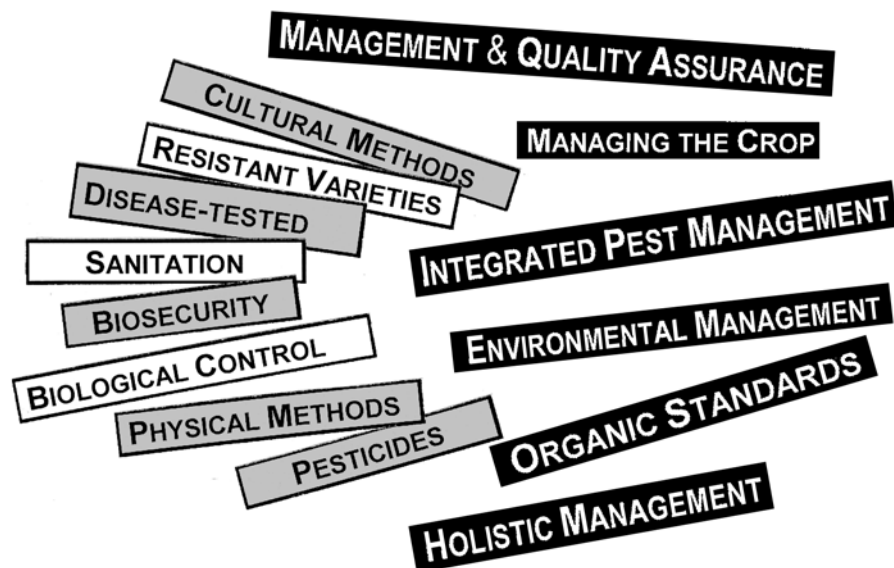


PLANT PROTECTION 2

Control Methods and their Management

4th edition



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

Control Methods and their Management

- **Control Methods**
 - Cultural methods
 - Sanitation
 - Biological control
 - Resistant, tolerant varieties
 - Biosecurity
 - Disease-tested planting material
 - Physical methods
 - Pesticides
- **Management & Quality Assurance**
 - Managing the crop
 - IPM (Integrated Pest Management)
 - Environmental systems
 - Organic standards
 - Holistic management

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
- Trees, shrubs and climbers
- Turf grasses
- Vegetables
- Also Australian native plants, Bonsai, Compost, Containers, Garden centres, Greenhouses, Herbs, House plants, Hydroponic systems, Interior landscapes, Manure, Mulches, Nurseries, Plant tissue culture, Postharvest, Potting mixes, Seedlings, Seeds, Soil, Urban bushland, Urban landscapes, Water, Water plants, Xeriscapes.

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 2

**Control Methods and
their Management**

4th edition

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

ROOTROT PRESS ACT

Copyright

Copyright for material in this book is held by the authors, illustrators and third parties who have made photographs, drawings and product labels available for educational purposes only. Trademarks used in this book to describe firms or their products are trademarks of those firms or the registered proprietor of the trademark and are therefore also protected by copyright. Other material in this book is available for personal use.

FOURTH EDITION PUBLISHED 2014

Previous editions: 1st edition 1985; 2nd edition 1990, 3rd edition 2001

Copyright©2014 Ruth M. Kerruish
Copyright©2014 Adrienne L. Walkington

DISTRIBUTED BY:

Qld Textbook Warehouse
PO Box 3220, Brackenridge, Qld, Australia 4017
☎ 07 3261 1300 1800 611300 Fax 07 3261 1966
email: info@qtw.com.au
web: www.qtw.com.au/

PRINTED BY:

Kwik Kopy Printing Strathpine
172 South Pine Road, Brendale 4500
☎ 07 3881 3133 Fax 07 3881 3260
email: sales@strathpine.kwikkopy.com.au
web: www.kwikkopy.com.au/

PUBLISHED BY:

RootRot Press - ACT
22 Lynch Street, Hughes,
Canberra, ACT, Australia 2605
☎ (02) 6281 3650

ISBN 978-1-875907-08-3 (print)

Dewey Number: 632.90994

Author: Kerruish, Ruth M. (Ruth MacNeil), 1936- author.
Walkington, Adrienne L., illustrator.
Title: Plant protection: control methods and their management /
Ruth M Kerruish; illustrations by Adrienne L Walkington.
Edition: 4th edition.
Series: Plant protection; v. 2.
Subjects: Horticulture--Australia.
Weeds--Control--Australia.
Pests--Control—Australia. Plants,
Protection of Australia.
Agricultural pests--Control--Australia.
Plant diseases--Control--Australia.

ISBN 978-1-875907-09-0 (ebook)

By the same author:

PLANT PROTECTION 1: Pests, Diseases and Weeds (with Phillip Unger)

PLANT PROTECTION 3: Selected Ornamentals, Fruit and Vegetables

PLANT PROTECTION 4: How to Diagnose Plant Problems

Disclaimer

This book is **a guide only**. While the information in this book is believed to be accurate at the time of publication, the author and publisher make no warranties, expressed or implied, as to the accuracy, adequacy or currency of the information presented in this book. The material contained in this book is not intended to provide specific advice.

No reader should act on the basis of anything contained in this book without taking appropriate advice **on their own particular circumstances**.

It should be recognized that there are differences in soils, climates and seasonal conditions, and that pests, diseases and weeds do not occur uniformly across Australia and may spread to new regions within Australia. New pests, diseases and weeds may enter Australia. Advisors and growers will need to adapt information to suit their particular conditions, regions and situations.

Reference to a product or a particular brand of product in this publication (whether the reference appears in an illustration, photograph or in any other form) does not imply the author's or publisher's approval or endorsement of the product or the brand. Similarly, by the omission of certain trade names and some formulated products, either unintentionally or from lack of space, the author or the publisher is not inferring that these products or brands are not approved.

By allowing the use of their product labels and other material, companies do not imply that they are endorsing the contents of the publication. Although efforts are made to have up-to-date material, labels change, and with time the labels in this publication may not be the current version.

The author and publisher do not guarantee the current status of registered uses of any of the pesticides or other products mentioned as these are constantly changing. Users must comply with current pesticide legislation and follow instructions on currently registered labels attached to the container. If information in this book conflicts with that on a current label, follow label instructions.

Summaries of legislation should **not** be regarded as a legal interpretation which should be sought from the administering authority. Legislation is subject to amendment and updating from time to time so it is necessary to keep up-to-date with any changes.

Websites referred to, or activated in this book, are not under the control of the author or publisher who accept no responsibility or liability in relation to their content.

**CHECK CURRENT REGISTRATION
STATUS OF PESTICIDES PRIOR TO USE**

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

Acknowledgements

The author would like to acknowledge the contributions made by the many professional people and their organizations that have made this book possible.

I would particularly like to thank Bill and Douglas Kerruish for their advice and support and Stefan Alexander and John Kerruish for their computing assistance.

The following drawings, diagrams, photographs and labels are reproduced for educational purposes only with permission of:

<p>Copyright©Canberra Institute of Technology. page 13. Black spot (scab) on pears page 35. Oedema page 139. Rust on antirrhinum, oak leafminer (Fig.16) pages 147, 315, 339. Twospotted mites pages 147, 307. Hormone herbicide injury to grape page 222. Apple russet ringspot symptoms</p> <p>Copyright©NSW Department of Industry and Investment. page 13. Magnesium deficiency page 34. Carnation frost page 38. Wind damage to citrus (Fig.5) page 51. Citrus deficiencies (Fig.6) page 79. Fruit tree borer damage page 98. Common spotted ladybird page 104. <i>Helicoverpa</i> caterpillars page 139. Woolly aphid damage, rust on geranium (Fig.16) page 167. <i>Rhizctonia solani</i>, <i>Sclerotium rolfsii</i>, <i>Phytophthora</i> (Fig18) page 307. Hormone herbicide injury to tomato (2,4-D)</p> <p>Copyright©State Forests of NSW. page 139. Gumtree scale (Fig.16)</p> <p>Copyright©CSIRO Australia. page 71. Compost (Handrek 1994) (Fig.9) page 85. Rust on skeleton weed page 85. Pest and natural enemy population dynamics page 89. Rabbits round a water hole (Fig.12) page 91. Cactoblastis caterpillars page 94. Cactoblastis caterpillars and damage</p> <p>Copyright©State of Victoria. Department of Sustainability and Environment Marks, G. C., Fuhrer, B. A. and Walters, N. E. M. 1982. Tree Diseases in Victoria. Forests Com., Vic. page 153. Gray mold on callistemon</p> <p>Copyright©The State of Queensland (through the Department of Agriculture, Fisheries and Forestry 2014. page 192. Electric ants</p> <p>Copyright©Australian Department of Agriculture. page 193. Branched broomrape page 178. Giant African snail page 185. Asian gypsy moth caterpillar</p> <p>Copyright©Plant Health Australia (PHA). page 177. Key components of Australia's Plant Biosecurity Continuum pages 76, 80, 201. Farm Biosecurity Sign</p> <p>Copyright©APVMA. page 287. Model Pesticide Chemical Labels (Table 21)</p> <p>Copyright©Insense/Desire Pest management page 245. Desire codling moth trap</p> <p>Copyright©Agsafe. pages 263, 282, 292, 309. <i>DrumMUSTER</i> logo pages 281, 309. Agsafe logo</p>	<p>Copyright©Min of Agriculture NZ. page 193. White rust of chrysanthemum</p> <p>Copyright©Dr Louise Morin CSIRO. pages 12, 147. Myrtle rust</p> <p>Copyright©Yates. page 9. Problem Solver</p> <p>Copyright©Organic Logos. page 388. Australian Certified Organic (ACO) page 388. NASAA Certified Organic (NCO) page 389. Organic Food Chain (OFC) page 389. Tasmanian Organic Dynamic Producers (TOP) page 389. Bio-Dynamic Research Institute (BDRI) page 389. Safe Food Production Queensland (sfq) page 390. Organic Federation of Australia (OFA)</p> <p>Copyright ©TAIR (www.arabidopsis.org). pages 168, 409. Arabidopsis</p> <p>Copyright©Shanahan, G. J. and Hughes, P. B. 1981. Looking at Insecticide Resistance. Seed & Nursery Trader. pages 303, 428. Selection of Resistant Pests</p> <p>Copyright©Wendy Unger. pages 183, 201. Apple</p> <p>Copyright©Cygnis insignis.Public domain.Oz Native plants. page 254. Bull banksia</p> <p>Copyright©Shirai, Y. et al. (2005). "Directional Control in Thermally Driven Single-Molecule Nanocars". Nano Letters. 5 (11): 2330–4. page 422. Chemical structure of a nanocar</p> <p>Copyright ©Pesticide and other Product Labels</p> <table border="0"> <tbody> <tr> <td>AgBiotech</td> <td>Monsanto</td> </tr> <tr> <td>Agrimm Technologies</td> <td>Multicrop</td> </tr> <tr> <td>Bayer</td> <td>Organic Crop Protectants</td> </tr> <tr> <td>Becker Underwood</td> <td>Sanoway</td> </tr> <tr> <td>Bioglobal</td> <td>Scotts Australia</td> </tr> <tr> <td>Chemtura</td> <td>SST Australia</td> </tr> <tr> <td>Colin Campbells</td> <td>Syngenta</td> </tr> <tr> <td>Crop Care</td> <td>UPL</td> </tr> <tr> <td>Desire</td> <td>Valent BioSciences</td> </tr> <tr> <td>Dow AgroSciences</td> <td>Yates</td> </tr> <tr> <td>Ecogrow</td> <td></td> </tr> </tbody> </table>	AgBiotech	Monsanto	Agrimm Technologies	Multicrop	Bayer	Organic Crop Protectants	Becker Underwood	Sanoway	Bioglobal	Scotts Australia	Chemtura	SST Australia	Colin Campbells	Syngenta	Crop Care	UPL	Desire	Valent BioSciences	Dow AgroSciences	Yates	Ecogrow	
AgBiotech	Monsanto																						
Agrimm Technologies	Multicrop																						
Bayer	Organic Crop Protectants																						
Becker Underwood	Sanoway																						
Bioglobal	Scotts Australia																						
Chemtura	SST Australia																						
Colin Campbells	Syngenta																						
Crop Care	UPL																						
Desire	Valent BioSciences																						
Dow AgroSciences	Yates																						
Ecogrow																							

Contents



Prelims
Identify the pest, pest information
Control methods
Cultural
Sanitation
Biological control
Resistant, tolerant varieties
Biosecurity
Disease-tested planting material
Physical methods
Pesticides
Management and Quality Assurance
Managing a crop
Integrated pest management (IPM)
Environmental management
Organic standards
Holistic management
Appendices
Appendix 1. Plagues and epidemics
Appendix 2. Genetic engineering (GE)
Appendix 3. Nanotechnology
Appendix 4. Risk assessment and management
Appendix 5. Pesticide resistance
Appendix 6. Pesticide residues (MRLs, WHPs, trade)
Appendix 7. 3 Generations of pesticides
Appendix 8. Training
Glossary
Index

Prelims

Copyright	ii
Disclaimer	iii
Acknowledgements	iv
Contents	v
Preface	ix

IDENTIFY THE PEST, PEST INFORMATION 1

Why identify pests, non-pests and beneficials?	2
Difficulties in identifying the host	4
Difficulties in identifying the pest	5
Other difficulties in the diagnostic road map	8
Diagnostic and information services	9
Identifying the pest and control	12
Review questions and activities	14
Selected resources	14

CONTROL METHODS 15

Host, pest and the environment	16
In a perfect world	17
Different control methods	18
Control methods for different objectives	19
Preventative and curative	19
Exclude, eradicate, contain, manage	20
Crop stages	22
Management	23
Limitations to choice of controls	24
Commonalities	25
Time and timing are everything	26
People and pests, diseases and weeds	27
Challenges	28
Review questions and activities	28
Selected resources	28

CULTURAL METHODS	29
Introduction	30
Modifying the environment	32
Planting, spacing, pruning, etc	42
Soil and soil organic matter (SOM)	43
Mulches	46
Nutrients	48
Conservation tillage (CT)	54
Crop rotation (CR)	56
Fallowing	58
Mixed plantings	59
Managing cultural methods	60
Pros, cons and challenges	63
Review questions and activities	63
Selected resources	64
SANITATION	65
Introduction	66
Diseased and infested plant material	67
Disposal and recycling	70
Hands, equipment, containers, soil	74
Mowers, harvesters, brushcutters	76
Managing sanitation	77
Pros, cons and challenges	81
Review questions and activities	82
Selected resources	82
BIOLOGICAL CONTROL	83
Introduction	84
Rabbits and other vertebrate pests	89
Weeds	91
Insects and allied pests	98
Plant diseases and abiotic factors	112
Effective biological control	125
Managing biocontrol methods	131
Pros, cons and challenges	134
Review questions and activities	135
Selected resources	135
RESISTANT VARIETIES, TOLERANT VARIETIES	137
Introduction	138
When to use resistant, tolerant varieties	142
Abiotic traits being looked at today	144
How plants defend themselves	148
Sources of resistant genes	151
How resistant, tolerant plants are produced	154
Screening plants for resistance, tolerance	159
Breakdown of resistance	162
Managing plant resistance	164
Pros, cons and challenges	169
Review questions and activities	169
Selected resources	170
BIOSECURITY	171
Introduction	172
Shared responsibility	174
Legislation and trade	176
Biosecurity – Commonwealth	177
Offshore activities	178
Border activities	182
Onshore activities	186
Biosecurity – State, Territory, Regional	196
Biosecurity – on-farm, orchard, nursery	200
Pros, cons and challenges	203
Review questions and activities	204
Selected resources	204

DISEASE-TESTED PLANTING MATERIAL 205

- Introduction **206**
 - Disease-free or disease-tested? **207**
- Contaminated planting material **208**
- Treatments to eliminate diseases and pests **213**
- Area freedom **218**
- Certification schemes **219**
- Managing disease-tested planting material **223**
 - Preventing re-infection or re-infestation **223**
 - Using certified plant material **226**
- Pros and cons and challenges **227**
- Review questions and activities **228**
- Selected resources **228**

PHYSICAL METHODS 229

- Introduction **230**
- Abrasive and absorptive inert dusts **231**
- Electric discharges **231**
- Environmental gases **232**
- Frightening devices and sound responses **232**
- Irradiation **233**
- Light-induced phenomena **234**
- Physical shocks **236**
- Relative humidity **237**
- Temperature **238**
- Traps and barriers **244**
- Managing physical methods **253**
- Pros, cons and challenges **255**
- Review questions and activities **256**
- Selected resources **256**

PESTICIDES 257

- What are pesticides? **258**
- Legislation **259**
 - Commonwealth legislation (registration) **259**
 - State / Territory legislation (control of use) **268**
 - Local government (councils) **270**
 - Regulations, Codes, Standards, Duty of Care **271**
- User licensing **273**
- User training **274**
- Manufacturers and retailers **281**
- Pesticide chemical labels **283**
 - Understanding pesticide chemical labels **287**
- Safety data sheets (SDSs) **293**
- Issues of concern and opportunities **297**
- Managing pesticides **314**
- Review questions and activities **315**
- Selected resources **316**

MANAGEMENT & QUALITY ASSURANCE (QA) 317


- Management systems **318**
- Quality assurance (QA) **320**
- Some Management / QA programs **324**
- Challenges **326**
- Selected resources **326**

MANAGING THE CROP 327

- Planning **328**
- Growing the crop **330**
 - Selection **330**
 - Establishment **331**
 - Maintenance **331**
 - Harvest and postharvest **332**
- The audit **332**
- Improve **332**

IPM - Integrated Pest Management	333
What is IPM?	334
Steps in successful IPM	336
Step 1. Forward planning	336
Step 2. Crop, farm, orchard, nursery, area	338
Step 3. Identify key pests and beneficials	339
Step 4. Preventative measures	342
Step 5. Monitoring pests and beneficials	343
Step 6. Thresholds	346
Step 7. Curative measures	347
Step 8. Evaluation (3 rd party audit)	350
Examples of integrated management	351
Crops and situations	351
Integrated Pest Management (IPM)	352
Integrated Disease Management (IDM)	353
Integrated Weed Management (IWM)	355
Pros and challenges	357
Review questions and activities	357
Selected resources	358
ENVIRONMENTAL MANAGEMENT	359
Introduction	360
Legislation, standards, codes, etc	362
Environmental management	363
Best Management Practice (BMP)	363
Environmental Management Systems (EMS)	364
Tool kits for EMS / QA programs	365
Environmental Assurance (EA) for horticulture	366
Sustainable agriculture / horticulture	370
Ecologically sustainable development (ESD)	370
Precision agriculture (PA) and Precision horticulture (PH)	372
Conservation agriculture (CA)	374
Resilient systems	375
Biological farming, organic farming, permaculture	376
Integrating EMS with other systems	377
Challenges	379
Review questions and activities	379
Selected resources	379
ORGANIC STANDARDS	381
Standards	382
Certification	384
General requirements	384
Production requirements	385
Certification requirements	386
Approved Certifying Organizations (ACOs)	388
Other organic and advisory groups	390
A National Organic Logo / Mark	391
Managing organic standards	392
Pros, cons and challenges	394
Review questions and activities	396
Selected resources	396
HOLISTIC MANAGEMENT	397
Features	398
Examples of holistic management	399
Challenges	402
Selected resources	402
APPENDICES	
Appendix 1. Plagues and epidemics	403
Appendix 2. Genetic engineering (GE)	409
Appendix 3. Nanotechnology	419
Appendix 4. Risk assessment and management	425
Appendix 5. Pesticide resistance	427
Appendix 6. Pesticide residues (MRLs, WHPs, Trade)	429
Appendix 7. 3 Generations of pesticides	432
Appendix 8. Training	441
GLOSSARY & ACRONYMS	445
INDEX	455

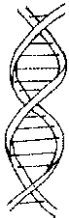
Preface

<p>What is in this book?</p> <p>Changes in this 4th edition</p> <p>Of the 4 books in the Plant Protection series, Plant Protection 2 – Methods of Control and their Management, is most subject to change</p>	<p>This book is a guide to understanding methods of controlling diseases, pests and weeds and how they are used in management and quality assurance programs. Each control method and management and quality assurance system is described, and the advantages, disadvantages, challenges, review activities and selected resources of each are listed.</p> <p>In this edition, the pesticide section has been greatly reduced to reflect the development of nationally accredited training courses in the safe handling and use of pesticides. The parts retained include legislation, training, labels and safety data sheets; a new section describes some issues of concern facing the industry.</p> <p>Non-chemical control methods have been expanded to reflect the need to develop more environmentally friendly methods and encourage the adoption of management and quality assurance systems.</p> <p>It is emphasized that a thorough understanding of the different control methods is required before their application in management and quality assurance programs. The following is a summary of the contents of the 4th edition:</p> <p>Control methods:</p> <ul style="list-style-type: none"> Cultural methods Sanitation Biological control Resistant, tolerant varieties Biosecurity Disease-tested planting material Physical methods Pesticides <p>Management and quality assurance (QA):</p> <ul style="list-style-type: none"> Managing a crop Integrated Pest Management (IPM) Environmental Management Organic Standards Holistic Management <p>Appendices</p> <ul style="list-style-type: none"> Appendix 1. Plagues and epidemics Appendix 2. Genetic engineering (GE) Appendix 3. Nanotechnology Appendix 4. Risk assessment and management Appendix 5. Pesticide resistance Appendix 6. Pesticide residues (MRLs, WHPs, Trade) Appendix 7. 3 Generations of pesticides Appendix 8. Training
<p>Factors likely to impact on the immediate future of horticulture and agriculture</p>  <p>Science has given us iPhones, the internet and GPS</p> <p>Knowledge is our greatest asset</p>	<p>Information Technology (IT). The increased capacity of computer-based information systems, our access to them and the rapidly expanding availability of applications software have had a huge impact on our industry. It provides easy and immediate access to a range of topics and activities including:</p> <ul style="list-style-type: none"> • Legislation, regulations, standards, codes of practice, etc. • Diagnosis of pests, weeds and diseases, diagnostic networks, remote microscopy. • Market information, trade statistics. • Management tools and systems which are getting larger and more complex, eg risk management, environmental management systems, organic standards, Quality Assurance (QA), Integrated Pest Management (IPM), holistic management. • Crop simulation models, crops sensors, grower applications, expert systems. • Information on new crops and cultivars, pesticides, advanced practices. • Training / updating skills, lifelong learning. • Improved communication between all sectors of the industry, websites, blogs, twitter, facebook. • Vast amounts of data can be processed and accessed. • Transfer of knowledge and technology, knowledge partnerships between government, industry and the community. • Simplifying record keeping, electronic diaries, hand held data loggers, storage and retrieval systems. • Early warning systems for pests and diseases. • Weather information for crop choice, planting / harvesting dates, spraying parameters. • Precision agriculture for large and small areas, fertilizers, irrigation and weeds. • Real time weather, on the go sensing for herbicides, fertilizing and irrigation. • Risk assessment and decision making.



