used on rice seed to protect seeds against *Pythium* spp.
Surfactants and other additives in pesticide formulations may be toxic to frogs.

Weed potential: ***Aquatic weeds*** in water features are common. Many ornamental aquatic plants have themselves become aquatic weeds, eg free-floating azolla (*Azolla* spp.). See Water N 92.

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State/Territory Departments of Agriculture/Primary Industry eg
Aquatic Plants (Rural Water Com. Vic)
Associations, Journals etc.
Australasia Aquaculture
Australian Water Resources Council
International Waterlily Soc.
See Water N 92

Remember, always check for recent references

MANAGEMENT

Select water plants suited to the climate, eg temperature, pond size and hardiness. The large spreading leaves of waterlilies also cut off light and shade the water beneath, preventing algal growth. ***Emergent plants***, eg waterlilies, are anchored or rooted in silt with the majority of the plant above the water surface. ***Submerged plants***, eg water milfoil, are useful in pools for spawning areas for fish. ***Free-floating plants***, eg duckweed, float on the water surface, most have prolific roots just below the water surface. These are not really suitable for ornamental gardens as they grow profusely and quickly cover the surface but they can provide shade and food for fish and excess growth is easily removed from most pools. ***Propagated*** by root division. When rootstocks of waterlilies are being split into small sections, prevent infection by dusting the cut wounds with powdered charcoal, dry before putting back in water. Where practical, plant in containers, this facilitates their movement and is neater and cleaner. To ensure good flowering some aquatic plants, eg waterlilies, may require ***full sun and repotting*** every 2nd or 3rd year. ***Clean ponds*** regularly. ***Remove*** all severely damaged plants, dead plant parts and old flowers promptly to prevent diseases and pests from multiplying on them. Individual leaves affected by ***fungal leaf spots*** may be picked off and destroyed. ***Aphids may be hosed off***, any fish in the pond will eat them. The value of ***waterlilies as a cut flower*** is limited by their habit of closing at night. Some florists wax the petal bases to keep them open (Moody 1994a).

Xeriscape

Xeriscape® is a trademarked name owned by the Denver Water Department and used to describe a program aimed at saving water in the landscape. Basically Xeriscape promotes ***water conservation*** through creative landscaping and the planting of drought-resistant grasses, shrubs and trees. Xeriscapes may cost slightly more initially but the extra cost is soon recouped by reduced water usage. Most capital cities in Australia have demonstration Xeriscape gardens.

XERISCAPE MANAGEMENT

Design a landscape aesthetically for the site considering its intended use (garden zones), existing vegetation, landform (contours, slope, natural drainage), natural rain patterns and microclimates (shade, wind). It may be necessary to provide sun and wind breaks.

Plant selection is the key to efficient water use. ***Group plants*** according to their water needs. Retain natural existing vegetation where practical, as it will be suited to the environment aesthetically and climatically, be attractive to animals and possibly require minimal maintenance. ***Total drought resistance*** is the product of drought avoidance and drought resistance. Some plants tolerate lack of water, while others may increase their water uptake in times of drought. In urban landscapes the ability to survive drought can be more significant than the ability to use water efficiently (Tipton 1994). If irrigation is to be used, select plants ***with some tolerance*** to low water requirements. Herbaceous perennials will require less supplementary watering than shallow-rooted flowering annuals. Succulent ground covers will thrive in poor or hot dry soils. Limit areas of turf where practical (in 1994 in Canberra, ***40%*** of the total water used was for irrigating turf areas). Available turf species are becoming more drought tolerant. Select plants with ***resistance*** to debilitating diseases and pests which might affect their growth, appearance and ability to withstand low water conditions and salinity. Select ***disease-free planting material*** so that any general diseases and pests are not introduced to plantings.

Soil improvements, eg loosening, addition of organic matter, improving drainage, moisture penetration and soil water holding capacity, will result in better plant growth. Though soils vary greatly, ripping compacted soil to about 200 mm and adding organic matter, usually leads to better plant growth and water usage. ***Soil analysis*** may identify nutrient deficiencies and other inadequacies of soil, which if corrected, would improve growth.

Mulches up to 100 mm deep can reduce water evaporation from soil by up to ***75%***, reduce weed growth and insulate roots from heat. Some mulches, however, may prevent moisture reaching the soil underneath. See Mulches N 49.

Irrigation systems should be efficient, carefully chosen and maintained. To reduce the amount of irrigation water used, maintain appropriate operating pressures, uniform precipitation rates and match head size to the area being irrigated to avoid watering pavements and buildings causing surface run off. Install ***separate irrigation zones*** for different microclimates, eg shady and sunny areas, turf, trees and shrubs, north and south slopes. Avoid watering in wind or periods of high heat (water between midnight and 8 am). Where practical install borders around irrigated areas. ***Maintain irrigation systems*** to promote efficient water use by repairing leaks promptly, checking the system after mowing and regularly checking nozzles. Adjust monthly water rate based on climatic conditions. Use rain shut-off valves, computerised sensors may save ***30%*** of watering. ***Recycle water*** where possible.

Maintain plants appropriately, eg prune, fertilise, replace plants as needed. Control weeds.