Legislation, Acts of parliament and their regulations, standards and codes. An important aspect of horticulture and agriculture that is often of least interest to growers.

- **IT** makes it easy to access current legislation on Commonwealth and State websites and to keep up-to-date. There is no excuse for not knowing legislative requirements.
- There is a wide range of legislation which regulates both chemical and non-chemical methods of disease, pest and weed control.
- The trend is to harmonize State and Territory legislation making it easier for businesses and workers to comply with their work and safety responsibilities, eg pesticide registration, control of use and training requirements.



Biotechnology. Recent developments in **genetic engineering** point the way to new crops and crop management practices that can increase production, plant breeding, diagnostic tests, quality and profitability, eg

- The synergies of IT and biotechnology.
- New crops, new varieties.
- Higher crop yields.
- Herbicide-tolerant crops.
- Insect resistant crops, eg **Bt** crops.
- Disease resistant crops, eg for rust diseases.
- Crops which tolerate drought, waterlogging, heat, frosts.
- Multi-trait, high yielding cultivars.
- Biofortified crops, eg to produce omega 3, vitamin A.
- Manipulating micro-organisms, eg nitrogen-fixing bacteria, biological control agents, more effective biological control programs.
- DNA diagnostic tests, molecular tests.
- Other biotechnologies include **nanotechnology** and **3D Printing** of cells that can then secrete or produce the plant and other products that we want.

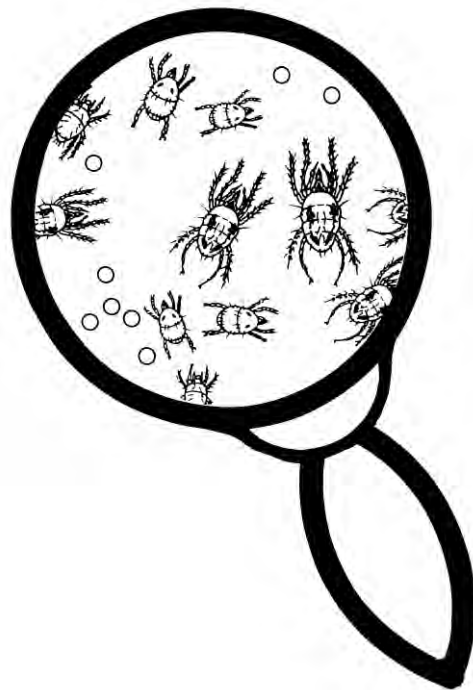
Social pressures. Community concern about food residues, land use practices and the desire to minimize environmental costs, will continue to impact on growers, reflecting itself in:

- Legislation that regulates practice.
- Market demands, eg price, organic crops.
- Grower focus on market requirements.
- Building grower management skills and capacity, eg elements that have the greatest impact on profitability, resilience and sustainability.
- Perceptions - both real and unreal - of what constitutes 'good practice'.
- **The adoption of safe workplaces** and concern for operator safety, eg desire to use less hazardous pesticides and extending the use of non-chemical control methods.
- **Minimizing pesticide residues in food**, eg fruit, vegetables and in animal feed.
- **Concern for the environment**, eg using less persistent pesticides.
- Increasing the uptake of reduced tillage and low hazard pesticides, including biological chemical products.
- Reducing land degradation and the impact of climate change.



Occasionally diagrams and topics are repeated in different sections of the book; however this is because they are important issues that warrant reinforcement in different contexts.

IDENTIFY THE PEST, PEST INFORMATION



WHY IDENTIFY PESTS, NON-PESTS AND BENEFICIALS?	2
DIFFICULTIES IN IDENTIFYING THE HOST	4
DIFFICULTIES IN IDENTIFYING THE PEST	5
OTHER DIFFICULTIES IN THE DIAGNOSTIC ROAD MAP	8
DIAGNOSTIC AND INFORMATION SERVICES	9
IDENTIFYING THE PEST AND CONTROL	12
REVIEW QUESTIONS AND ACTIVITIES	14
SELECTED RESOURCES	14

WHY IDENTIFY PESTS, NON-PESTS AND BENEFICIALS?

Diagnostics is essential for IPM, biosecurity and all plant health programs.

As a minimum, be able to identify the **key pests, diseases and weeds** and their **beneficials** in your **crop**.

However, remember, it is just as important to know what it is not, as to know what it might be.

Costs



Growers everywhere may lose crop value due to pests, diseases, weeds, unseasonal weather and are also faced with the increasing costs of chemicals, fuel, labor and seed. Plant pests and diseases are major constraints to agricultural production and food security in developing countries.

- **In horticulture and agriculture there are high financial gains** to be made in the control of weeds.
- **25% of costs to consumers** associated with food products are due to invasive weeds, pests and diseases.
- **It has been estimated that if left uncontrolled**, stripe rust alone, could wipe almost \$1 billion from wheat returns nationally.
- **Biosecurity measures** that limit the loss of food from the spread of pests and diseases can reap the same, if not greater benefits, as efforts to increase yield.
 - Without management controls, estimates of losses from pests, disease or weeds:

Rice	64-80%
Potatoes	73-80%
 - Some examples of losses caused by individual diseases and pests include:
 - Phytophthora* costs of lost production and control measures are in excess of \$300 million / year in Australia
 - Black Sigatoka on bananas can reduce yields by 50%
 - Rice blast production losses could feed 60 million people
 - Rodents consume at least 6% of a rice crop

Legislation



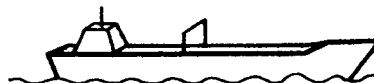
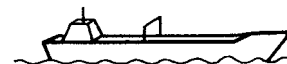
XPERT




Only once the identity (and biology) of a pest, disease or weed is known, can control methods be developed. Some control methods may be mandated by law, eg

- **Pesticides** are registered for use for particular **pests** on particular crops.
- **Sanitation** measures required for fruit fly.
- **Use of a resistant variety** or tolerant variety in a particular area.
- **Disease-tested** seed standards.
- **Biosecurity**. Mis-identification of an exotic pest species poses as much of a threat to trade as the actual presence of a pest species.
- **It is essential for continuity of trade to know:**
 - Which exotic pests, diseases and weeds **are not known to occur** in Australia and in which other countries they **do occur**, so that **phytosanitary measures** can be put in place.
 - **Similarly when exporting products**, some countries do not have some of the pests, diseases and weeds present in Australia. This also applies to trade between States / Territories and regions within Australia.
 - **Accurate, reliable accessible and speedy diagnostic tests** play an important role in providing the ability to demonstrate and potentially certify that a product is free from a specific pest at the point of import or export.
 - **Accurate diagnosis and associated information** assist in effective responses and for maintaining the biosecurity service and standards required to meet Australia's obligations under existing World Trade Organization (WTO) agreements. These include identifying pest-free areas.



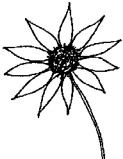

Trade



<p>Control methods</p> 	<p>Identification of pests, diseases and weeds in your crop is a crucial first step in finding effective responses to preventing their spread. This includes:</p> <ul style="list-style-type: none"> • Identifying beneficial insects, diseases, etc which may also be present. • Early detection of pests, diseases and weeds in a crop is vital if they are to be contained. Know when, where and what to look for or test, eg <ul style="list-style-type: none"> • When, eg presowing soil and water diagnostic tests. • Where to look, seed, traps, roots, soil, etc. • What to look for or test, eg adult insects, larvae, soil fungal diseases. • Similarly early detection of exotic diseases that are a biosecurity threat to Australian agricultural and horticultural industries is vital if they are to be eradicated or contained and appropriately managed. • Detection of plant pathogens in seed, vegetative propagating materials and in plant products is also an essential component of disease management strategies.
<p>Management & Quality assurance (QA)</p> <p>IPM</p> <p>QA</p>	<p>Identification of pests is an essential step in all management and QA systems and provides access to information on the problem and the appropriate responses. Incorrect identification can lead to inappropriate control methods.</p> <ul style="list-style-type: none"> • Integrated pest management (IPM) involves correctly identifying the various stages of a pest, disease or weed in a crop and clarifying environmental effects, thresholds, and other factors which affect pest populations, such as beneficial insects and plant growth, eg <ol style="list-style-type: none"> Step 1. Plan Step 2. Crop, region Step 3. Identify the problem and any beneficials Step 4. Preventative control measures Step 5. Monitor Step 6. Threshold Step 7. Curative control measures Step 8. Evaluate the effectiveness of the IPM program • Quality Assurance programs involve declaring treatments, inspections, etc: <ul style="list-style-type: none"> • Pest-free zones. • Vendor declarations. • Certification schemes. • Phytosanitary certificates (biosecurity). • Best Management Practices.
<p>Forecasting epidemics</p>	<p>Disease diagnosis is the first step in the prediction of probable outbreaks or increases in intensity of disease and allows us to determine whether, when, and where a particular management practice should be applied.</p> <ul style="list-style-type: none"> • Initial misdiagnosis of the real pathogen is likely to miss the appropriate management measures early in the development of the epidemic and make it difficult to prevent serious losses. • Forecasting plant disease epidemics involves an assessment of initial inoculum of disease and monitoring weather factors that affect disease development (page 407).
<p>Access information</p>	<p>Correct identification of the various stages of the diseases, pests and weeds enables you to locate information on the problem and the appropriate responses. Much of the information is available free online, eg</p> <ul style="list-style-type: none"> • Best Practice manuals and Quality Assurance programs are available for most of the economic crops in Australia. • Industry Biosecurity Manuals for various crops are available on the Plant Health Australia website to assist industry with the major biosecurity threats for their crops. • Fact sheets for a range of pests, diseases and weeds are available from State / Territory websites (see also page 341). <ul style="list-style-type: none"> Scientific name / common name Identification of pest (diagnostics) Importance of pest Host range, crops, regions, situations Description, damage, symptoms Disease / pest / weed life cycle Overseasoning Spread Conditions favoring, epidemiology Management and Control <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p style="text-align: center;">Fact Sheet</p> <p>Chilean needlegrass</p> </div> <div style="margin-top: 10px;">   </div>


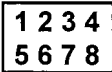

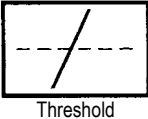
DIFFICULTIES IN IDENTIFYING THE HOST

Difficulties with host identity may mean that diagnosis may take longer or be inconclusive.

<p>New crops, new varieties, new hosts, trade</p>	<p><u>New crops and new varieties of crops are continually being developed</u>, some for new regions and markets, new ornamental flower cultivars, others to produce higher yields, tolerance to drought. Some may be susceptible to previously uncommon diseases.</p> <ul style="list-style-type: none"> • Host cultivars may be difficult to identify with certainty. The Olive Cultivar Identification System™ (OCIS) has enabled the verification of about 100 olive varieties using a database of DNA fingerprints. www.oliveaustralia.com.au • Host ranges may rapidly expand soon after arrival, eg myrtle rust (<i>Uredo rangelii</i>). Known pests and diseases may extend their host range and regions of occurrence. Climate change may exacerbate this problem. • Increased demand and new markets for Australia's fledgling white pea industry in India and China. • New crops. As many growers look to new crops to help differentiate themselves and improve profits, it is imperative to recognize different cultivars and learn their cultural requirements as well as their potential susceptibilities. • Most is known about crop species, but there are still many problems of pasture, forest, ornamental and Australian plants that have not been fully investigated.
<p>What is its correct name?</p> 	<p><u>Do you need the botanical or common name or both?</u> Diagnosticians should aim to know the genus and species. Common names are acceptable for home gardeners.</p> <ul style="list-style-type: none"> • The name of the cultivar and the family to which the plant belongs is often useful. • Marketing or trade names can be confusing. • Horticulturists often identify plants by image-matching, but some may be able to use keys to identify plants to family, genus and species. • It may be necessary to check references such as International Code of Botanical Nomenclature (ICBN) or Royal Horticultural Society (RHS) Plant Finder. If proof of identification is required, plant material can be sent to a botanic garden or diagnostic service. • If a definitive identification is necessary, DNA fingerprinting can be done by experts. • Scientific names of host plants may change.
<p>Access to information</p>	<p><u>Identifying the host plant</u> can open the door to a wealth of information.</p> <ul style="list-style-type: none"> • Be aware of legislation and why plant identification is important for biosecurity, trade and contact with other industries or organizations. • Access a list of known and potential pests and diseases to which your crop is susceptible in your region. If the plant is not listed, select a closely related species with care. • Access a fact sheet for each present and potential pest listed for your crop. They will provide information to help you identify and effectively control the problem.
<p>Be willing to seek help</p> 	<p><u>Never be unwilling to seek advice regarding a plant / variety identification</u></p> <ul style="list-style-type: none"> • Some plants and weeds are easily misidentified, eg proteas / waratahs, deciduous plants when not in leaf, bare-rooted nursery stock. Clients often bring in samples with only a few leaves, or without flowers or seeds. Some hosts like grasses may be difficult to identify, eg tussock grasses. • If host identify is uncertain or unknown, diagnostic services can assist with plant identification. A pest index may be useful.
<p>Which other plants may need to be identified?</p> <p><i>Example only</i></p>	<p><u>List types of other plants</u> growing near (around, over or under) crop plants.</p> <ul style="list-style-type: none"> • If it is a pest or disease problem and you want to apply an insecticide or fungicide, you must also know the botanical and common names and types of other plants growing near the affected plants, including both desired and weed species. • If it is a weed problem, both the weeds and surrounding plants must be correctly identified before herbicide recommendations can be made. <ul style="list-style-type: none"> • Find out the botanical or common names and types of other plants growing near the weeds, eg whether the crop is broadleaved or grass-like, annual or perennial. • If herbicides are to be applied to weed seedlings, recognize the different stages of weed growth. And the name of the crop or situation in which the weed is growing.
<p>Plant labels</p>	<p><u>The National Plant Labelling Guidelines</u> helps the nursery and garden industry provide clear and accurate information on plant labels.</p> <ul style="list-style-type: none"> • These guidelines aim to establish an accepted standard in the preparation of plant labels and marketing material. • They are recommended for adoption by all plant producers, suppliers of plant material, plant retailers and label manufacturers.

DIFFICULTIES IN IDENTIFYING THE PEST

<p>Ideally</p>	<p>You should be able to distinguish between:</p> <ul style="list-style-type: none"> • Key pests, diseases and weeds and their beneficials. • Minor pests, diseases and weeds and their beneficials. • Non-pests (diseases, pests and weeds) and their beneficials. <p>But this is a big ask!</p>
<p>The extent of what you have to be able to identify for a start</p>	<p>Examples include:</p> <ul style="list-style-type: none"> • Key pests and beneficials. Growers need to be able to distinguish between: <ul style="list-style-type: none"> • Different types of insects, eg aphids, whiteflies, thrips, wasps, ladybirds. • Different life cycle stages, eg eggs, caterpillars / nymphs, adults. You need to know which stage will be monitored. • Insect genera and usually species, but identifying strains needs expert assistance. • In some vineyards the symptoms of phylloxera may not be recognized for 3-5 years after initial infestation. • Key diseases and their beneficials <ul style="list-style-type: none"> • Some virus, bacterial and fungal diseases can usually be recognized visually from symptoms on leaves and other plant parts but for an accurate diagnosis, microscopic examination and DNA tests are required. • Non-parasitic problems, eg nutrient deficiencies, can be checked using soil, plant tissue and water analyses. • Key weeds and their beneficials, biocontrol agents <ul style="list-style-type: none"> • Understanding the biology of the problem weeds is necessary in order to recognize when they are at their most vulnerable stage for control. • Recognition of seedling leaves of crop weeds is important for early weed control.
<p>Constant additions to your repertoire</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-top: 10px;"> <p>Pest, disease and weed incursions are likely to increase because of travel</p> </div>	<p>Examples include:</p> <ul style="list-style-type: none"> • Emergence of established pests, diseases and weed, eg <ul style="list-style-type: none"> • Instances of fungal diseases have been increasing in severity and scale since the middle of the 20th century, mainly due to trade and travel, and now pose a serious danger to global food security and the environment. The threat to plants from fungal infections has now reached a level that outstrips that posed by bacterial and viral diseases combined and is projected to continue rising (Fisher et al 2012). • Re-emerging pests, diseases and weeds, eg Irish blight of potato has become a re-emerging disease worldwide, more than 150 years after the great famine. <ul style="list-style-type: none"> • The disease has reached epidemic proportions in North America, Russia, and Europe due to the development of resistance to phenylamide fungicides in populations of the pathogen and the widespread occurrence of new genotypes. • New pests, diseases and weeds, eg <ul style="list-style-type: none"> • Crops develop new pests and diseases both within Australia and overseas. • Carrot virus Y (CVY) is a newly-described aphid-borne virus that is currently threatening our national domestic and export carrot industries. • New viruses are found, eg Capsicum chlorosis virus (CaCV) discovered in tomato, capsicum, hoya and peanut. • Incursions from overseas which growers may not recognize. • Weeds become common problems in certain crops and seasons. • New hosts of pests and diseases, eg <ul style="list-style-type: none"> • Many pests extend their host range under certain conditions, eg black scale. • New weed hosts of CaCV. • New species, new strains, new hybrids of the pest, eg <ul style="list-style-type: none"> • Wheat rusts, eg strain UG99 which is not yet known in Australia. • Strains of pests, diseases or weeds resistant to insecticides, fungicides or herbicides respectively. • Different strains of a pathogen, eg myrtle rust, identification of which was initially uncertain. New strains of tomato spotted wilt virus (TSWV) in capsicum in SA. • New varieties of plants with resistance or tolerance to certain pests and diseases. • Rhizoctonia root rot (<i>Rhizoctonia solani</i>) is classified into 13 strains or subgroups. The so-called “potato-attacking” strain usually belongs to the AG3 group; however, the AG2 strain can also attack potatoes and many other plant families. So if Rhizoctonia is a problem get the strain identified. • More hybrids of Phytophthora have been discovered in WA's forests, heathland and waterways, some of which could pose a threat similar to the deadly <i>P. cinnamomi</i>, the most well known cause of Phytophthora dieback. Some have not previously been found anywhere else and several exotic species never recorded before in WA. The new species were identified using DNA technology that enables them to be distinguished from similar species (White 2012). www.sciencewa.net.au • New parts of a life cycle which were previously unidentified or unknown or the viewer is not familiar with. • New vectors of virus diseases. Identifying the insects that transmit crop diseases (and the plants that host disease between cropping seasons) is a crucial part of research efforts that will help manage and control the spread of both established and exotic viruses.

<p>Types of pests</p> 	<p>Key problems, eg brown rot of stone fruit, which appear year after year at such levels that control measures, are essential if economic losses are to be avoided.</p> <ul style="list-style-type: none"> • Occasional pests, eg cottony cushion scales, which in most places and at most times are under adequate control, occasionally they escape restraints and the population rises to economic levels. • Potential pests which cause no significant change in the agro-ecosystem in its current state but which could become troublesome if it changed. • Non-resident and migratory pests, eg locusts, which appear from time to time and may invade a crop in large numbers.
<p>Several 'causes' may contribute to disease or pest damage</p>	<p>Plants in the field are rarely attacked by a single kind of pathogen or pest.</p> <ul style="list-style-type: none"> • Furthermore it is not unusual for nearly 50% of all of the problems brought to grower clinics for diagnosis to be caused by abiotic problems, eg culture, environmental stress or injury due to pesticide application. • More often than not leaf spots and blotches caused by abiotic factors may be present along with spots and blemishes caused by fungi or bacteria and so the real cause may be difficult to diagnose accurately. • This is more likely in the early stage in the development of a disease when accurate assessment is most needed for determining if a threshold for the development of an epidemic has been reached and appropriate control measures need to be initiated. • Misdiagnosis of the real problem means that appropriate management measures will not be carried out early in an outbreak. • Diseased seedlings or other plant materials are often symptomless when shipped and planted, resulting in rapid and widespread outbreaks.
<p>Common names, Scientific names of pests</p>	<p>Global re-classifications and confusions.</p> <ul style="list-style-type: none"> • Classification of the fungi seems to be updated regularly. • A case has been made for re-inventory of some of Australia's disease organisms, eg <i>Botryosphaeria</i>, <i>Colletotrichum</i>, <i>Fusarium</i>, <i>Phomopsis / Diaporthe</i> and <i>Mycosphaerella</i>. Validation can only be done for suspect identities if specimens are re-collected, re-isolated and subjected to DNA analysis and living culture. • Pests, diseases and weeds may change their scientific names. • Most, pests, diseases and weeds have several common names. • The identity of sting nematode which is widespread in the Sydney-Newcastle area and around Perth has always caused confusion as 2 sting nematodes have been described from turf in Australia, <i>Ibippora lolii</i> from Newcastle and <i>Morulaimus gigas</i> from WA while a third species <i>Belonolaimus longicaudatus</i> which has also been found in Australia, is a major problem on turfgrass in the south east of the USA. Another issue in Australia is whether we are dealing with native or introduced species.
<p>Monitor and test at the right time</p>   	<p>Know when the pest is likely to be active, and when to monitor, decision support systems will help with this.</p> <ul style="list-style-type: none"> • Regular monitoring is carried out for some pests, eg <ul style="list-style-type: none"> • Exotic fruit flies in northern Australia. • Fruit fly-free Tasmania continually monitors for fruit flies in order to maintain its fruit-fly free status. • Early detection of exotic diseases that are a biosecurity threat to Australian horticultural industries is vital if they are to be contained or appropriately managed. To assist industry awareness the major biosecurity threats for most economic crops are illustrated and described in Industry Biosecurity Manuals (page 187). • Lentil anthracnose (<i>Colletotrichum truncatum</i>) remains a major threat to the lentil industry both in Australia and overseas. • Some soilborne diseases are more difficult to detect and monitor. Potato cyst nematode was probably in Australia for decades before being detected and identified. It is possible the exotic crater rot of carrots (<i>Rhizoctonia carotae</i>) may not be detected for some time after arrival. • Quality assurance management requires regular monitoring, early detection, correct pest identification and early action, eg regular checking / monitoring of stored grain is fairly simple, and should really be a monthly practice for farmers during the year and as often as fortnightly in the warmer spring and summer conditions. • Seasonal monitoring may be necessary, eg <ul style="list-style-type: none"> • If significant pest numbers are detected during autumn monitoring of paddocks before sowing, they are likely to cause significant crop damage at emergence. Consider the use of seed dressings or rotating with a less susceptible crop. • Predictive / decision-support / warning systems may be available that tell you when to monitor.

The tests themselves



As detecting and identifying pathogens provides the basis for understanding their biology and selecting appropriate control strategies, improved tests are constantly being sought. For example, Australian scientists have developed a far more accurate test for the devastating apple and pear disease fire blight that will help keep Australia free of the disease. Fire blight is endemic in most apple-producing countries including NZ. Fortunately a gene in a wild apple species conferring resistance to fire blight has been identified.

DNA sequencing has become one of the most important tools for identifying organisms and for biodiversity studies (see chromosomes on page 140).

- **DNA (deoxyribonucleic acid)** is the genetic code that contains all the information needed to build and maintain an organism (page 140).
- The **Biosecurity Bank** provides a reference collection of DNA from a range of agriculturally important plant pathogens and pests for molecular analysis. Where possible **DNA** specimens are linked to voucher specimens to allow taxonomic verification.
- **DNA sequencing has been made much more effective** through the use of the **polymerase chain reaction (PCR)** technique which amplifies greatly the specific fragment of **DNA** present on a probe and produces millions of copies which are abundant enough to be detected, identified and studied by conventional and other molecular tools. This enables minute quantities of the target pathogen's **DNA** to be detected.
- **Species-specific PCR assays** for the rapid and accurate detection of *Phytophthora* species in infected plant tissues, soil, and water are being developed, eg for *Phytophthora capsici* which is a serious disease affecting pepper production and other important vegetable crops.
- **Through DNA-based analysis** the emergence and spread of **highly aggressive forms** of Irish blight (*Phytophthora infestans*) have been identified. These aggressive strains have displaced other less aggressive forms in Europe and are one reason why the disease has become more difficult to manage.
- **DNA assays are available for root pathogens** such as take-all and *Rhizoctonia* by SARDI's Root Disease Testing Service in SA.
- **Automated spore traps**. **DNA** assays allow **the rapid and accurate detection of spores** of blackleg of canola, yellow leaf spot of wheat, as well as for ascochyta of chickpeas and net blotch on barley. The **DNA** assays allow spore traps to be used to determine the number of spores released per week or per day enabling better timing of fungicide applications.
- **Soil tests**. The **PreDicta B Test** can identify the risk of the incidence of root diseases before seeding (page 12).
- **For some diseases**, eg citrus canker (*Xanthomonas campestris* pv. *citri*) testing is now safer (cultures are not required) and more reliable.

Other ways of testing plant material for various problems are described on page 212. The use of drones, etc in data collection is outlined on pages 372, 373.

The trend is generic multi-taxa tests, eg having one test that detects more than one disease of interest

National protocols are in place so that everyone uses the same method to identify a particular problem.

Diagnostic protocols are described on page 189.

OTHER DIFFICULTIES IN THE DIAGNOSTIC ROAD MAP

Side effects of control methods	<p>When pests become resistant to pesticides they tend to spread from country to country. So called “super-resistance” tends to develop in countries with a wide range of pesticides, high pest pressure and the minimal use of biological or integrated controls.</p> <ul style="list-style-type: none"> Control one pest using resistant or genetically modified crops and other minor pests may become pests due to declining use of insecticides, etc.
Changing in farming practices	<p>An ever-changing range and intensities of pests, diseases and weeds have often occurred as a consequence of changing cropping systems, eg</p> <ul style="list-style-type: none"> Ginger rhizomes designated for planting were invariably infected with <i>Fusarium oxysporum</i> f. sp. <i>zingiberi</i> (<i>Foz</i>) (Stirling 2004). <ul style="list-style-type: none"> The soft rot bacterium (<i>Erwinia chrysanthemi</i>) was also recovered from rotting seed-pieces but nearly always in association with <i>Foz</i>. It was not involved in the disease under normal soil moisture conditions but rotting often occurred when seed pieces were inoculated with both <i>E. chrysanthemi</i> and <i>Foz</i>. <i>Foz</i> was found to be the main cause of poor emergence as only fungicides effective against <i>Foz</i> reduced the percentage of seed-pieces that rotted in the ground. Changes in growing practices may be responsible for increased disease severity.
Minor crops, other plants	<p>If the crop / plant is not a key economic crop difficulties may be encountered at each step:</p> <ul style="list-style-type: none"> The enquiry may not be clear. The identity of the host may be unclear. No fresh specimen, sample not representative, photograph unclear. Unable to visit site, no tests. Resources not readily available, or minimal. Expert help – and diagnostic protocols not available. Reporting the diagnosis therefore, can be unsatisfactory. Sometimes problems remain unresolved for a long time.
The Diagnostic Road Map	<p>General steps for advisors are well documented in the diagnostic road map (Fig. 1 below). Remember that although a diagnosis may be made at any step and steps may be by-passed, combined or re-visited, steps should not be omitted without consideration.</p> <ul style="list-style-type: none"> Unfortunately, sometimes there is a disinclination to seek professional help. This can apply to all areas of pest control.

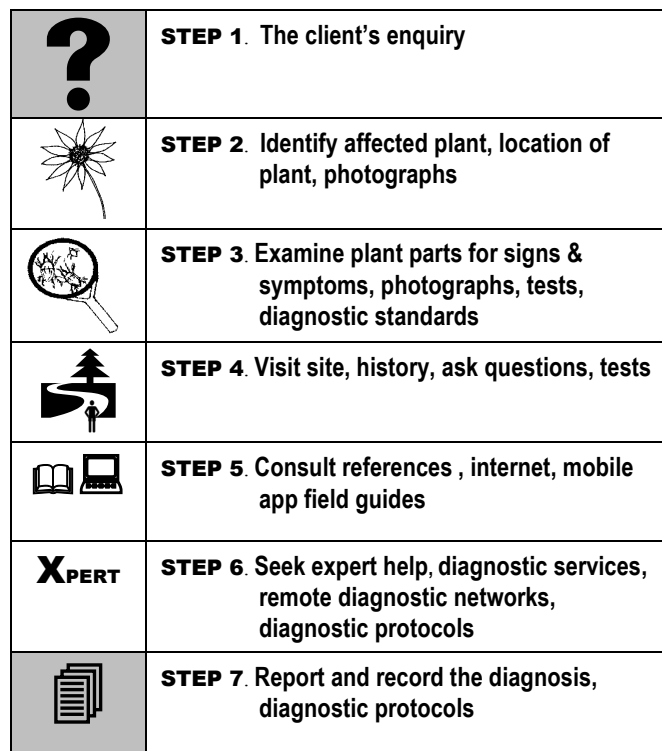


Fig. 1. The Diagnostic Road Map.

DIAGNOSTIC AND INFORMATION SERVICES

Home garden advice

Free home garden advice may be provided by your local horticulture college, botanic gardens, garden centers, and garden clubs. Talkback radio, Gardening Australia TV and newspapers all provide further opportunities for gardeners to seek advice. On-line fact sheets and problem solvers are a big help. However, a pest still needs to be correctly identified, so plant specimens or their photos may still need to be sent or taken to a garden advisory service. Remember some problems can still be difficult to identify from photographs.



Yates Problem Solver App for iPad and iPhone. Photos©Yates.

Relating to your crop online

Most industries have Best Practice manuals and Quality Assurance programs which include photographs and information on the economic pests, disease and weeds of their crops. Biosecurity has prepared **Industry Biosecurity Manuals** for crops of economic importance. Fact sheets on individual pests, diseases and weeds are also available.

Field diagnostic kits and iPhones

Never be unwilling to seek advice if unsure

Exotic Plant Pest Hotline
1800 084 881

Report an unusual pest, disease or weed

An increasing trend is field diagnostics, ie for programs to be available on iPhones to diagnose symptoms caused by common problems. You can just feed in a photograph of a weed, pest or disease, etc.

- **Growers are all familiar** with **water, soil tests, nutrient and plant tissue analysis** and are always requesting new field diagnostic kits.
- **Many of the investments** in managing and controlling pests, diseases and weeds relate to improving the accuracy, reliability, accessibility and speed of diagnostic tests.
- **More and more diagnosis is being determined by diagnostic kits** and new technologies providing more accurate diagnoses of economically important exotic and endemic diseases, eg black sigatoka disease (*Mycosphaeraella fijiensis*) of bananas.
- **DNA tests** are available for root knot and other nematode species.
- **Soil tests** aim to allow identification of a range of soilborne organisms including nematodes from a single soil sample (page 12).
- **A simple dip stick test for bacteria** is a long term objective.
- **Lucid tools** are available for a wide range for insects and weeds.
- **Hotlines** can help.
- **New Iphone apps are constantly being developed**, eg for vertebrate pests.
- **Beneficial insects**. Rapid molecular tests to identify Australian parasitoid species are being developed.

Commercial diagnostic services

Commercial diagnostic services and pest management services are offered by State / Territory Departments, consultants, industry associations, etc. Some are free, others are cost recovery.

- **Most diagnostic services specialize** in pests or diseases, soil or water testing, etc.
- There are diagnostic services for some **crops**, eg grape, cotton and turf.
- **Some crops have a 'One Stop Shop for Your Crop'** via the internet, eg CropWatch Online for grapevines.
- **The Nursery & Garden Industry** has developed a pest identification tool for use in the field on handheld PDAs (Personal Data Assistants) and some Smartphones.
- **Local councils offer advice on noxious weeds and vertebrate pests, bees, possums.**
- Examples of diagnostic services are shown in Table 1.

Table 1. Examples of commercial diagnostic services.

<p>Australia-wide</p> <p>GrowSearch Australia A National Ornamental Crop Database and Information Centre ☎ (07) 3824 9555 www.ngia.com.au</p> <p>Biosecurity</p> <p>Plant Health Australia is the lead national coordinating body for plant health in Australia. There are links to the website below at www.planthealthaustralia.com.au/</p> <p>Emergency Plant Response Deed (EPRD) Underpinning the EPRD is PlantPlan the agreed technical response plan used by jurisdictions and industry in responding to an Emergency Plant Pest (EPP) incident.</p> <p>PaDIL (Pest and Diseases Image Library) provides high quality images of exotic organisms, assists with diagnostics and encourages public awareness in biosecurity. www.padil.gov.au</p> <p>National Pest and Disease Outbreaks <i>Outbreak</i> only reports on pests and diseases that are exotic to Australia, and are under eradication programs. www.outbreak.gov.au/</p> <p>A Remote Microscope Network (RMN) RMN provides timely and accessible information on outbreaks of exotic plant pests and diseases and diagnostic information on emergent plant pests.</p> <p>CSIRO - Australian National Insect Collection (ANIC) The ANIC is the pre-eminent collection of Australian insects, maintained by CSIRO for researchers, industry and government agencies. Australian National Insect Collection - ACT Clunies Ross Street, Acton ACT 2601 ☎ 1300 363 400 www.csiro.au/ email: Enquiries@csiro.au</p> <p>SESL Australia Soil, plant, water advice for agriculture, environment, horticulture, turf, and waste. 16 Chilvers Rd, NSW 2120 ☎ 1300 30 40 80 www.sesl.com.au</p> <p>AUSVEG The national peak industry body for vegetable and potato growers. Search their website for diagnostic services www.ausveg.com.au</p> <p>Northern Australia</p> <p>Northern Australia Diagnostics Network (NADN) NADN is concerned with detection, management and control of diseases and pests of horticulture and agriculture in the NT, north WA and north Qld. www.tpp.uq.edu.au/Default.aspx?tabid=722</p> <p>Australian Capital Territory</p> <p>XCS Consulting A European Wasp and Insect Identification Service. ☎ (02) 6282 5325 www.xcsconsulting.com.au</p>	<p>New South Wales</p> <p>Plant Health Diagnostic Service (PHDS) laboratories www.dpi.nsw.gov.au/</p> <p>Elizabeth MacArthur Agriculture Institute (EMAI) Woodbridge Road, Menangle, NSW 2568 ☎ (02) 4640 6327 email menangle.rvl@industry.nsw.gov.au</p> <p>Orange Agricultural Institute Forest Road, Orange, NSW 2800 ☎ (02) 6391 3800, 1800 675 821 email orangeai.phds@industry.nsw.gov.au</p> <p>Plant Disease Diagnostic Service Royal Botanic Gardens & Domain Trust Mrs. Macquarie's Road, Sydney, NSW 2000 ☎ (02) 9231 8186 www.rbgsyd.nsw.gov.au/ email: pddu@rbgsyd.nsw.gov.au</p> <p>Northern Territory</p> <p>Dept. of Primary Industries and Fisheries (DPIF) www.nt.gov.au/d/Primary_Industry/ look for laboratory services</p> <p>Entomology A range of entomological services is provided to growers, government departments, householders, home gardeners and the general public.</p> <p>Plant Pathology Branch Identifies plant diseases caused by various bacteria, fungi, nematodes, phytoplasmas, viruses and viroids as well as non-living agents. Also develops disease management practices.</p> <p>Address Berrimah Agricultural Laboratory (BAL), Berrimah Farm Makagon Road, Berrimah, NT 0828 ☎ (08) 8999 2261 (Plant Pathology)</p> <p>Queensland</p> <p>Dept. of Primary Industries</p> <p>Grow Help Australia provides a disease and pest diagnostic service for horticultural crops, testing for disease organisms in plants, seeds, potting mix, soil and water; plant pathogen testing to fulfil nursery accreditation scheme and export requirements; remedial advice. www.dpi.qld.gov.au/26_12360.htm</p> <p>Grow Help Customer Service ☎ 13 25 23 or 07 3404 6999 email growhelp@daff.qld.gov.au</p> <p>HORTUS Technical Services Australia Laboratory and field testing, pre- and post-plant analysis, fruit testing, potting mixes, quick soil and hydroponic tests, fruit, sap tests and potting mix tests, pest monitoring, training. Unit 1, 336 Goodwood Rd, Bundaberg Qld 4670 ☎ (07) 4132 5000 email: techservices@hortus.net.au www.hortus.net.au/</p> <p>South Australia</p> <p>SA Research and Development Institute (SARDI) www.sardi.sa.gov.au/ and follow the links</p> <p>Crop diagnostics provide seed and plant pathology services, virus testing, nematode identification and sampling ☎ (08) 8303 9384</p> <p>Horticulture Diagnostic Services provide disease diagnosis, virus testing, nematode identification and sampling ☎ (08) 8303 9585</p> <p>Insect Diagnostic Services provides insect identification, biological control advice when requested. They offer free insect diagnostic service for PestFact subscribers. ☎ (08) 8303 9539</p> <p>PreDicta B (B = broadacre) is a DNA based soil testing service to identify which soilborne pathogens which pose a significant risk to broadacre crops prior to seeding.</p> <p>Cropwatch SA online Bookpurnong Road, Loxton, SA 5333 www.cropwatch.com.au/</p>
---	--

Tasmania

Department of Primary Industries, Parks, Water and Environment

Weeds, pests and diseases

www.dpipwe.tas.gov.au/ and search for invasive species

Invasive Species Enquiries

171 Westbury Road
Prospect, TAS, 7250

☎ (03) 6777 2200

email: invasivespecies@dpiwpe.tas.gov.au/

Victoria

Department of Primary Industries

Crop Health Services (DPI – Knoxfield) provides diagnostic services for plant diseases and pests and management recommendations as appropriate. Also provides disease-tested planting material of potatoes, strawberries and other crops and monitoring services. 621 Burwood Highway, Knoxfield, Vic 3180
Fernree Gully Delivery Centre, Vic 3156

☎ (03) 9210 9356

www.dpi.vic.gov.au and search for Crop Health Services

Cropwatch

Cropwatch is the division of **Fruit Growers Victoria Ltd** which provides Integrated Pest and Disease Management (IPDM) and field services to commercial fruit growers on a fee for service basis.

Global

PestNet is an email network that assists growers overseas with diagnostics and advice.