CLASSIFICATION OF XERISCAPES

Xeriscapes have been classified in many ways, the following is a classification according to their style or appearance.

True Xeriscape is found in naturally arid regions, utilises locally adapted species, uses no irrigation except for establishment, but may utilise precipitation concentration to increase available moisture. Usually artificial barriers are not used.

Artificial Xeriscape is not normally found in arid regions, utilises arid-region species, uses no irrigation except for establishment, but may use precipitation concentration, soil barriers or microclimates to artificially create aridity or stress.

Simulated Xeriscape is found in humid regions, uses arid-region species or a mix of arid-region and humid-region species, may or may not be irrigated, used for 'look and feel' rather than to save water, usually uses soil barriers to create aridity or stress.

Accidental Xeriscape may be in any region, may use any species in plantings, no intent to withhold water, usually uses soil barriers above natural soil, usually intended to decrease maintenance.

XERISCAPE FAILURES

For plantings in arid and semi-arid localities, most failures can be attributed to unintended precipitation concentration which in turn accelerates the soil-forming process, allowing growth of plants, especially weed species, which like moist habitats.

Poor original species selection is a ***common*** contributing factor.

For plantings in which stress or xeric results are unintended, failure is likely to be attributable to the use of impermeable membranes. The accidental creation of stressful microhabitats, when combined with the use of species characteristic of moist habitats, is a prescription for failure.

For all types of plantings, many installers appear to ignore the consequences of soil-forming processes and the precipitation concentration or deficit resulting from the effects of slope.

DISEASES, PESTS AND WEEDS

Parasitic diseases and pests: Plants grown in Xeriscapes are susceptible to the same pests and diseases as they would be elsewhere, eg ***strawberry***

tree (*Arbutus unedo*) to **phytophthora root rot** (*Phytophthora cinnamomi*), **root knot nematode** (*Meloidogyne* spp.), **leaf case moth** (*Hyalartica huebneri*) and **purple scale** (*Lepidosaphes beckii)*.

Weeds: For plantings in arid and semi-arid areas, most failures may be attributed to unintended precipitation concentration, which allows creation of **moist habitats** which accelerate the soil-forming process, allowing growth of **moisture-requiring plants** especially **weed species**.

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Associations, Journals etc.

Capital City Xeriscape Demonstration Gardens
Journal of Arboriculture
Landscape Australia
National Xeriscape Council Inc. PO Box 767936 Rosewell GA 30076 USA.
Society for Growing Australian Plants (SGAP)
Water Efficient Gardening (Greening Australia)

See Mulches N 50, Soil N 82, Water N 92

Remember, always check for recent references

MANAGEMENT

Plants are divided into 3 categories based on their need for moisture:

Desert plants or **xerophytes** proliferate with very little water, eg cacti, often have very shallow and fibrous root systems that can act as sponges and immediately absorb any slight amount of rainfall falling on the surface. Their leaves have been modified to reduce water loss by transpiration and their stems are often covered with a thick, waxy resinous material, or they could be pubescent (stems and leaves covered with hairs) to reduce transpiration. The stems of some xerophytes can store tremendous quantities of water for long periods of time. At the opposite of the scale are **hydrophytes** which thrive in or close to water, eg waterlilies. Between these two extremes are **mesophytes**, the most populous of the three, which include practically all the economically important agricultural plants. They can adapt to quite diverse environments.

Some plants suitable for Xeriscapes include:

Exotics (deciduous and evergreen)
Yarrow (*Achillea clypeolata*)
Belladonna lily (*Amaryllis belladonna*)
Golden marigold (*Calendula officinalis*)
Celtis (*Celtis australis*)
Desert ash (*Fraxinus rotundifolia*)
Flame tree (*Brachychiton acerifolius*)
Primrose jasmine (*Jasminum mesneyi*)
Red-hot poker, torch lily (*Kniphofia* sp.)
Loquat (*Eriobotrya japonica*)
Sacred bamboo (*Nandina domestica*)
Lavenders (*Lavendula* spp.)
Poppy (*Papaver nudicaule*)
Nasturtium (*Tropaeolum majus*)
New Zealand flax (*Phormium tenax*)
Strawberry tree (*Arbutus unedo*)

Australian natives (evergreens)
Bottlebrush (*Callistemon* spp.)
Broadleaved paperbark (*Melaleuca quinquenervia*)
Casuarina (*Casuarina* spp.)
Everlasting (*Helichrysum bracteatum*)
(= *Bracteantha bracteata*)
Eucalypts (some *Eucalyptus* spp.)
Heath banksia (*Banksia ericifolia*)
Pin-cushion hakea (*Hakea laurina*)
Pittosporum (*Pittosporum undulatum*)
Tussock grass (*Poa labillardieri*)
Wattles (*Acacia* spp.)
Westringia (*Westringia fructicosa*)

Some native plants are not as drought-tolerant as previously thought. While some Australian native plants are thought to require very little water and be highly stress-tolerant, many traditionally considered hardy may in fact, not be tolerant of water stress. For example, reduced water supply causes a decrease in total flower production and retards plant growth of Geraldton wax.