Western Australia

Department of Agriculture and Food, Western Australia (DAFWA)

AGWEST Plant Laboratories: Plant Disease Diagnostics

Provides a range of services including seed certification, weed and insect identification and plant disease diagnosis. Department of Agriculture and Food Western Australia
3 Baron-Hay Court, South Perth, WA 6151

☎ (08) 9368 3333

www.agric.wa.gov.au/

Grain Guard and Hort Guard provide specialist diagnostic service for many plants problems, eg broomrape.

- **PestWeb** - a searchable database that contains identification and control information for insect pests of farms and quarantine significance.
- **Keys to allied pests of extensive agriculture** - an adapted and abridged web version of the popular extension booklet.
- **Identifying and managing aphids in potatoes** - aphid management and identification keys
- **Bruchid pest host database** - a database to outlining bruchid pests, distribution and various host plants.

Pest and Disease Information Service (PaDIS)

Free advice and specimen identification

Free call 1800 084 881 or email: info@agric.wa.gov.au

Turf Consultants

Australian Golf Course Superintendents Assoc. (AGCSATech)

Suite 1, Monash Corporate Centre
752 Blackburn Road, Clayton VIC 3168

☎ (03) 9548 8600

www.agcsa.com.au/

Globe Australia

Soil testing and plant diagnostic services
87 Allingham St., Condell Park, NSW 2200

☎ (02) 8713 5555

www.globeaustralia.com.au/turf

SportsTurf Association (STA)

Diagnostic Soil, Water and Plant Analysis

Soil, plant tissue and water analysis
Disease, insect and weed identification

Nematode testing

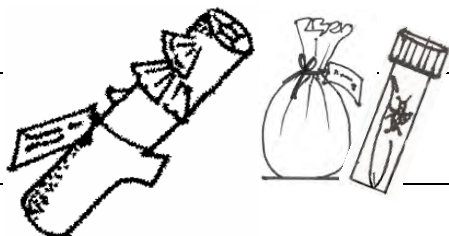
45 Westerfield Drive
Notting Hill VIC 3168

☎ (03) 9574 9066

www.sportsturf.com.au and follow the links to your State or Territory

SAMPLES

- Consult the advisory service or website 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.
- Photographs, digital images and maps assist diagnosis.
- Soil and water samples must be in secure containers.
- All samples must be clearly labeled.
- Diagnostic forms can be downloaded from the laboratory's website, filled in and attached to the specimen.
- If posting specimens use express post and mark urgent.
- Postal address may be different from delivery address.



Services offered include:

Pest and disease identification
Weed identification
Online diagnostics
Guidelines for control
IPM strategies

Some are highly specialized:

Nematode identification
Seed certification
Soil and water analysis
Soil moisture monitoring
Irrigation advice
Plant tissue analysis
Potting mix test
Sap tests
Fruit tests
Root identification
Environmental monitoring
Specific crops



DIAGNOSTICS ONLINE

PDA devices make it possible to have a complete guide for known crop pests and diseases on every grower's mobile phone, eg the electronic **Pest, Disease, Beneficial & Weed Identification** tool (Nursery & Garden Industry Qld (NGIQ)).

IDENTIFYING THE PEST AND CONTROL

Identify the problem then consider how it can be managed

Guava rust, eucalypt rust, myrtle rust

Myrtle rust is now established in Australia, eradication is not considered possible

Myrtle rust is a recent introduction to Australia.

- Guava rust (*Puccinia psidii*) in its native Brazil, was named after its original host plant. The pathogen infects developing foliage, flowers and fruits and stunts growth.
- Guava rust also attacks other plants in the Myrtaceae family, eg eucalypts, melaleucas in Australia and overseas.
- *P. psidii* became known as eucalyptus rust and recognized as a threat to eucalypt plantations across the globe, not to mention native Australian flora. In the early 1980s, a reference specimen representing *P. psidii* was discovered to contain two different kinds of spores, one 'prickly' all over, while the other presented a bald patch among its protuberances prompting its description as a 'complex' of biological forms.
- Three decades later, the form that produced the bald-patch spores was found in Australia in 2010 and was given the name ***Uredo rangellii***, referred to as myrtle rust.
- Today, it still remains unclear whether the complex of forms should be considered as a group of distinct species or merely varieties, in spite of no genetic differences being found between the forms. Until such questions are resolved, the pathogen continues to be technically defined as *Puccinia psidii* sensu lato (s.l.) (McRae 2013).
- **Various groups in Australia are working on the best way to manage myrtle rust** in particular situations, eg the **Australian Nursery Industry** has released **Myrtle Rust Management Plan 2011 Version 1.0.**
 - **For new plantings** the selection of species or varieties with some resistance or tolerance to myrtle rust is a must. This could decrease disease severity on susceptible species.
 - **For existing plantings** it is not so simple and will depend on the situation, eg doing nothing, spraying with an approved fungicide in a nursery, removing and disposing of diseased plants. An aim would be to reduce the spread and severity of the disease.



The fungal disease myrtle rust on *Agonis flexuosa* (willow myrtle). Photo©Dr Louise Morin, CSIRO.

Identify the problem before planting

**Root diseases
Soil tests**

SARDI (South Australian Research and Development Institute)

Knowing the risk of pests, diseases or weeds before sowing helps take the guesswork out of crop selection, eg

- **Root diseases are common** and interfere with root function, reducing a plant's ability to access water and nutrients.
- The **Predicta** team has gained a global reputation as leaders in DNA testing to indicate the risk of soilborne diseases to crops before they are sown.
- **Soil tests** indicate which susceptible crops to avoid in certain paddocks to safeguard income. Grain producers can access PreDicta B via agronomists accredited by SARDI to interpret results and provide advice on management options to reduce risk of yield loss.

Definition. PreDicta B (B = broadacre) is a DNA based soil testing service to identify which soilborne pathogens pose a significant risk to **broadacre crops prior to seeding**. It has been developed for cropping regions in southern Australia and includes tests for:



- Cereal cyst nematode
- Take-all (*Gaeumannomyces graminis* var *tritici* (Ggt) and *G. graminis* var *avenae* (Gga))
- Rhizoctonia barepatch (*Rhizoctonia solani* AG8)
- Crown rot (*Fusarium pseudograminearum* and *F. culmorum*)
- Root lesion nematode (*Pratylenchus neglectus* and *P. thornei*)
- Stem nematode (*Ditylenchus dipsaci*)
- Blackspot of peas (*Mycosphaerella pinodes*, *Phoma medicaginis* var *pinodella* and *Phoma koolunga*)

Dormancy of weeds seeds

Correct identification and biology

Weed life cycles and seed dormancy are important in determining control programs.

- **Rigid brome** (*Bromus rigidum*) seeds require exposure to chilling and dark conditions for germination. Seeds can persist in the soil for up to 3 years with more than 20% of the seedbank carrying over from one season to the next – **so a single year of management is likely to be ineffective** – at least 2 consecutive years of seed set control is needed (Baxter 2012).
- **Two highly invasive Hieracium species** (Asteraceae) have recently established in the Australian Alps, threatening biodiversity and agricultural productivity. A study of their seed ecology, establishing that *Hieracium* produces large amounts of short-lived seeds that readily germinate with light and moisture, leaving little to enter the soil seed bank. These findings, together with the fact that seeds are killed by high temperatures have important implications for the design of control programs that aim to eradicate the species (Bear et al 2012).

<p>Abiotic problems</p>	<p>Abiotic problems can be difficult to identify.</p> <ul style="list-style-type: none"> • Sunscorch can damage the leaves, fruit and limbs of stone fruit trees. Severely sunscorched trunks of ornamental <i>Prunus</i> may be invaded by secondary wood rots and insect borers, making it difficult to identify the original cause of the problem. • Frost can burn leaf edges of avocados, scar fruit, burn shoot tips and the surfaces of branches; newly planted trees may be ring barked. • Compare the photographs on the right. 	 <p>Left: A variegated lemon leaf (genetic makeup). Right: Magnesium deficiency, leaves develop green V-patterns on pale yellow background tissue.</p>
<p>The problem is identified but managing it is difficult</p>	<p>The soilborne plant pathogen <i>Phytophthora cinnamomi</i> is listed as one of the world's 100 worst invasive alien species by the International Union for Conservation of Nature (IUCN), yet it is still being spread in containers.</p> <ul style="list-style-type: none"> • In a study of nursery stock imported into WA from other states, <i>Phytophthora</i> species were present in 10% of the samples and <i>Pythium</i> species were present in 25% of the samples taken from 15 consignments. Plant pathogenic nematodes were isolated from 12 of 13 consignments. Nursery stock must be purchased from either accredited nurseries or those with high hygiene standards (Davison et al 2006). • Garden weed escapes. It is well known that certain plants sold by nurseries, may "escape" from gardens and become environmental weeds in certain regions of Australia. It has been difficult to persuade nurseries to toe the line. 	
<p>Apple and pear scab</p>	<p>Primary and secondary inoculum for apple scab (<i>Venturia inaequalis</i>).</p> <ul style="list-style-type: none"> • The amount of primary inoculum (ascospores) is usually large and is released over a period of 1-2 months following budbreak. Secondary infections (conidia) from this can be prevented with well-timed fungicide applications during blossoming, early leafing and fruit development otherwise the entire crop is likely to be lost. • Secondary infections (conidia) are produced with each succeeding generation and infect wet leaf or fruit surfaces at a range of temperatures from 6-28°C. By combining temperature and leaf wetness duration data the apple scab forecast system can predict whether the infection periods will result in light, moderate or severe disease. Growers can be advised of the need and timing of fungicide applications and about the kind of fungicide (protective or eradicant) that may be used to control the disease. 	 <p>Unmarketable pears. Scabbing and cracking caused by apple scab. Photo©CIT, Canberra Institute of Technology.</p>
<p>New DNA tests for biosecurity pest</p>	<p>DNA (deoxyribonucleic acid) is the genetic code that contains all the information needed to build and maintain an organism. The DNA test to identify organisms whether plant or animal has revolutionized diagnostics.</p> <ul style="list-style-type: none"> • Khapra beetle is one of the world's most damaging pests of stored grain but identification is not so simple. Misdiagnosis poses just as much of a threat through the imposition of trade barriers because of its presence. For this reason the following have been developed: <ul style="list-style-type: none"> • New protocols for DNA identification of different <i>Trogoderma</i> spp. and • A national <i>Trogoderma</i> laboratory and an international <i>Trogoderma</i> collection. 	
<p>Pests of stored grain</p> <p>Early detection, correct identification</p>	<p>Grain pest and grain quality management requires regular monitoring, early detection, correct pest identification and early action. Know when to monitor.</p> <ul style="list-style-type: none"> • If you find any insects it is important that you identify them correctly so as to be able to treat the infestation effectively. Different treatments are required for different pest species. Some species have resistance to certain chemicals. • The insect you have found may not even be a grain pest. • Early detection and correct identification of grain pests reduces grain losses, allows time for fumigation and reduces insect spread to other storages. 	
<p>New pests</p>	<p>The ease and frequency of world travel has led to increased movement of seeds, tubers, nursery stock and other agricultural goods and increased the possibility of introducing diseases and pests into areas where the hosts have not had a chance to evolve resistance to these problems. Local growers may not be quick in identifying the new problem.</p>	

REVIEW QUESTIONS AND ACTIVITIES

1. Name 2 reasons why you might be **unable to identify a host plant**.
2. Name 2 difficulties in **identifying a pest or disease**.
3. Why is **early detection** of a pest or disease important?
4. What **legal requirements** are there for you to identify a particular pest, disease or host?
5. Acquire a **fact sheet of a pest, disease and weed** in your crop.
6. Acquire a **fact sheet for a beneficial** of a pest in your crop.
7. List reasons why you might be unable to diagnose a **fugal leaf spot**.
8. Perform **practical exercises** in **diagnosing** plant problems.
9. Describe the **most important first step** of any **control recommendation**.
10. List the **7 steps** which should be followed through in the diagnostic road map.
11. Describe **3 reasons** why you need to know the **biology** of a weed, disease or pest.
12. Name **diagnostic services** available in **your region** for your crop:
 - Commercial growers.
 - Home gardeners.

SELECTED RESOURCES

- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- Agrans Research and White, B. 2010. *Impact Assessment Report Series: An Economic Analysis of GRDC Investment in the National Invertebrate Pest Initiative*. GRDC. (ATR00008 Nov 2010).
- Baxter, N. 2012. *Advisors Get Up to Speed on Weeds*. GRDC Jan-Feb.
- Bear, J. L., Giljohann, K. M., Cousens, R. D. and Williams, N. S. G. 2012. *The Seed Ecology of Two Invasive Hieracium (Asteraceae) Species*. Australian Journal of Botany 69 (7).
- Bodman, K., Carson, C., Forsberg, L., Gough, N., Hughes, I., Parker, R., Ramsey, M. and Whitehouse, M. 1997. *Ornamental Plants: Pests, Diseases*. Qld. DPI.
- Cooke, T., Persley, D. and House, S. 2009. *Diseases of Fruit Crops in Australia*. CSIRO Pub.
- Cooke, D. E. L., Cano, L. M., Raffaele, S., Bain, R. A., Cooke, L. R. et al. 2012. *Genome Analyses of an Aggressive and Invasive Lineage of the Irish Potato Famine Pathogen*. PLoS Pathogens 8 (10): e1002940.
- Davison, E.M., Drenth, A., Kumar, S., Mack, S., Mackie, A. E., and McKirdy, S. 2006. *Pathogens Associated with Nursery Stock Imported into Western Australia*. Aust. Plant Path. 35 (4).
- Fisher, M. C., Henk, D. A., Briggs, C. J., Browstein, J. S., Madoff, L. C. and McCraw, S. L. 2012. *Emerging Fungal Threats to Animals, Plant and Ecosystem Health*. Nature Vol 1(484) 12 April 2012.
- Goodwin, S., Steiner, M., Parker, R., Tesoriera, L., Connellan, G., Keskula, E., Cowper, B, Medford, A. and Rodriguez, C. 2000. *Integrated Pest Management in Ornamentals: Information Guide*. NSW Agric/HRDC, NSW Agric., Sydney. Also *Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide*.
- Handreck, K. and Black, N. 2010. *Growing Media for Ornamental Plants and Turf*. UNSW Press.
- Hertel, K., Roberts, K and Bowden, P. 2011. *Insect & Mite Control in Field Crops Area: Primary Industries Management Guide*. NSW DPI.
- Horne, P. and Page, J, 2008. *Integrated Pest Management for Crops and Pastures*. Landlinks Press.
- Kerruish, R. M. 2006. *Plant Protection 4: How to Diagnose Plant Problems*. RootRot Press ACT.
- McMaugh, J. 2000. *What Garden Pest or Disease is That?* Lansdowne Press, Sydney.
- McRae, M. 2013. *Whatever Happened to Myrtle Rust?* Ecos 21 June. Online.
- Moody, H. 2000. *Making Diagnostic Services Work for You*. Aust. Hort. Dec.
- Persley, D., Cook, T. and House, S. 2010. *Diseases of Vegetable Crops in Australia*. CSIRO Pub.
- Plant Health Australia **Industry Manuals** for growers, eg *Almonds, Apple and Pears, Avocadoes, Bananas, Berries, Cherries, Chestnut, Citrus, Cotton, Dried fruit, Ginger, Grains, Hazelnuts, Honey bees, Lychees, Macadamias, Mangoes, Passionfruit, Pineapples, Pistachios, Plantation forestry, Processing tomatoes, Production nurseries, Rice, Strawberries, Sugarcane, Summerfruit, Table grapes, Vegetables and Potatoes, Walnuts, Wine grapes*
- Rainbow, R. 2010. *Unified Attack on Pests and Diseases*. Ground Cover Supplement May-June 2010.
- Stirling, A. M. 2004. *The Causes of Poor Establishment of Ginger (Zingiber officinale) in Queensland, Australia*. Aust. Plant. Path. 33, 203-210.
- Storey, R. and Zborowski, P. 2003. *A Field Guide to Insects in Australia*. NSW DPI.
- White, N. 2012. *More Insidious Hybrids of Phytophthora Discovered*. Environment & Conservation. Jan 2012. www.sciencewa.net.au
- Commonwealth and State / Territory websites
State / Territory museums
Keys, eg Lucid keys, Qld
Apps have been developed for some pests, eg Field Guide to Pest Animals of Australia App
Growcom provides representation, leadership, information and consultancy services to the fruit, vegetable and horticultural industries in Qld.
PestNet (network of professionals assisting with diagnostic enquiries from Australia's region of the world) www.pestnet.org/
The Weed's Network - *The Weed's News* (join) www.weedsnetwork.com

CONTROL METHODS

Cultural methods



Sanitation



Biological control



Resistant varieties,
tolerant varieties



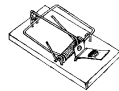
Biosecurity



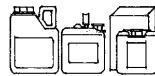
Disease-tested
planting material



Physical methods



Pesticides



HOST, PEST AND THE ENVIRONMENT	16
IN A PERFECT WORLD	17
DIFFERENT CONTROL METHODS	18
Control methods for different objectives	19
Preventative and curative	19
Exclude, eradicate, contain, manage	20
Crop stages	22
Management	23
LIMITATIONS TO CHOICE OF CONTROLS	24
COMMONALITIES	25
TIME AND TIMING ARE EVERYTHING	26
PEOPLE AND PESTS, DISEASES AND WEEDS	27
CHALLENGES	28
REVIEW QUESTIONS AND ACTIVITIES	28
SELECTED RESOURCES	28

HOST, PEST AND THE ENVIRONMENT

The Pest Triangle

For effective and efficient pest control it is essential to have knowledge of the host, its pests and diseases, their natural enemies and the environment. Environmental factors affect the development of **both** the host and the pathogen. This interaction is known as the “pest triangle” (Fig. 2. below). Eliminate or alter any of these 3 parts of the triangle and you change the ability of the pest to cause economic damage.

- **For a disease or pest to develop** all components must be present, eg
 - Susceptible host.
 - Aggressive pest or disease.
 - Environment favorable for the pest.
- **There is usually some stage in the pest or disease life cycle** in which we can intervene. This might be by acting on any one or two or all components, eg
 - **Pest.** You could remove alternate weed hosts where pests may survive and hand pick insects. Use weed, disease and insect-free soil and media, add beneficial predators or apply a pesticide at a vulnerable stage in the life cycle of the pathogen to restrict its development.
 - **Host.** Use genetically resistant plants, ensure optimal plant health, protect the host with defense activators.
 - **Environment.** Change humidity levels, alter temperature or sunlight levels, decrease or increase irrigation, etc.

POWDERY MILDEW CAN BE A SERIOUS DISEASE ON MANY ORNAMENTALS

- By applying a fungicide you will suppress the disease in the short term.
- Powdery mildew fungi are very sensitive to bright sunlight and air movement. Altering a shady environment by pruning will increase sunshine levels and limit fungal growth to some extent and may provide some long term control.
- By selecting a resistant variety you will achieve long term control.

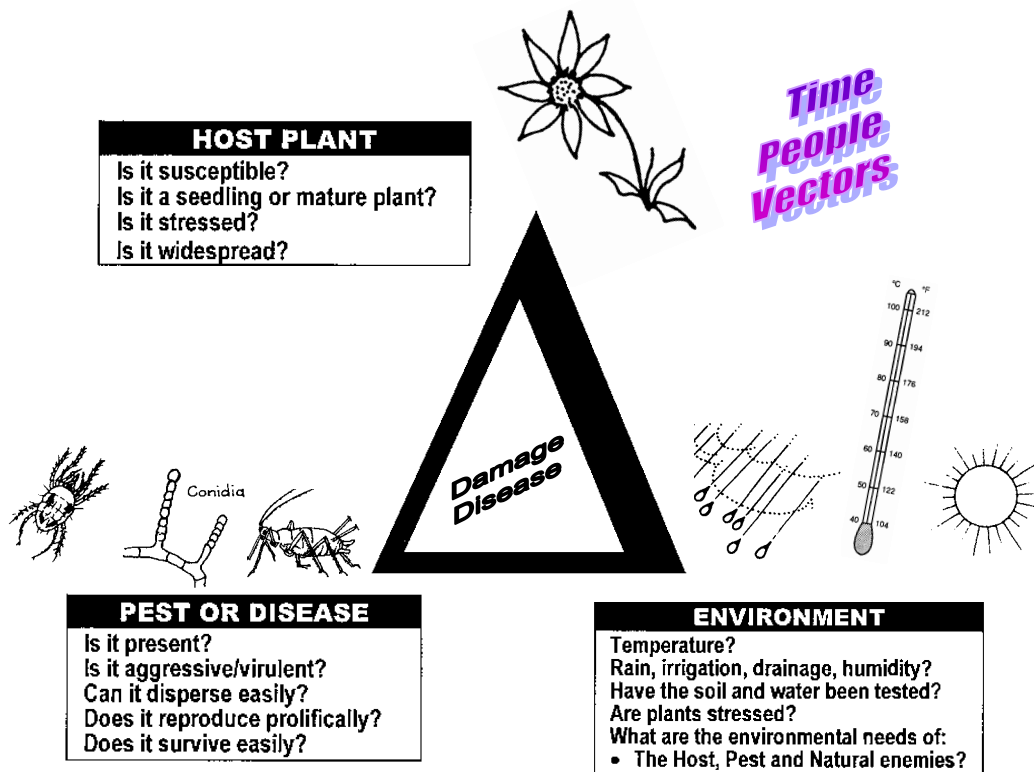



Fig. 2. A generalized pest and disease triangle showing the factors (not exhaustive) that affect the occurrence of a plant pest or disease. Ideally you should do a pest triangle for each major pest in your crop.

IN A PERFECT WORLD

There are many tools that can be used to minimize the damage caused by pests, diseases and weeds, ie to keep their populations at a level where the damage they cause is not economically significant. Control methods are examined **before** management systems because you need to understand them **before** you can integrate them into a management program. Control methods are changing all the time. They may be complex and difficult.







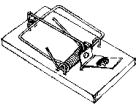
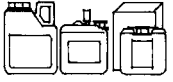
Perfect world	<p><u>In a perfect world</u>, we would prefer to use control methods in the following order:</p> <p style="text-align: center;">Biological > Physical > Non-chemical > Chemical</p> <p><u>However</u>, this is not always possible for a variety of reasons.</p>
<p>Whatever control methods are selected as a minimum:</p>  <p style="text-align: center;"><i>Attempt to anticipate unforeseen developments resulting from control actions</i></p>	<p><u>Legislation</u> must be complied with, eg</p> <ul style="list-style-type: none"> • Biosecurity Act, the Agvet Code, standards, codes of practice. • Training (mandatory in most cases if applying pesticides). • In some instances landholders are legally required to control declared pests. <p><u>Generally:</u></p> <ul style="list-style-type: none"> • Accurately diagnose the problem. • Prevent problems where possible, eg try to reduce population levels of the pest and protect the host. Problems should be dealt with when small rather than when out of control. • Responses must be based on the results of monitoring and be cost-effective. • Control measures are more likely to succeed where a range of different control methods are used, eg <ul style="list-style-type: none"> • Rotate crops, rotate crop varieties, practice mixed cropping. • Rotate control methods as in IPM (page 333). • Rotate pesticides and pesticide groups as recommended. • Use the least hazardous methods first that will provide satisfactory control, eg <p style="text-align: center;">Biological > Physical > Non-chemical > Chemical</p> <ul style="list-style-type: none"> • Use highly targeted methods, such as pheromones to disrupt pest mating, or physicals control, such as trapping or weeding. • If further monitoring, identifications and action thresholds indicate that less risky controls are not working, then additional pest control methods could be employed, such as targeted spraying of pesticides. Broadcast spraying of non-specific pesticides is a last resort. • There should be no side-effects from control actions, eg. <ul style="list-style-type: none"> • Try to anticipate unforeseen developments. • Do not damage beneficials and the surrounding environment. • Do a risk assessment on each control option regarding its effect on neighbouring people and beneficial and non-target plants, insects, animals and the environment. • Control methods that encourage biodiversity should be used where possible. • Methods must be sustainable and not have a broad impact on the environment. • Limit chance resistance / virulence development. • Keep accurate records. You may find that the same problems appear on the same hosts year after year. The pest triangle is dynamic and changes with time and the season. • Evaluate what you do; did it work?
Be prepared	<p><u>Food security</u> means being prepared for pests and diseases; this may involve:</p> <ul style="list-style-type: none"> • Maintenance of pest / disease free status. • Having access to germplasm collections that underpin the development of resistant / tolerant cultivars, eg pre-emptive breeding of resistant and tolerant varieties. • The availability of effective and safe plant protection pesticides. • Prioritizing problems.
Control methods	<p><u>Different control methods</u> are described briefly on the next page; they will be used in different ways depending on the situation, eg growing a crop, biosecurity requirements.</p> <ul style="list-style-type: none"> • Preventative and curative. • Exclude, eradicate, control, manage, eg biosecurity. • Different stages of the crop, eg selection, establishment, maintenance and harvest / postharvest. • Management.

DIFFERENT CONTROL METHODS

Rarely will a single control method provide good long term control.

These control methods should not be viewed as being mutually exclusive of each other. Each has its own advantages and disadvantages. Some control methods can overlap, eg digging up weeds is placed under physical methods here but may be placed under sanitation in other publications.


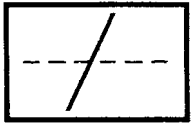
- **Frequently several methods are involved in the control of one problem.** Measures are more likely to succeed when a range of diverse control methods are employed and reliance is not placed solely on pesticides.
- **Some non-chemical control methods are effective against several pests, diseases or weeds,** eg certain hot water treatment of dormant vine cuttings and rootlets is used to control a number of external and internal pests and pathogens including nematodes, crown gall and Australian Grapevine Yellows (AGY).

<p>Cultural methods</p> 	<p>Many cultural practices (page 29) are useful in IPM systems, eg</p> <ul style="list-style-type: none"> • Crop rotation. • Timing of planting, sowing and harvesting to avoid peak diseases and pests. • Analyses of water, soil, and plant tissue. • Irrigation scheduling and planning. • Providing optimum culture for the crop, but least favorable for the pest, eg stressed trees are very susceptible to borer infestations.
<p>Sanitation</p> 	<p>Sanitation (page 65) is an essential part of Nursery Industry Accreditation Schemes and Biosecurity Industry Plans.</p> <ul style="list-style-type: none"> • Unfortunately the benefits of sanitation practices are often hidden and mostly impossible to quantify in cost / benefit terms. • Pruning cuts provide entry points for disease, wood rots. • Remove plant debris from growing facilities.
<p>Biological control</p> 	<p>Biological control (page 83) should be the cornerstone of IPM where possible.</p> <ul style="list-style-type: none"> • Biocontrol programs do not have disruptive effects on the natural enemies present in the environment and so can be integrated with partially resistant varieties. • Integration of biocontrol programs with pesticides can be difficult but it can be and is done. • Releases of biocontrol agents must coincide with susceptible pest stages. • Sources of biocontrol agents (page 125). • Know which biocontrols are present or could be introduced.
<p>Resistant varieties/host</p> 	<p>Resistant varieties (page 137) play a vital role in IPM systems, reducing the need for pesticides, allowing biocontrol agents and natural enemies of diseases and pests to play a significant role in pest control.</p> <ul style="list-style-type: none"> • Select resistant or tolerant cultivars, eg in areas where phylloxera occurs the growing of grape varieties on resistant rootstock may be compulsory. • Long term strategies include the pre-emptive breeding and commercialization of resistant or tolerant varieties which provides immediate protection and risk minimization if key economic pests and diseases should enter Australia.
<p>Biosecurity</p> 	<p>Biosecurity (page 171) to keep pests out of crop areas can be one of the first avenues considered to reduce the need for other control measures.</p> <ul style="list-style-type: none"> • Inspect and quarantine incoming plants for pest and other problems. • Biosecurity Industry Plans include contingency plans for exotic incursions. • Phytosanitary certificates may be necessary for export and imports.
<p>Disease-tested planting material</p> 	<p>Select disease-tested planting material (page 205) which is certified to be free from specified pests and diseases:</p> <ul style="list-style-type: none"> • This may be the only way a problem can be controlled, eg strawberry viruses. • Plant high quality “clean” planting material. Do not propagate from infested or diseased plants. • Use seed certified free of weed seeds, herbicide- resistant weed seed and varietal contaminants.
<p>Physical methods</p> 	<p>Physical methods (page 229) include:</p> <ul style="list-style-type: none"> • Insect-proof screens to exclude pests from greenhouses; shade clothe. • Sticky traps to monitor some flying pests. • Cooling or heat treatments of harvested fruit for controlling fruit flies. • Various traps and barriers.
<p>Pesticides</p> 	<p>Integration of pesticides with the action of natural enemies or biological control agents is an important technique of IPM systems. Pesticides must play a supportive rather than disruptive role (page 257).</p>

Control methods for different objectives

Preventative and Curative (for growers)

Many methods can be both preventative and curative

<p>Preventative</p>  <p>Hygiene!</p> <p>HIGH HEALTH VIRUS-TESTED ELITE STOCK</p>	<p>Presowing tests are a vital link in prevention, eg</p> <ul style="list-style-type: none"> Identifies threats, test the soil, seed, water, etc. <p>Prevent, where possible, the pest building up to damaging levels and protect the host plant, eg</p> <ul style="list-style-type: none"> Cultural methods, eg select paddocks carefully and use crop rotation; landscaping, mulching; plant when the pest, disease or weed is inactive, at low levels, absent or in geographic areas which are environmentally unfavourable to the pest, disease or weed. Adjust sowing rates, seed depth and weed control. Sanitation, eg reduce inoculum level of the pathogen, weed control, clean machinery. Control summer weeds to prevent them acting as a green bridge for aphids, rusts, snails, etc over the hot summer months. Biological control, eg soil biofungicides, pheromones. Resistance varieties, eg select crop varieties with some resistance to the key pests or diseases, such as rusts. Biosecurity, eg exclude the pest, avoid the pest and plant in areas where the pest is not present. The concept of evading or avoiding a disease or pest is not new. <ul style="list-style-type: none"> During much of the 20th century, banana production in Central America depended on evading <i>Fusarium</i> wilt or Panama disease (<i>Fusarium oxysporum</i> f.sp. <i>cubense</i>) of banana, by moving onto new, previously uncultivated fields as soon as older banana fields infected with <i>Fusarium</i>, became unprofitable. Disease-tested planting material, eg test and treat seed, use disease-tested rootstock. At least start with healthy seeds or planting material. Today, disease-tested planting material, especially seed production, may be produced by growing the crop and producing the seed, tubers, runners and rootstocks, in areas that are: <ul style="list-style-type: none"> Free of the disease, pest or vector. Isolated from the disease or pests. Not suitable to the disease or pest, or vector. Kept free from the target disease or pest by destroying or spraying diseased or infested plants in these areas when there are incursions. Regularly monitored for disease and pest incursions, eg trapping for western flower thrips (WFT) (<i>Frankliniella occidentalis</i>) in the Toolangi area. Physical methods, eg controlled environments for storage of produce. Pesticides, eg fungicide and insecticide seed treatments, pre-emergent herbicides.
<p>Monitor, threshold</p>	<p>Determine if control is necessary, eg</p> <ul style="list-style-type: none"> Monitor crops and growing areas to see if the pest population is increasing to the level at which economic damage is likely to occur. If the threshold is reached growers can decide what action, if any, to take. 
<p>Curative</p>	<p>Curatively control the pest once it reaches the economic threshold.</p> <ul style="list-style-type: none"> Cultural methods, eg reduce humidity, fertilize, irrigate. Sanitation, eg prune out branches infested with scale, removed dead trees, maintain hygiene in packing shed and greenhouses. Biological control, eg release predatory mites, bacterial, fungal and nematode bioinsecticides. Remember biological control is no quick fix and must be applied when pest numbers are low. Physical methods, eg trapping mice, cooling treatments, root barriers, water filtration, light traps. Pesticides, eg herbicides, fungicides, low hazard insecticides, biological chemical products. <p>Post sowing testing curative:</p> <ul style="list-style-type: none"> Use fungicides to provide partial protection from fungal diseases. Harvest crop early.

Exclude, eradicate, contain, manage (as in Biosecurity)

<p>Exclude the pest, pathogen and weed Avoid the pest</p>	<p>Australian and State / Territory biosecurity prevents movement of infected plant material which is a major threat to agricultural and horticultural industries.</p> <ul style="list-style-type: none"> • Policies and strategies must be in place to exclude a pest from entering and establishing, eg <ul style="list-style-type: none"> • Offshore mandatory treatments, phytosanitary certificates to validate pest or disease freedom. • Border inspections, testing, some items are prohibited, eg soil. • Onshore, contingency plans to deal with any incursions. • Exclusion or pest-free zones within Australia do not have the pest in them, eg no fruit fly. Monitoring and exclusion techniques maintain pest-free zones, eg border inspections, treatment of suspect produce.
<p>Eradicate the pest, pathogen or weed Eradicate the host?</p>	<p>Eradicate the pest, pathogen or weed before it becomes widespread. Many problems cannot be cost-effectively eradicated, but eradication is more likely to succeed if:</p> <ul style="list-style-type: none"> • An incursion is detected soon after it has occurred. • The pest does not fly. • The disease cannot be spread by air-borne spores or insect vectors. • The pest or disease does not have a wide host range. • The weed does not produce windblown seeds. <p>Eradication, is it possible? May be cost effective only if the pest / disease / weed population is low. Contingency plans for exotic incursions of economic crops are outlined in Biosecurity Industry Plans (available online) and include:</p> <ul style="list-style-type: none"> • Sanitation, eg destruction of infested fruit, host plants. Host eradication is common in biosecurity campaigns and has been successfully trialed in WA to eradicate the soil-borne disease <i>Phytophthora</i> dieback. • Biological control which is unlikely to eradicate a pest. • Resistant varieties, eg breeding resistant varieties which cannot host the pest or disease. • Biosecurity, eg monitoring and establishing boundaries of infested areas. Prohibiting movement of specified plant material, soil, equipment, etc. • Disease-tested seed, planting material, certified to be free of the pest. • Physical methods, eg, heat, refrigeration of produce postharvest. • Pesticides, eg treat source of inoculum with chemicals, insecticides, fungicides, herbicides.
<p>Contain, manage, suppress Change environment Reduce pests Protect the host</p>	<p>These measures can be implemented to prevent the pest building up to damaging levels or curatively to control the pest once it reaches the economic threshold. In some cases landholders are legally required to control declared pests. There are many tools that can be used alone or integrated to minimize the damage caused by pests and diseases and keep populations at a level where the damage they cause is not economically significant.</p> <p>Moderate the ENVIRONMENT</p> <ul style="list-style-type: none"> • Cultural methods. Environmental factors affect the development of the host, the pest or disease, and the beneficial organisms. The aim is to manipulate the environment to favor the host plant's growth and development and any beneficial organisms while restricting the development of the pest or disease (see Fig.3, page 21). <p>Reduce levels of the PESTS & PATHOGENS at the beginning / during the season</p> <ul style="list-style-type: none"> • Cultural methods, eg <ul style="list-style-type: none"> • Crop rotation. For soilborne diseases, crop rotation produces the best results for those that survive only on living hosts or on host residues. Crop rotation is less effective for those diseases that can persist in the soil for long periods in the absence of a susceptible host. • Incorporating organic manures into the soil increases the activity of microorganisms antagonistic to soilborne plant pathogens. • Manipulating the environment can reduce certain disease and pests. • Sanitation includes all activities aimed at eliminating or reducing the amount of inoculum in a plant, field or packing house. Measures include: <ul style="list-style-type: none"> • Hand pull weeds and hand pick insects. Removing diseased plant material by chipping or pruning to reduce disease carryover, promptly destroying crop residues and alternative weed hosts, removing diseased fruit and thoroughly cleaning packing facilities and equipment with a suitable disinfectant. • Some disinfectants are deactivated when contaminated with organic matter. Solutions must be changed regularly to ensure disinfectant efficacy is maintained. • Biological control during the growing season, eg monitoring, release parasitic wasps, predatory mites. • Disease-tested planting material, eg presowing testing for soil pests, diseases and weed seeds. Plant certified seed in disease and insect-free soil. • Physical methods, eg insect screens on greenhouses, trapping feral pest animals. • Pesticides may be used to treat soil, seed, seedlings or the crop foliage.

Contain, manage, suppress

Change environment
Reduce pests
Protect the host



Seek advice regarding controlling insect vectors

Protect the HOST OR PLANT

Losses may be minimized by many methods, including:

- **Cultural methods**, eg make sure the crop is fertilized, irrigated, planted at the correct time, etc to achieve appropriate plant health.
 - Ensure good drainage.
 - Carry out water and soil tests.
- **Resistant or tolerant varieties** may prevent infestation and infection or slow down their development sufficiently to allow a biocontrol agent or low hazard pesticide to be effective.
 - **Defense activators**, are non-pesticide agents which are applied before pathogen infection to activate the plant's inherent resistance mechanisms. They may be of synthetic origin (formulated chemical) or biological (eg non-pathogenic microorganisms or their products).
- **Pesticides**.
 - **Fungicides**. For many vegetable diseases, targeted fungicide application is an important component of a disease management program. Both foliar and seed treatments are common.
 - **Insecticides**. Insect vectors of some viruses are managed effectively with insecticides but the mode of action of virus transmission is a crucial factor. Persistently transmitted viruses that require long feeding times by the vector may be controlled. However spread of non-persistent transmitted viruses may actually be increased because vectors require only feeding times of only few seconds and their feeding time may increase after contact with insecticide. Foliar and seed treatments are used.

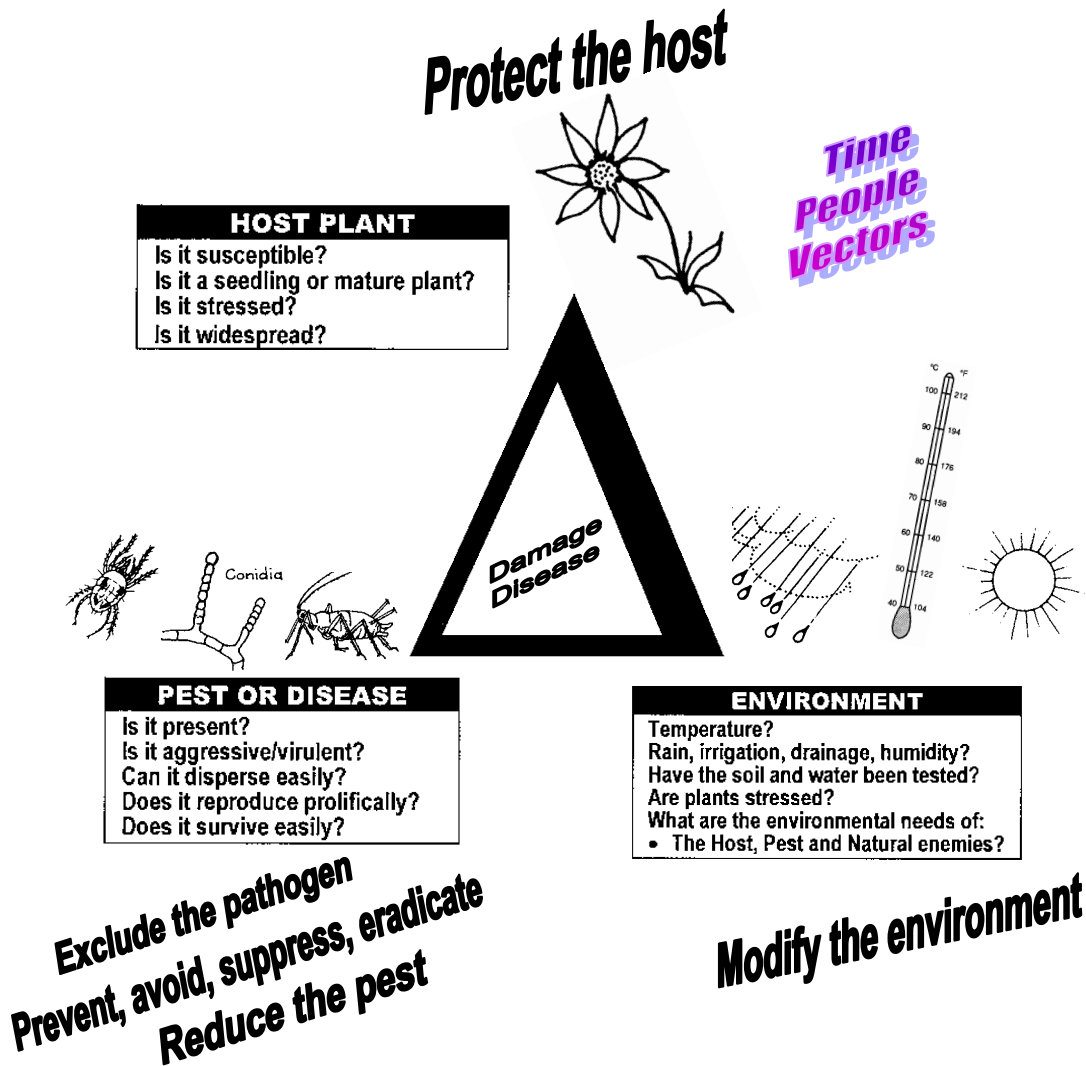




Fig. 3. A generalized pest and disease triangle showing control methods (not exhaustive) that could be used to control a pest or disease.