Converting existing conventional landscapes to Xeriscape

Even with existing landscapes, the principles of Xeriscapes should be carefully followed.

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Transverse ladybirds
(*Coccinella transversalis*)
about 5 mm long

STEPS IN DIAGNOSING PLANT PROBLEMS

Remember these steps are not set in concrete, some may be bypassed, combined or even reversed. For example, you may need a reference to identify the host plant, you may decide to send the plant specimen directly to a diagnostic service. Telephone enquiries mean that you do not have the specimen to examine at that particular moment, but you could ask for one to be forwarded.

STEP 1. NAME AND TYPE OF THE HOST PLANT/CROP

- **Identify the host** by its common names (and botanical name if necessary). The name of the cultivar is often useful.
- **List the pests and diseases** to which the crop is susceptible in your region.
- **List types of any other plants** growing near, around or under crop plants.

STEP 2. VISUALLY EXAMINE THE PLANT

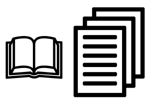
- **Examine** foliage, stems, flowers, fruit and roots. **Look for:**
  - **Presence** of insects, fungal spores, etc.
  - **Symptoms**, ie reaction to thrips feeding, eg silvering of leaves.
- **Cut open** fruit, seeds, stems and roots.
- **Hand lens, microscope**. Examine affected tissue under a low power (hand lens or dissecting) or high power (compound) microscope. You can compare features with published descriptions found reference texts.
- If you have **not** yet identified the problem, move to Step 3.

Record history

Ask ?

STEP 3. ON-SITE VISIT, HISTORY/QUESTIONS

- Examine plants on-site. This often provides information for a diagnosis.
- If it is not possible to visit the site, ask the grower about the history of the crop: Try to ask question systematically.
  - **Look for patterns**; try to eliminate, or exclude, possibilities.
  - How is the problem **distributed in the field?**
  - Is the problem **restricted to one species** or across species
  - Are **all** the plants of **one species** affected?
  - It **really a problem** or just of interest?
  - **Source** of propagation material, growing media, containers.
  - Recent applications of **fertilizers and pesticides?**
  - Has the **weather been unusual?** Check environmental data. high and low temperatures, humidity and over/under-watering, source of water, etc.
  - **Disease severity**, predisposing factors, eg nutritional imbalances, crop hygiene.
- **On-site tests**, eg **ELISA** tests.
- If you have **not** yet identified the problem, move to Step 4.



STEP 4. CONSULT A REFERENCE

- **To assist with** and **confirm** diagnosis. **Diagnostic tests** may be available, eg
  - For **some soil diseases**, eg *Phytophthora* in plants, soil and water.
  - **Soil probes** can measure soil moisture, temperature and salinity.
- **Obtain information on the biology of the disease or pest**, eg host range, symptoms, life cycle, overwintering, spread, conditions favouring.
- **Options for prevention and control**. Most economic crops have Integrated Pest Management **(IPM)** programs, Quality Assurance **(QA)** systems or computer programs detailing processes for managing crops from **'field-to-plate'**.
- **Internet sources** can be very helpful, but use with caution as many problems listed do not necessarily occur in Australia or in your region.
- If you have **not** yet identified the problem, move to Step 5.

XPERT

Different diagnostic services offer different test facilities

Some industries have their own diagnostic services, eg grapevines, cereals, turf

STEP 5. CONSULT A DIAGNOSTIC SERVICE. **see Preface page xii**

- **To confirm or obtain a diagnosis**.
- **Types of services** available include:
  - Identification of diseases, pests, beneficials, weeds, also symptoms.
  - Advice on monitoring and thresholds, eg sticky traps, scouting, Cropwatch.
  - Advice on control and **IPM**, purchase of beneficials.
  - Develop disease management systems for some crops, eg Asian vegetables.
  - Testing for pesticide resistance, eg is your weed resistant to glyphosate?
  - Quarantine assistance, incursion management.
  - Disease-testing for accreditation/certification schemes, eg raspberry, garlic, ornamentals, nurseries; microbial testing for Quality Assurance.
  - Seed, plant tissue, soil, media and water testing and analyses.
  - How to collect and dispatch samples.
  - Pest and disease fact sheets for key pests, diseases and weeds.
  - Services are usually 'user pays'. Expense may be necessary for effective control.
  - Training workshops on diagnosis and control in particular crops.
  - Distance diagnostics by specialists.

The Author's Aim in this series of books is to provide users with the systematic understanding of Plant Protection and Plant Management required of modern horticulture. The books are used to teach Plant Protection throughout Australia and as a reference by people working in the horticulture industry.

Ruth Kerruish's interest in diseases and pests of plants commenced with her post-graduate studies at the University of Western Australia. She later worked as a researcher with CSIRO (Forest Products, Melbourne and Plant Industry, Canberra) and taught Plant Protection in the Department of Horticulture in the Canberra Institute of Technology.

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Plant Protection Series:

1. Pests, Diseases and Weeds
2. Methods of Control
3. Selected Ornamentals, Fruit and Vegetables
4. How to Diagnose Plant Problems

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