Crop stages (for the grower)

Some control methods may be used at every stage of crop production

<div style="background-color: black; color: white; padding: 5px; font-weight: bold; text-align: center;">Selection and establishment</div> <p style="font-weight: bold; margin-top: 5px;">Preventative</p> 	<p><u>Disease, pest and weed control.</u></p> <ul style="list-style-type: none"> • Cultural methods. Crop choice is an important decision determined by the markets, condition of the paddocks and the outlook for the season ahead. Soil and water analysis may be required. Choose varieties or species to suit the physical and other attributes of the site. Practice crop rotation where practical, for vegetables, annual and herbaceous flower crops. For soilborne pathogens crop rotation with non-susceptible crops produced the best result for diseases that survive only on living hosts or on host residues. • Sanitation includes all activities aimed at eliminating or reducing the amount of inoculum in greenhouses, grain storage areas, on equipment, etc. • Biological control. Assess whether natural controls operate or whether there is a need for biocontrol agents. Incorporating organic manures into the soil increases the activity of microorganisms antagonistic to soilborne plant pathogens. • Resistant varieties. Select species or varieties which have some resistance or tolerance to any local key problems or are generally problem-free. • Biosecurity. Avoid the pest, disease or weed. Plant in declared pest-free or exclusion zones, or in paddocks where testing indicates the pest, disease or weed is absent, low in numbers or the environment is unfavorable. • Disease-tested or virus-tested planting material is available for many commercial crops, eg carnation, strawberries and potato. Material may be certified as free from specified diseases or pests and of a specified variety; it may still need to be treated. Seed crops are often grown areas away from commercial production areas. • Physical methods. Small volumes of soil in seed and cutting beds may need to be pasteurized. Hot water treatments for bulbs, seed and other material may be recommended. • Pesticides. Soil, seeds, cuttings, bulbs or other plant material may need to be treated with an insecticide or fungicide.
<div style="background-color: black; color: white; padding: 5px; font-weight: bold; text-align: center;">Maintenance, caring for the crop</div> <div style="border: 1px solid black; padding: 5px; margin-top: 10px; font-size: small;"> <p>Integrated pest management (IPM), Best Management Practice (BMP) or organic standards may be available for your crop.</p> </div>	<p><u>Disease, pest and weed control</u></p> <ul style="list-style-type: none"> • Cultural methods, eg maintain correct irrigation, humidity, light, temperature and fertilizer regimes. Apply optimal water and nutrient requirements only after appropriate water, soil and tissue analysis. • Practice good sanitation, eg diseased plants and weeds that host diseases and pests that affect your crop, should be removed as soon as practical to prevent spread of diseases to neighboring plants. • Biological control agents can be introduced if available, eg predatory mites to control twospotted mite (<i>Tetranychus urticae</i>). • Biosecurity, eg avoid the introduction of diseased or infested plants or soil. Have an area set aside where new acquisitions can be located until their freedom from diseases and pests can be assessed. Isolate susceptible species for special treatments. • Physical methods, eg netting may be necessary to prevent bird damage, traps are used for monitoring pests and controlling mice and rats. • Pesticides. Monitor diseases and pests so that spot treatments can be carried out to prevent widespread damage, for some, early warning systems are available. Know which pesticides are registered for use and when to use them. Make sure they are available. Follow regimes which prevent the development of resistance.
<div style="background-color: black; color: white; padding: 5px; font-weight: bold; text-align: center;">Harvest and postharvest, storing and transporting</div> 	<p><u>Disease and pest control,</u> eg</p> <ul style="list-style-type: none"> • Cultural methods, eg select correct picking and harvesting weather and techniques, eg picking and placing flowers stems directly into water, harvest early before postharvest diseases become severe. • Sanitation, eg remove debris from packing areas. Ensure good sanitation practices are followed when washing produce. Change wash water regularly to ensure that disinfectant efficacy is maintained. • Biological control, eg <i>Trichodema</i> sp. is applied to strawberries and grapes at harvest and in storage to reduce <i>Botrytis</i> rot post-harvest fruit rot (Dodd et al 2004). • Biosecurity, eg fruit fly road blocks. Phytosanitary certificates may be required prior to dispatching a product interstate or overseas. • Physical methods, eg refrigerated storage and transport units, forced-air cooling, cold water, ice, room cooling, shade, vacuum cooling, hydro-cooling, cool rooms, refrigerated transport units; heat treatments, eg curing sweet potatoes to control <i>Rhizopus</i> and soft rot bacteria; lowering humidity to prevent development of grey mould (<i>Botrytis cinerea</i>) and other postharvest diseases; environmental gases, eg carbon dioxide. • Pesticide and other chemical treatments, eg fungicide and insecticide dips, waxes.

Management

Control methods used within different management programs


The purpose of management programs is to prevent disease from exceeding some level where profits or yields are significantly diminished. They aim to provide a combination of appropriate control methods to obtain effective, economically sound control with minimal risk to human health and the environment. Most have similar activities and involve adhering to similar steps (page 317).

General steps	<p>General steps include:</p> <ul style="list-style-type: none"> • Identification of pests, diseases, weeds and beneficials. • Prevent pests from becoming a threat, eg practice crop rotation, select resistant or tolerant varieties, plant disease-tested seed, rootstock, vegetative material. • Monitor pests and diseases. • Observe predetermined thresholds. • Curative measures, eg cultural, sanitation, biological, biosecurity, mechanical methods and targeted pesticide application.
Integrated pest management (IPM) <small>(page 333)</small> <div style="text-align: center; color: red; font-weight: bold; font-size: 1.2em; margin: 10px 0;">IPM</div> <div style="border: 1px solid black; padding: 2px; font-size: 0.8em; margin-top: 5px;">There are IPM programs for most economic crops in Australia</div>	<p>Note similar steps to above</p> <p>Step 1. Plan the whole program before you start.</p> <p>Step 2. Crop, farm, orchard, nursery, region.</p> <p>Step 3. Identification of pests, diseases, weeds and beneficials.</p> <p>Step 4. Prevention</p> <ul style="list-style-type: none"> Cultural methods Sanitation Biological control Resistant varieties Biosecurity Disease-tested planting material Physical methods Pesticides <p>Step 5. Monitoring to tell you if control might be required.</p> <p>Step 6. Thresholds</p> <p>Step 7. Curative / manage / contain</p> <ul style="list-style-type: none"> Cultural methods Sanitation Biological control Biosecurity Physical methods Pesticides <p>Step 8. Evaluation</p>
National action plan IPM 2012 EU directive	<p>The European Union Directive on IPM has the following:</p> <ul style="list-style-type: none"> • Prevention (rotation, sanitation, host resistance, healthy seed, landscaping). • Monitoring pathogens. • Control methods eg biological > physical > non-chemical > chemical • No side-effects from control actions, eg try to anticipate unforeseen developments. <ul style="list-style-type: none"> • Do not damage beneficials and the surrounding environment. • Do a risk assessment on each control option as to their effect on neighbouring people, beneficial and non-target plants, insects and animals. • Control methods which encourage bio-diversity should be used where possible. • Limit chance resistance / virulence development. • Sustainable pesticide applications that do not have a broad impact on the environment. • Appropriate, science-based measures.

Farming techniques are based on proven principles, but years of experience are also invaluable in efforts to combat pests, diseases and weeds.

The principle of minimum harm – how do we control pests, diseases and weeds in a manner that is least harmful to people and the environment?

LIMITATIONS TO CHOICE OF CONTROLS

Not all problems have a solution!	<p><u>There is unlikely to be a “one-size fits-all” solution</u> because different crops have different cultural needs and different pest, disease and weeds in different climates. Some crops resist efforts to effectively control them, include:</p> <ul style="list-style-type: none"> • South American Rubber Blight (<i>Microcyclus ulei</i>) and coffee wilt disease (<i>Fusarium xylarioides</i>) (IPM News. <i>World’s Worse Plant Pests</i>. 18/1/2012). • Some soilborne diseases, eg <i>Phytophthora cinnamomi</i> (Pc) has been around for decades, its life cycle studied and a CRC has been developed for it but there have not been major advancements in its control. Pc which has decimated susceptible forests in WA is considered to be an introduced disease. Recent trials suggest that clearing all living hosts from contaminated bushland sites in WA can eradicate the disease.
Trade	<p><u>Trade</u>, eg other states or other countries may only accept produce treated in a certain manner.</p>
Costs 	<p><u>In some situations certain methods of control may be impractical</u>, eg</p> <ul style="list-style-type: none"> • Rotating crops may be too costly and not a viable option. • Some pesticides are expensive, eg Dimension® (dithiopyr), Surflan® (oryzalin). • Purchase of genetically modified seed by growers on a regular basis can be expensive. • A requirement for zero pest presence, eg biosecurity requirements. • A profit has to be made; growing a crop is not just about yield and sustainability. • Imprecise thresholds mean it can be difficult to calculate potential yield loss.
Depends on type of problem but this may change with time	<p><u>The type of problem</u> often determines the method of control used, eg</p> <ul style="list-style-type: none"> • Virus diseases in tulips and strawberries are controlled by the use of virus-tested bulbs and runners respectively, there being no other known way at present, of controlling virus diseases in these plants. • Regular preventative applications of fungicides are necessary for the control of key problems such as peach leaf curl (<i>Taphrina deformans</i>) simply because there are currently no other effective methods of control on very susceptible varieties. • Insects may develop resistance to an insecticide; weeds may develop resistance to certain herbicides. • Exclusion of a pest or disease from production areas may be the only way to prevent crop loss or another crop chosen.
Lack of knowledge	<p><u>Details of the pest may not be known</u> because the host plant may not be of economic importance and therefore not well studied, eg identity of the pest may be imprecise, life cycle not completely known. Testing for abiotic problems not carried out.</p>
Low / high pest pressures	<p><u>Some problems such as green vegetable bug</u> (<i>Nezara viridula</i>), which attacks ornamental plants as well as vegetables, are under biological control but still may occasionally require additional control measures. Similarly, low hazard biopesticides may provide control only when pest pressure is low.</p>
Availability of control products	<p><u>Effective pest control products</u> such as baits or fungicides may not be readily available. Biocontrol agents or resistant varieties may not have been developed. The pest, disease or weeds may have developed resistance to previously effective pesticides.</p>
Weather	<p><u>The effect of weather on timing on the application</u> of pesticides, biocontrol agents and other measures. Timing of pesticide applications is important not just for controlling a pest but also ensuring Maximum Residue Limits (MRLs) will not be exceeded.</p>
New genotypes, new threats	<p><u>Irish potato late blight</u> (<i>Phytophthora infestans</i>) is a fungal disease that has caused food shortages and starvation in the past, still poses a significant threat to global food security. New strains of <i>P. infestans</i> have emerged and spread, making the disease even more difficult to manage (Cooke et al 2012) due to a combination of:</p> <ul style="list-style-type: none"> • Increased aggressiveness of the new strains. • Their ability to attack some sources of cultivar resistance. • Development of resistance to a key fungicide.
Constant change	<p><u>Control measures for a particular pest change with time</u>, eg</p> <ul style="list-style-type: none"> • Production systems change, eg fewer soilborne diseases in hydroponic systems. • Packaging systems change, eg systems than can absorb damaging ethylene. • A biosecurity pest becomes widespread and is no longer quarantinable, eg myrtle rust. • New techniques, eg ‘lure and kill’ baits with powerful attractants attractive to both male and female fruit flies plus a toxic insecticide. There are no chemical residues on fruit and little effect on beneficials. • Some treatments become restricted or illegal, eg metal traps for foxes, certain hazardous pesticides. • Land-based and aerial UAVs (Unmanned Aerial Vehicles) used for survey work and product applications. • Development and improvements in Precision Agriculture (PA) (page 372).

COMMONALITIES

Conventional, Ecological, Organic, Sustainable?

The term “**conventional agriculture**” refers to the **standard, dominant, farming approaches** promoted and researched by most government and agribusinesses groups and practiced by farmers and growers throughout the world. “Organic” growers have influenced conventional agriculture, reducing the use of chemicals.

Many common growing practices

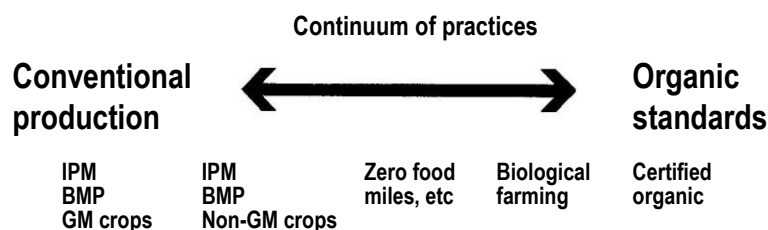
IPM (Integrated Pest Management)

BMP (Best Management Practice)

Although there are many management systems for growing crops most have more in common than they do differences. The one chosen usually depends on the situation, eg the biocontrol used to control locusts in areas close to habitation or for organic crops.

One fix does not fit every situation, eg

- **Many conventional producers** minimize the use of synthetic fertilizers, grow non-GM crops, select low toxicity, non-persistent pesticides, practice **IPM** and **BMP** techniques and conserve the environment in the same way that proponents of organic growers advocate. They use **inputs** such as disease-tested seed, mulches to control annual weeds and less risky pesticides such as pheromones.
- **A wide range of energy and existing technologies are compatible with all systems**, eg precision agriculture, sustainable management. All growers identify their pests and diseases, carry out soil and water tests and use **IT** programs to record fertilizer inputs and other activities.
- **By emphasizing the differences** between the various types of management systems instead of their similarities we discourage people from understanding that improvements can be made in any system whether it’s organic or conventional. No one system is inherently better than another, why not take the best from each?
- **Promotion of the concepts** of organic growing can influence public and political opinion to improve the standards of all types of crop production.
- **Both conventional and organic growing practices use registered pesticides** which are regulated by **APVMA** and other agencies. There is a common perception that all registered pesticides are toxic but many are classified as low hazard or biological chemical products. They can be subject to review as are synthetic ones and must be appropriately labeled; some may not be suitable for use on edible plants, etc.
- **Conventional and organic farming** are both input dependent.
- **Organic production** faces essentially all the challenges of conventional agriculture with some additional ones along the way, such as controlling weeds in a chemical-free manner.
- **The classification into organic and conventional is in reality**, a gross over-simplification; there is a continuum of practice between both.







Sharing information between agriculture, horticulture, turf and forestry.

- There are also many commonalities between the above industries. Practices in one can be useful in another, eg avoiding environmental pollution from fertilizers and pesticides, precision agriculture, etc.

TIME AND TIMING ARE EVERYTHING

Timing is critical for most activities associated with producing a crop. A common cause of poor weed control is bad timing of herbicide applications (Thomson et al, 2004).

<p>Time framework</p> <p>5-10-? years</p>	<p><u>The time framework within which we must plan some activities</u>, eg</p> <ul style="list-style-type: none"> • Chilean needle grass produces more than 20,000 seeds per sq.meter which can survive for years in the soil. • Wild radish can maintain viable seed in the seedbank for 10 years. • Sclerotia of sclerotinia rot (<i>S. sclerotiorum</i>) can survive in the soil and can remain infective for at least 5-7 years. • In some vineyards the symptoms of phylloxera aphids may not be recognized for 3-5 years after infestation, indicating they could be spread unwittingly on grape harvesters. • The effect of time on the development of epidemics can be misleading (page 406).
<p>Real time</p>  	<p><u>The availability of real time information</u> such as on-the-go sensing of crop, weed and soil variables and indicators is increasing.</p> <ul style="list-style-type: none"> • Decision-making regarding crops, eg cut for hay or keep for seed, frost control. • In-crop sensors for pest and disease control and analysis of soil samples on-the-go for precision agriculture and horticulture. Near real time accesses remote-sensed data. • Predictive services (early warning systems) provide real-time information on fungal diseases (Davidson 2011). • Continuous real time weather data before, during and after spraying can avoid drift. • On-the-go record keeping.
<p>Timing of actions</p>   <p>Warning services</p>	<p><u>Whatever the control methods</u>, they must be carried out at the right time.</p> <ul style="list-style-type: none"> • <u>Timing is the key to risk management</u>. Do what needs to be done at the right time and to a high standard. • <u>Opportunity timing</u>. Choosing the right crop and planting at the right time for that particular season. Fertilize after testing and at the right time. • <u>Harvest and markets</u>. Timing the crop for good market prices and the consumer is a prime consideration for most growers. • <u>Harvest and pests</u>. Select early fruiting varieties of stone fruits that mature early so that fruit can be removed from the tree before fruit fly populations are a major problem. • <u>Diagnostics, preventative testing, monitoring</u>. <ul style="list-style-type: none"> • Pre-sowing diagnostic soil tests for insects and diseases, water, etc. Soil nutrient testing and interpretation of soil tests avoid excessive fertilizer application and allow for precision applications. • Early detection after planting means more effective control. • Young black scales are controlled more effectively when young before their outer covering hardens. • In glasshouses growers can easily monitor insects to indicate when control is needed. • <u>Life cycles / growth stages of the weeds or the host</u>. <ul style="list-style-type: none"> • Control weeds when they are small to prevent seed set. • Release biocontrol agents at the optimum time, ie at the correct stages of the pest and the beneficials. • <u>Predictive services tell you when to do something</u>. They warn growers when pests, diseases and weeds are going to appear, so that control can be implemented at the most effective time. There are predictive services for all stages of managing a crop, eg <ul style="list-style-type: none"> • The optimum dates for sowing field peas in SA reduce the risk of black spot and is communicated to individual growers via a mobile SMS that will inform subscribers of the risk of black spot in April and early May. SARDI is encouraging SA growers to subscribe to the new and free Black Spot Manager Service. • Management strategies for other diseases may include timing of fungicides for spore release, effect of stubble age on spore release and modification of crop rotations to minimize disease. • <u>Control methods</u>, eg <ul style="list-style-type: none"> • Optimum time for monitoring seasonal pests, eg fruit fly, codling moth. • When to spray, eg timing of fungicide applications for <i>Botrytis</i>, brown rot, etc. • When and where to spray locust bands before they take to the air. • European wasps are active during the heat of the day so this is not a good time to treat the nest. Insecticide can be applied in the evening when the wasps are home for the night.

PEOPLE AND PESTS, DISEASES AND WEEDS

More than most activities involved in growing a crop, methods of controlling pests, diseases and weeds demand specific levels of knowledge and skill (pages 274, 406, 441).

<p>A science based technology that requires good management and application skills</p>	<p>Those responsible for decisions involved in the planning, supervision and implementation of control methods require higher levels of knowledge of biology, computing and management systems to implement these activities safely and effectively.</p> <ul style="list-style-type: none"> • The effect of people on agronomic practices often influence disease, pest or weed incidence for better or for worse (page 406). • Life style may motivate growers rather than that of managing a sustainable and profitable business. • Some in the industry may have limited English, mathematics and IT skills.
<p>Resources available to assist</p>	<p>There are substantial resources available to assist growers including:</p> <ul style="list-style-type: none"> • The Australian Department of Agriculture and State / Territory websites provide much free information. • Grower industry associations. • Diagnostic services. • Training is available for growers practicing organic growing (page 381), pesticide application (page 274) and many other aspects of producing the crop. • Consultants and product companies run workshops.
<p>Public perceptions</p>	<p>There are some aspects of agricultural and horticultural practice that the public perceive to be detrimental to human health and the environment. The more obvious of these being monocultures, chemical pesticides and fertilizers, genetic engineering and most recently, nanotechnology. Organic growing has a perception of being good.</p> <ul style="list-style-type: none"> • The public is right to be sceptical of new technologies – there are a number of well-known disasters resulting from the adoption of new technologies, eg some pesticides. However, the technology has moved on and these chemicals are no longer available or if they are, there use is tightly regulated. The current generation of chemical and bio-pesticides are less hazardous and more narrowly targeted and a wide range of alternatives to pesticides has been developed (page 438). • Returning to traditional methods of growing food will not feed the world; we will need these new technologies and the people to make it work safely and efficiently.
<p>Communication Wider dissemination of knowledge</p>	<p>Perceptions tend to be based on past events and once formed, can be very difficult to change. Attitudes, once strongly formed can be slow to change in both the grower and the public. Debate can be highly politicized and polarized. People look for data to support their decision rather than seeking information to help them reach a decision.</p> <ul style="list-style-type: none"> • The new media and ‘lifetime learning’ does offer opportunities to inform the public more widely and there is reason to hope that they will be effective vehicles for disseminating more widely, currently available information from credible sources to those in the agricultural and horticultural industries. • Horticulture is comprised of many industries ranging from large well-organized groups with administrative support to newer or smaller crops with a few growers and no administrative support. This diversity causes many more communication problems than in most industries; language and skills vary widely. • Peoples’ capacity to adapt varies widely between growers due to differences in social connectedness and the ability and readiness to use information (Hogan et al 2011).
<p>Common failings</p>	<p>Many well established best practices are not implemented; a few examples include:</p> <ul style="list-style-type: none"> • Not identifying the problem properly. • Not carrying out control measures properly, eg <ul style="list-style-type: none"> • Agronomic practices, eg poor site selection, low lying poorly drained areas. • Policy, eg biosecurity can influence the occurrence of diseases, bounty schemes do not deliver long-term solutions to a widespread pest animal problem; • Resistant / tolerant varieties not used when available. • Selection of propagation material. The use of seed or nursery stock that carries pathogens increases the amount of initial inoculum within a crop. • Disease-tested planting material and susceptible varieties may be planted in contaminated soil. • Poor sanitation practices, eg visitors not following sanitation and record keeping protocols for themselves and their vehicles when visiting or leaving premises. • Incidents and accidents associated with pesticide use, eg fish and bird deaths. • Biocontrol and pesticide resistance strategies not carried out properly. • Work, Health and Safety requirements not properly followed. • Not carrying out Management and Quality assurance (QA) properly, eg <ul style="list-style-type: none"> • Inadequate IPM strategies, eg planning, record keeping and auditing. • Inadequate environmental management.



CHALLENGES

- Consultants tend to make control strategies more complicated than they really are.
- Ensure that whatever crop or pest you are dealing with has a systematic framework for management.
- Always remember the pest triangle and other factors that may be part of the same triangle, eg parasites and predators, weeds. All components of a disease triangle must be compatible for a certain period of time before an epidemic can occur.
- Keeping up to date with new developments and legislation. This can be a special problem for small scale, language limited growers.
- Horticulturists should be familiar with **all** the control methods that can be used to control a particular problem. Relying on a single chemical or other control agent is **not** likely to succeed in the long term.
- Being aware of the major need to reduce dependence on insecticides.
- Community efforts. It will be much easier and more effective if everyone plays a part in controlling some problems, eg fruit flies, wheat rusts.
- Attempt to anticipate unforeseen developments resulting from control actions, eg
 - When replacing insecticide applications with resistant crops other minor pests may become pests due to declining use of insecticides, etc,
 - As more genetically-modified cotton is grown to control *Helicoverpa* spp., insects which were controlled by sprays before, become more of a nuisance, eg sucking insects such as green mirids and apple dimpling bug. Spring crops and weeds support large numbers of these pests which then move onto cotton when weed hosts dry up.
 - Insecticides which control one pest may inadvertently kill the parasites or predators of another insect resulting in new pests emerging.
- When pests become resistant to pesticides they tend to spread from country to country. So called “super-resistance” tends to develop in countries with a wide range of pesticides in current use, high pest pressure and minimal use of biological or integrated controls.

REVIEW QUESTIONS AND ACTIVITIES

1. Describe **1 example** of **each method** of pest control.
2. List at least **1 method of control** affected by **legislation** and give 1 example.
3. Name **preventative** methods of control for a pest, disease or weed of your choice. Which you would consider when selecting and establishing your crop?
4. Name **curative** methods of control for a pest, disease or weed of your choosing in a crop of your choice.
5. When may **eradication of a pest**, disease or weed deemed necessary?
6. How could you **exclude a pest**?
7. How can you **avoid a pest**?
8. How can you **protect the host**?
9. Name 2 things that could **prevent you carrying out your control option**?

SELECTED RESOURCES

- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- Australian Academy of Science. 1998. *General Symposium: Pests and People: Prospects for 2020*. Canberra.
- Brown, J. F. and Ogle, H. J. 1997. *Plant Pathogens and Plant Diseases*. Rockvale Pubs., Armidale NSW.
- Cooke, T., Persley, D. and House, S. 2009. *Diseases of Fruit Crops in Australia*. CSIRO Pub.
- Cooke D E L, Cano L M, Raffaele S, Bain R A, Cooke L R. *et al.* 2012. *Genome Analyses of an Aggressive and Invasive Lineage of the Irish Potato Famine Pathogen* in PLoS Pathogens **8** (10): e1002940.
- Davidson, J. 2011. *Early Warning Systems*. Ground Cover Sept-Oct. Crop Protection Supplement.
- Dodd, S.L., Hill, R. H. and Stewart, A. 2004. *Monitoring the Survival and Spread of the Biocontrol Fungus *Trichoderma atroviride* (C65) on Kiwifruit using a Molecular Marker*. Aust. Plant Path. 33(2).
- Goodwin, S., Steiner, M., Parker, R., Tesoriera, L., Connellan, G., Keskula, E., Cowper, B, Medford, A. and Rodriguez, C. 2000. *Integrated Pest Management in Ornamentals: Information Guide*. NSW Agric/HRDC, NSW Agric., Sydney. Also *Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide*.
- Hogan, A., Berry, H. L., Peng Ng, S. and Bode, A. 2011. *Decisions Made by Farmers that Relate to Climate Change*. RIRDC Publication No. 10/208.
- Page, J. and Horne, P. 2012. *Controlling Invertebrate Pests in Agriculture*. CSIRO Pub.
- Persley, D., Cook, T. and House, S. 2010. *Diseases of Vegetable Crops in Australia*. CSIRO Pub.
- Sutherst, R. W. 2000. *Pests and Pest Management: Impact of Climate Change*. No.00/16. RIRDC, Barton, ACT. www.rirdc.gov.au
- Thomson, S.P., Heinz, K. and Krauter, P. C. 2004. *Timing is Everything*. Ornamental Outlook. Sept.
- Bulletin of the European and Mediterranean Plant Protection Organization (EPPO)*. Dec. 42 (3).2012.
- Join the *The Weed's Network - The Weed's News* www.weedsnetwork.com



CULTURAL METHODS






INTRODUCTION	30
MODIFYING THE ENVIRONMENT	32
Temperature	33
Water	35
Relative humidity	37
Light	38
Wind	38
Predictive weather stations	39
Choosing the crop or the crop site	40
A changing climate	41
PLANTING, SPACING, PRUNING, ETC	42
SOIL AND SOIL ORGANIC MATTER (SOM)	43
MULCHES	46
NUTRIENTS	48
Acidity and alkalinity	48
Fertilizers	49
Biostimulants	53
CONSERVATION TILLAGE (CT)	54
CROP ROTATION (CR)	56
FALLOWING	58
MIXED PLANTINGS	59
MANAGING CULTURAL METHODS	60
PROS, CONS AND CHALLENGES	63
REVIEW QUESTIONS AND ACTIVITIES	63
SELECTED RESOURCES	64

INTRODUCTON

Cultural methods are used increasingly with more emphasis on proper management

<p>What are cultural methods?</p>	<p>Cultural methods are mostly preventative and are compatible with other control methods.</p> <ul style="list-style-type: none"> • They figure prominently in the control of many plant problems and involve the use of ordinary day-to-day horticultural practices and equipment. • Practices should favor crop growth but not pests, disease or weeds. • Symptoms caused by incorrect cultural practices are often difficult to recognize. • Usually used in conjunction with other methods of control.
<p>Legislation</p>  <p>AUSTRALIAN STANDARDS</p> <p>CODES OF PRACTICE</p>	<p>A variety of legislation and Australian standards regulate cultural methods, eg</p> <ul style="list-style-type: none"> • Acts of Parliament, eg <ul style="list-style-type: none"> • Noxious Weeds Acts. • Environmental Acts restricts the discharge of nutrient-laden run-off water from any premises, including nurseries. Restrictions of water usage regardless of the source. • There are registration requirements in some State and Territories for fertilizers; others just require that the label complies with standards. • Australian Standards, eg <ul style="list-style-type: none"> AS 3743.2003. <i>Potting Mixes</i>. AS 4419.2003. <i>Soils for Landscaping and Garden Use</i>. AS 4454.2012. <i>Composts, Soil Conditioners and Mulches</i>. • Codes of practice, eg <ul style="list-style-type: none"> • National Code of Practice for Fertilizer Description and Labeling, 2001.
<p>Available knowledge</p> 	<p>There is lots of software to help with growing a crop, eg</p> <ul style="list-style-type: none"> • Pest Risk Analysis Systems use climate data (temperature, humidity, rainfall) and geographic distribution patterns of pest organisms, weeds and biological control agents to predict their geographic distribution in Australia. • Irrigation programs can continuously monitor moisture resulting in water and fertilizer savings, more even water distribution, reducing disease and weed invasion. • Early warning systems can monitor and record a wide range of environmental data, eg temperature, humidity, rainfall, hours of sunshine and leaf wetness. Warning messages are displayed when critical conditions are reached for infection (page 39). • Orchard management. Programs for apples and pears in Tasmania deliver best practice advice for thinning apples taking into account the age of trees, weather patterns, etc. • Crop / plant selection. There are many internet sites with pictorial descriptions of plants for particular situations, their tolerances and cultural requirements. • The Canopy Chlorophyll Content Index (CCCI) and Normalized Difference Vegetation Index (NDVI) are used for predicting nitrogen status of crops. • Electromagnetic induction (EMI) for mapping salinity, soil water and clay content in some soils. • Real-time on-the-go sensing of crop and soil variables and near real time accessing remote sensed data. • Expertise online, eg iPhone apps, the Australian Pesticides and Veterinary Medicines Authority (APVMA)'s database of registered products (PUBCRIS), industry websites. Some websites provide information and images of pests, diseases and weeds and advice on how to manage them • User-friendly simulation models are available for many crops, eg <ul style="list-style-type: none"> • Yield Prophet® aids crop tactical decision making, eg variety, time of sowing, plant spacing, arrangement and density as well as nitrogen management, aim to control canopy development. • Nufarm's internet service predicts optimal conditions based on a farm's geographic and climatic conditions. Neutron probes installed in certain field monitor soil moisture. • Agriculture Production Systems Simulator (APSIM) researches soil characteristics, crop and soil monitoring, climate forecasting and farm management obtained through discussion groups. • Toro's Turf Guard wireless monitoring system helps golf courses and sports field managers improve their turf, soil and water efficiency.

<p>Genetic engineering</p> 	<p>Genetic engineering techniques are used to improve yields, nutritional quality, promote faster growth and improve adaptation to certain environments, eg improved tolerance to temperature extreme, frost, drought and salinity (pages 409-418).</p> <ul style="list-style-type: none"> • Ornamental crops, eg <ul style="list-style-type: none"> • Improved quality and growth of major cut flower and pot plant crops. • New flower colors, eg blue and green carnations, free flowering varieties. • Increased vase life. • Fruit and vegetables, eg <ul style="list-style-type: none"> • Increased crop yields and improved flavor. • More nutritious vegetables, eg increased iron content to help prevent anemia. • Slowing the fruit ripening process of tomatoes, reducing transport damage and increasing shelf life. • Field crops, eg <ul style="list-style-type: none"> • Increased crop yields and improved nutritional qualities to enhance livestock feed. • More nutritious grains, eg raising the calcium content of grain to help prevent osteoporosis. In Thailand rice has been engineered to have a vitamin A derivative, a deficiency of which causes blindness in children in the developing world. • Better utilization of atmospheric nitrogen by soybeans, reducing need for fertilizers. • Modifying the plant architecture of canola to reduce wind damage leading to more efficient nutrient uptake and seed production, photoperiod modifications in sensitive cultivars and plant structure to suppress weeds. • Controlling the time of flowering in canola and other crops.
<p>Plant growth regulators (PGRs)</p>	<p>PGRs been available for decades but the reduced phytotoxicity of current products has increased interest in their use and become standard practice in many instances, eg</p> <ul style="list-style-type: none"> • Primo® (trinexapac-ethyl) to reduce unfavorable environmental conditions. PGR's offer an opportunity to modify a plant's growth habit to enable it to be better adapted to a shady environment. • Regalis® (prohexadione-calcium) significantly reduces shoot growth within the treated area of apple orchards resulting in more manageable trees and reducing summer pruning costs for the first year in some varieties. More buds per limb develop, boosting yield the following season. Unprofitable blocks can be cropped. • Corasil™ (dichlorprop-P) has the ability to increase fruit size of oranges and mandarins for Australian citrus growers.
<p>Precision agriculture and horticulture</p> <p>PA, PH</p>	<p>PA is the precision placement of inputs to reduce costs, optimize efficiency of operations, and prevent environmental damage – matching inputs with crop requirements.</p> <ul style="list-style-type: none"> • Precision is exercised at many levels, eg seed, fertilizer and spray placement (herbicides, fungicides, insecticides); permanent wheel placement to stop random compaction; individual weed killing with spot-spraying rather than field spraying; irrigation, etc (page 372).
<p>Training, education and cultural methods</p>  	<p>Training Farmscape, representing farmers, advisers and researchers, covers monitoring, simulation, communication and performance evaluation and is run by CSIRO tropical agricultural researchers at Toowoomba. The key to Farmscape's success is the presentation of the Agriculture Production Systems Simulator (APSIM) in the context of off-farm research soil characteristics, crop and soil monitoring, climate forecasting and farm management obtained through discussion groups.</p> <ul style="list-style-type: none"> • Farmscape online uses the Internet for supporting interactions among farmers, advisers and researchers. <p>Soil biology workshops provide opportunities to understand how soil organisms contribute to soil health and how to manage them to increase soil fertility and sustainability, eg</p> <ul style="list-style-type: none"> • Recognize a healthy soil ecosystem. • Understand the diversity and benefits of soil organisms for sustainable production and ecosystem health. • Identify land management practices that support activities of soil organisms. • Understand how to build soil organic matter levels for soil biological health. • Monitor soil organisms in the field. • Appreciate the benefits of conservation tillage. • Interpret soil tests. <p>Irrigation workshops explain the benefits of a balanced watering (and fertilizing regime) which keeps plants growing vigorously and often minimizing pest damage, eg</p> <ul style="list-style-type: none"> • Mapping, measuring, monitoring salinity and drainage. • Interpreting water tests. • Deal with climate variability. • Precision irrigation. <p>Others include:</p> <ul style="list-style-type: none"> • FertCare Accreditation Program for all personnel engaged in handling, storage, transport and application of fertilizers and to the sales and advisory roles. • On-farm demonstrations.

MODIFYING THE ENVIRONMENT

Temperature and water are the most important aspects of climate that affect plant production

They directly affect plant growth, pest and disease development and can affect vector movement for many virus diseases, eg impatiens necrotic spot virus (INSV), tomato spotted wilt virus (TSWV) and wheat streak mosaic virus (WSMV).


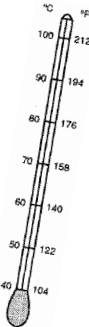
Global and local problem	<p>Improved water and soil management is the key to feeding the growing world population. By 2050 food production will need to double to accommodate the increased population. Water scarcity is the major threat to agriculture and food security in developing countries; it is more of a threat than access to land.</p> <ul style="list-style-type: none"> • Australia has national problems of drought, heat, frost and salinity. • The two greatest drivers of yield for many Australian farmers are: <ul style="list-style-type: none"> • Plant available moisture at seeding. Timing of sowing is therefore critical. • The impact of spring temperature shocks, either frost or heat waves.
Monitoring growing conditions	<p>Monitor and adjust environmental conditions to:</p> <ul style="list-style-type: none"> • Optimize conditions for plant growth and • Minimize conditions favoring diseases, pests or weeds and vectors. Botrytis blight (<i>Botrytis cinerea</i>), which affects nearly all floriculture crops, is most serious when temperatures are between 15 and 21°C. Poor air circulation, high relative humidity and slow plant growth all contribute to a <i>Botrytis</i> outbreak. By maintaining temperature control, reducing humidity, increasing air flow and using sub-irrigation rather than overhead irrigation, growers can minimize risk of infection.
Field crops, greenhouses	<p>Changing the growing conditions of some crops can be difficult.</p> <ul style="list-style-type: none"> • Field grown crops. Modifying the environment to manage field grown crops is possible. Collar rot (<i>Phytophthora citrophthora</i>) of citrus has been managed by improving soil drainage. • Orchards and crops can be protected by netting and film. Crops are also protected from high winds, hail, excessive moisture loss, birds, small mammals and airborne insects. Weed growth, water splash and evaporation are reduced. • In greenhouses it is possible to control the physical environment, eg temperature, light intensity, day length and humidity, as well as the chemical environment, eg quantities and ratios of various nutrients, especially in hydroponic systems. • Protected cropping is increasing.
Anti-transpirants	<p>Anti-transpirants such as Envy[®] and Droughtshield[™] are polymer coatings which are applied as liquid sprays. Once dry, they form a semi-permeable biodegradable film on the plant surface which reduces transpiration and protects plants from climatic extremes such as drought and frost.</p>



ENVY

Envy is a unique water emulsifiable polymer concentrate which can be used on most trees, vegetables and flower crops. When dry, Envy forms a semi-permeable, biodegradable film, which reduces transpiration and protects plants from climatic extremes

Temperature

Decision-support	<p><u>Improving understanding</u> of the effects of temperature extremes on growth and development of crops will help in developing more functional decision-support tools and field management strategies.</p>
Sunscorch	<p>Sunscorch is caused by high temperatures and occurs on leaves (page 35), flowers, fruit, branches or trunks of trees. Sunburnt trunks are predisposed to wood rotting fungi and insect borers. When avocado trees are young, they are very easily damaged by sun and / or herbicide over-spray. Growers can protect the young green bark of newly planted avocado trees by firstly painting the exposed trunk with a white acrylic paint.</p>
Pollination 	<p>For many fruit and vegetable crops suitable pollinators must be available.</p> <ul style="list-style-type: none"> • Cold, heat or rain may prevent pollinators from 'working'. Climate change may exacerbate this problem. • Bees are highly susceptible to insecticide applications. • Bees are subject to pests and diseases, some of which are already present in Australia. Some exotic pests such as the highly destructive Varroa mite is already present in NZ. • There is a general decline in pollinating bees worldwide. Many overseas countries use pollination management to accomplish or enhance pollination of a crop, to improve yield or quality. Due to the large number of wild European honeybees in Australia, only a few producers manage the process through paid pollination. • Scientists overseas are working on breeding a new super honey bee that they hope will be resistant to cold, disease, mites and pesticides.
Hardening off	<p>Young, pampered seedlings that were grown either indoors or in a greenhouse will need a period to adjust and acclimatize to outdoor conditions, prior to planting otherwise they may languish, become stunted or die from sudden changes in temperature. This transition period is called "hardening off" and gradually exposes tender plants to wind, sun and rain and toughens them up by thickening the cuticle on the leaves so that the leaves lose less water. This helps prevent transplant shock. Hardening off times depend on the plant species, the temperature and temperature fluctuations.</p>
Soil temperature <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>In spring the lower soil temperature beneath mulches may slow growth of early spring crops</p> </div>	<p>Soil or root temperatures are often more important than the atmospheric temperature.</p> <ul style="list-style-type: none"> • There are optimum temperatures for particular crop and weed seeds to germinate and subsequently grow. Knowing these will help with planting times, weed control, etc. • There are optimum temperatures for all microorganisms, both pest and beneficials. • To prevent damping off diseases, seeds and cuttings should be planted when soil temperatures are favorable for plant growth so that they are at a susceptible stage for as short a period as possible. • Coated seeds. Growers prefer to plant seeds early especially if soil conditions are good but sometimes temperatures are too low for germination and seed of some plants can be injured by chilling. <ul style="list-style-type: none"> • Seeds are sometimes coated with a polymer which is insoluble at low temperatures and prevents moisture from reaching the seed. At a given and regulated temperature the polymer becomes water soluble, allowing the seeds to take up water and germinate.
Atmospheric temperature 	<p>Each plant species has an optimum range of temperature for growth, flowering and fruiting, etc. Heat waves may damage temperate species and abnormally cold conditions affect sub-tropical and tropical species.</p> <ul style="list-style-type: none"> • Selecting the correct aspect for a crop in any locality is of vital importance. How much sun will the crop get? Which way does the slope of the land face? Is the area subject to frost? Is it the spring or autumn frosts which could damage the crop? • Length of growing season. The length of growing season and number of hours above and below a particular daily temperature are important requirements for many plants, eg tomatoes can ripen in 2 weeks at 18-22°C. • Parasitic diseases and pests are affected by temperature. <ul style="list-style-type: none"> • Downy mildew diseases are favored by cool (and moist) conditions. • Redlegged earth mites (<i>Haloitydeus destructor</i>) are active during the winter months. • Some scales in greenhouses can be controlled by raising the temperature to 40°C for a short period. Check if this is appropriate for your crop and situation. <p>Plenty of plants can survive heat stress. With those that do not, eg azalea, it is often due to incorrect placement. Almost all plants with underground storage organs are known survivors, eg day lilies.</p>
Cold water	<p>Cold water applied directly to hairy leaves of African violets and similar plants causes them to develop yellow ringspot patterns.</p>

Frost



Twisted leaves on carnation caused by frost. Photo©NSW Dept. of Industry & Investment.

There are several ways of controlling frost, including:

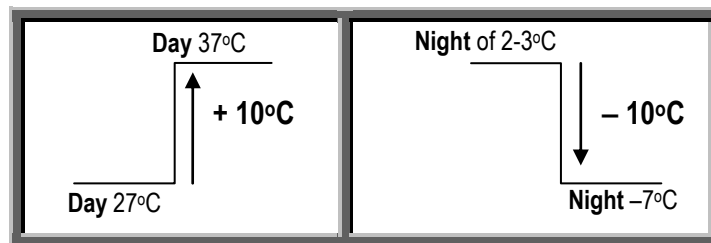
- **Passive designs**, eg planting dates. Growing in frost-free locations is not always possible in areas where heavy frost occurs. Either select frost tolerant species for growing during the colder months and locate frost-sensitive plants in frost-free sites, or have in place steps to minimize frost risk. Frost-prone areas are generally sown last to help avoid the high-risk period.
- **Wind machines raise and maintain temperatures** by drawing warm air down from above the inversion layer that exists at times of **radiant frost conditions** in vineyards. There are a large number of wind machines installed and operating in Australia protecting a wide range of crops, vines, citrus, orchards, and flowers.
- **Heaters, water, chemicals and fog (smoke)** can be used to complement the operation of a wind machine. Fog (smoke) is not generally allowed in Australia. Check with local authorities.
- **Clean cultivated soil, rolled and irrigated** will retain heat during periods of frost. This source of heat could be utilized as part of a vineyard frost control program.
- **Wind breaks** should be properly maintained during frost threats, eg thinned to allow cold air to pass through. Improperly maintained windbreaks can add to frost and freeze risk.
- **Spraying with water, overhead or flood irrigation etc.** Many plants are frost tender, particularly when young. **During mild frosts** (-1 to -2°C) an irrigation system (if set up properly) can reduce their severity and often eliminate any damage within an **orchard**. The principle behind using a standard irrigation system is that the **temperature of water**, by nature is more than 0°C; therefore by turning on the irrigation, the temperature around your trees will be kept above freezing point. The trick, however, is to cycle the water through your orchard without the pipes freezing, to not waterlog your soil or to use all your valuable water reserves or to have to get up at 3am in the morning when it's 3°C outside to turn on the irrigation system (McCarthy 2001).
- **Covers** are available for all types of crop protection including frost, heat, rain, hail and wind (page 251).
- **During periods of frost conditions**, cleanly-cultivated soil, rolled and irrigated retains heat.
- **Cereals.**
 - **Frost at flowering** can severely damage cereals and causes estimated annual losses of \$100 million across Australia. Frosts in the order of -4 to -8°C can cause floret sterility or damage to the developing grain. The threat of frost also affects production because growers delay sowing so that flowering occurs after the period of maximum frost risk.
 - **Frost detection** in the grains **National Variety Trials** is one of the most important factors when monitoring individual sites as this weather phenomenon can significantly influence quality / yield results and alter a varieties general performance.
 - **Frost tolerant grain varieties** are currently not available in Australia. Geneticists are using frost simulation chambers to develop cereals with true tolerance to frost.
 - **Growers must resort to management strategies** detailed in the Ground Cover Supplement: *Turning up the Heat of Frost in Cereals*. Issue 109. 2014.

Combined heat and water stress can be devastating

- Many crops do not perform at their best** under hot weather but combining heat stress with water stress can be devastating. Hot conditions in the field test the ability of many irrigators to keep water requirements up to their crops. Irrigation schedules can be shortened to ensure that crops are being watered earlier in the day rather than later, to reduce the chance of crops being stressed during periods of high water demand.
- **Avocado trees are of a sub-tropical origin**; as such they are heavily affected by the hot and dry conditions often experienced in WA. Fruit may be shed by the tree during summer. Some growers have had a degree of success by adjusting the trees micro climate through irrigation, eg applying short bursts of irrigation (5-10minutes) at regular intervals during hot, dry conditions. Growers need to monitor soil moisture levels, watch salt accumulation in the soil and plants and other factors (McCarthy 2001).

Suddenness of temperature changes

Sudden increase in maximum day temperature or sudden decrease in minimum night temperature exacerbates the effects of high and low temperatures.



- **Acute effects of high temperature** are most striking when heat stress occurs during the flowering period of the plant especially the maturing of the stamens. Hot conditions can impact on the fruiting of a crop.
- **Cold shocks** in cotton production systems, are defined as a situation of <11°C and each event extends the duration to flowering by 5.2 day degrees. Events where the minimum daily temperature falls below this value are referred to as 'cold shocks'.
- **Spring temperature shocks** may either be an unexpected frost or a heat wave.

Water

Water management must be a worldwide priority (Haigh 2013)

The quest to make all rain lead to yield (GRDC Ground Cover May-June 2010)

Water's function in plants

Water is Gold
(Lake 1998b)

A small amount of water is used to form part of the dry matter in the plant by combining with atmospheric carbon dioxide to form carbohydrates and proteins.

- Another small amount helps to keep the cells turgid so the plant remains upright.
- Most of the water passes through the plant from the roots and is expelled by the stomata in the leaves. This water carries nutrient and helps keep the plant cool.
- As the temperature rises the plant uses more water for temperature control, as we do.
- Limit the cropping hectares to the amount of water that is available for that season.
- Stirzaker, R. 2010. *Out of the Scientist's Garden: A Story of Water and Food*. CSIRO Pub.

Soil moisture



Oedema on umbrella (*Schefflera actinophylla*). Photo©Canberra Institute of Technology.

Unless it is a known source, ie rainfall, **water analysis is essential**, eg

- Prior to use for irrigation and in recycling systems.
- Prior to use in pesticide applications.
- Analyses must include water hardness, pH, dissolved salts, available nutrients.

All plants must be supplied with their correct soil moisture requirements, eg

- **Many evergreen plants**, eg avocado and boronia require regular soil moisture throughout the year.
- **Dead leaf tips and edges of indoor plants** may be due either to insufficient or too much soil moisture (Fig. 4 below).
- **Conifers** may suffer from moisture stress during dry summers. This is often not apparent until the following winter, when dead twigs or branches become obvious.
- **Leaf scorch of rhododendrons and azaleas** is usually associated with insufficient soil moisture during hot, windy weather.
- **French beans**. Lack of sufficient soil moisture during hot, windy weather can result in shrivelling of young pods.
- **All plants**. Excessive soil moisture, together with poor drainage (waterlogging), can cause death of root systems due to lack of aeration.
- **Oedema** (small scabby areas, or corky ringspots) develop on leaves of camellias and some other plants when they absorb more water through their roots than they can transpire through the stomates on their leaves.
- **Different types of plants** vary enormously in their requirements for water. In landscapes it is easier to locate plants with higher water needs together.
- **The prospect of drought affects crop selection**.

Flooding, for obvious reasons, has little practical use in Australia.

- **Rice is often criticised for being grown in a water scarce environment**, but being an annual crop it can be grown only when water is available.
- **Flooding** requires lots of water and keeps land out of production for varying periods.
- **Flood waters can spread *Phytophthora***, weed parts and weed seeds.
- **It can reduce pests, diseases and weeds by lack of aeration and bacteria.**
 - **Flooding mainly controls weeds** and is sometimes used for this purpose in organic growing.
 - **Flooding for long periods** may reduce numbers of some soilborne fungi (*Fusarium*, *Sclerotinia sclerotiorum*), insects and nematodes, probably by soilborne bacteria.
 - **Root knot nematodes** (*Meloidogyne* spp.) need soil aeration for survival. To kill nematodes an area would need to be flooded for several months.
 - **Flooding** (for about 4-6 weeks) has been used to eliminate **fairy rings** from lawns. The lack of aeration causes the fungus in the soil (and the lawn) to die.

Soil moisture levels can affect development of parasitic diseases and pests.

- **Some soilborne pathogens**, eg *Aphanomyces*, *Phytophthora* and *Pythium* are favoured by high soil moisture.
- **Infestations of sucking insects** such as mealybugs, and mites can be **tolerated** by the host to a greater extent if there is adequate soil moisture.
- **Various seed priming materials and seed coatings control hydration of seed** both before and after planting, allowing vigorous growth of seedlings and increased resistance of seedlings to damping off (*Pythium* spp.).
- **Christmas beetle** (*Anoplognathus* spp.) larvae thrive beneath damp pastures and adults emerge easily through moist soils. Wet years may herald a bad season for rural eucalypt defoliation in SE Australia.

Low water use plantings

may enhance water conservation in dry landscapes.

Irrigation is greatly improved if it is designed to take into account a soil's capacity to store available water for plants and its ability to drain excess water.

Moisture problems in the soil are probably responsible for more plants growing poorly and being unproductive annually over large areas.

Plants weakened by drought are also more susceptible to certain pathogens and insects.

Root loss caused by *Rhizoctonia* does not always cause crop stunting if enough water and nutrients are available.



Mealybugs (3-4 mm long)

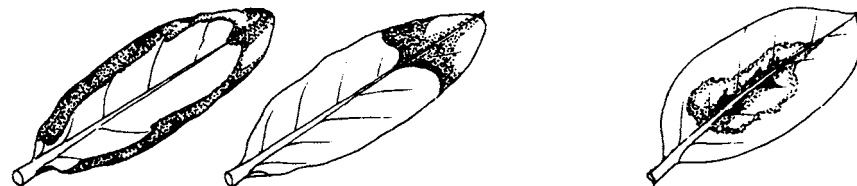



Fig. 4. Left and Centre: During **water stress** leaf margins and tips become **brown and brittle**; during **excess water** leaf margins and tips **become brown and soft**. **Right:** **Sunscorched leaves** have yellowish or brown areas in the **centre**; whole leaves and whole plants may be affected.

<p>Nursery & Garden Industry Water Policy</p>	<p>Few industries are more affected by water policies implemented by government and water authorities than the nursery and garden industry. The industry has finalized its own water policy which may be accessed online.</p>
<p>Measuring soil moisture</p>	<p>There are many different methods of measuring soil moisture, eg</p> <ul style="list-style-type: none"> • Taking soil cores and drying them to determine the depth of the moisture. • Using a dip stick to observe and feel moisture and using knowledge and experience. • Electronic probes which automatically log moisture at different depths have been used in irrigated crops such as turf, vines, and cotton. • Multi-electrode scanning technology can detect water content in the soil over a wide area and possibly could be used as an irrigation tool. • CSIRO runs a demonstration Wireless Soil Moisture Monitoring system which uses a combination of short-range radio communication and the mobile phone network to automatically deliver soil moisture measurements from field-to-desktop, eg Yield Prophet[®] which predicts soil moisture.
<p>Water additives</p>  <p>Eco-hydrate rehydrates soil and rejuvenates plants that are under moisture stress</p>	<p>Various water additives improve soil wetting and penetration, moisture retention and water use efficiency.</p> <ul style="list-style-type: none"> • Soil wetting agents break up the surface tension of water allowing it to flow more readily and are used in horticulture and turf to overcome soil water repellency. <ul style="list-style-type: none"> • Choose ones safe to use with plants. • They maximize the capacity of the soil to soak up and retain the water applied but applications need to be fine-tuned for each user's terrain (Illingworth 2004). • They reduce run off which can gather fertilizers and may end up forming pools in another part of the property or be carried from the property into drainage systems. • The application of wetting agents has a limited ability to reduce water usage. • Water saving products can reduce the requirements and duration of watering and ensure rapid uptake of water and even distribution throughout the soil profile. <ul style="list-style-type: none"> • Some products slow the drying cycle of soils in summer, so the need to irrigate again is postponed, enhancing the soil environment for microbes and roots alike. • Water storage granules and gels are especially useful when transplanting stock. • Superabsorbent products can absorb from 350-500 times their own weight of water and when incorporated in soil or potting mix will hold this water in a form available to plants, replenishing itself each time the plant is watered.
<p>Irrigation, waterways pests and diseases</p> <p>Everyone is under increasing pressure to restrict their water use</p>	<p>Irrigation may influence spread and development of some diseases.</p> <ul style="list-style-type: none"> • Irrigation salinity is caused by overwatering, which raises the water table and brings high concentrations of salts within the root zones of plants. • Irrigation during dry seasons means that disease propagules are not exposed to drying out during periods of drought, so the level of inoculum increases. • Alternating drying and rewetting soil encourages microbial decay of fungal sclerotia. • Overhead irrigation: <ul style="list-style-type: none"> • Promotes disease by increasing the time free moisture remains on leaf surfaces. • Washes inoculum from higher to lower parts of plants, and out of the air onto plants facilitating spread of pathogens by water splash, eg <i>Alternaria solani</i>. • Overhead irrigation early in the day allows spores of Irish blight (<i>Phytophthora infestans</i>) of potato to dry out on the plant before evening, preventing infection. • May control frost in some crops (page 34) • Irrigated crops may become a green island in a dry environment and attract insect vectors of virus diseases. • Trickle or drip irrigation produces a mosaic of soil moisture conditions rather than uniformly moist conditions which probably inhibits the spread of root pathogens. • More than 12 Phytophthora species have been isolated from 48 waterways across WA (Huberli et al 2013).
<p>Irrigation Management Strategies (IMSS)</p> <p>Many different types of below ground irrigation systems which vary in efficiency</p>	<p>Irrigation of agricultural land accounts for >85% of water use worldwide, so there is an urgent need to manage demand and identify effective IMSSs.</p> <ul style="list-style-type: none"> • A properly designed, installed, maintained and managed irrigation system can greatly reduce the volume of water wasted every year. • Overhead sprinklers use more water and create more waste than recirculating sub-irrigation systems. They can be made more efficient by collecting run off for re-use. • Closed sub-irrigation systems, eg drippers, with appropriate disinfestation, reduce water use while minimising nutrient rich run off in nurseries. • Xeriscape gardens arose in response to pressure on water resources and excess nutrient load run off. Lawns were targeted as major contributors to these problems. • Irrigation must be appropriately managed to reduce or rehabilitate salinity, eg <ul style="list-style-type: none"> • To reduce water infiltrating into the water table. • Using appropriate drainage; ground water pumping to lower the water table. • Trees can assist in lowering water tables, intercepting ground water recharge. • Subsurface irrigation systems for landscape and turf offer substantial water savings, eliminate vandalism and mechanical damage. They provide safe and efficient delivery of fertilizers; healthier and better quality turf and plants, fewer weeds, lower maintenance costs and safe application of effluent and grey water as viruses and disease organisms cannot come in contact with humans. • Precision irrigation is in its infancy (pages 31, 372).

Water Use Efficiency (WUE)

Ups and downs of soil water

CSIRO's flagship Sustainable Agricultural Flagship is researching:

- The value of summer fallow rain to crop production.
- The roles of the size and frequency of rainfall events needed to store water.
- Under what circumstances summer weed control is economic.
- And how to change crop practices to make better use of water.

PI

(Precision Irrigation)

WUE is the yield of plant product per unit of crop water use and is important in all areas of plant production. It includes the **use of water stored in the soil** and **rainfall during the growing season**.

- **WUE management practices** mainly include:
 - **Time of sowing** (often the factor that limits yield).
 - **Crop rotation**, eg rotate cereal crops with pulses, summer crops and pastures and
 - **Fallow management**
 - **No-till conserves** fallow moisture for subsequent crop use.
 - **Summer rainfall** is just as important to yield in winter crops as rain that falls through the growing season. Growers accumulate more soil moisture outside the growing season through early and effective summer weed control.
 - **Stubble retention** reduces in-season evaporation and helps with crop establishment on marginal soil moisture providing weeds are controlled.
 - **Residual soil moisture**. Relatively small amounts collected over summer or stored from the previous crop may make a significant difference to grain yield.
- **WUE relies on:**
 - The soil's ability to capture and store water.
 - The crop's ability to access water stored in the soil and rainfall during the season.
 - The crop's ability to convert water into biomass then grain.
- **WUE is greatly improved if:**
 - **Water application is matched to crop demand**, eg by precision irrigation (pages 372).
 - **The right tools are used to help achieve WUE**, eg controlled traffic (straight rows using GPS), permanent crop beds (reduced tillage), break crops (rotation) and selecting the right herbicides for weed control
 - **Online Seasonal Stream flow Forecasting Systems**. Maps and graphs indicate how much water is likely to flow into rivers and storages three months in advance.
 - **The Agricultural Production Systems sIMulator (APSIM)** has been used to model impact of out-of season rainfall in many regions.
 - **Online irrigator calculators improve on-farm water use** and help growers make more informed crop production decisions.

Branded water-wise schemes

All States / Territories and industries have water-wise programs, eg parks, golf, gardens:

- Smart Approved WaterMark System (2011). www.smartwatermark.org
- Smart water-saving pots.
- Water Smart Australia Program.
- Water Efficiency Labeling Scheme for indoor plant products.
- An Industry Water Policy (Nursery & Garden Industry Australia).
- Water Best Practice.
- CropWater Use www.cropwateruse.dpi.qld.gov.au
- Rural Water Use Efficiency (RWUE) programs.

Relative humidity (RH), atmospheric moisture

What is relative humidity?



Black spot (*Marssonina rosae*) of rose

Diurnal variation in relative humidity:

- Mean maximum RH occurs in the early morning.
- Mean minimum RH occurs in the early afternoon.
- Low RH in the afternoon is due to increased temperature, expansion of air and so increases the total water vapor capacity.

Relative humidity (RH) is the amount of water vapor actually present in the air compared to the greatest amount possible at the same temperature and pressure, expressed as a percentage (%). **RH** influences crop production **directly** by affecting the water relations of plant and **indirectly** affecting leaf growth, photosynthesis, and pollination, occurrence of pests and diseases and finally economic yield (page 237).

- **High relative humidities.**
 - **The incidence** of insect pests and diseases is high under high humidity conditions.
 - **Black spot of rose** (*Marssonina rosae*) is favored by wet weather and overhead irrigation.
 - **Relative humidities in excess of 95%** can reduce evaporation so much that nutrient uptake from soil is impaired leaving plants vulnerable to physiological disorders such as oedema (page 35). Optimum relative humidity is generally between **75-85%**.
 - **Space plants** correctly to improve air circulation and prevent high humidities on plant surfaces to inhibit infection by some pathogens, eg *Botrytis*. Direction of row crops may influence disease incidence.
 - **Air recirculation** by air blowers can help to prevent crop diseases.
 - **Avoid working when crops are wet.**
 - **Stored produce** must be aerated to hasten surface drying inhibiting germination and infection by any fungal or bacterial pathogens on produce.
- **Low relative humidities** are usually temporary and seldom cause damage unless combined with **high wind velocity and high temperatures** which may lead to excessive loss of moisture from the foliage.
 - **House plants prefer high humidity** and some require high humidity to grow and flower properly. Heating in modern homes have good conditions for plant growth but it often dries the air to a **RH** of 15-25% which is the equivalent to that of desert environments.
 - **Twospotted mite** (*Tetranychus urticae*) numbers build up rapidly during hot conditions. Humidity and temperature can be controlled in glasshouses to minimize risk of severe outbreaks. Adequate irrigation can reduce the effect of their feeding.

Light

Adequate light	<p>Adequate light is a necessary requirement of plants for photosynthesis.</p> <ul style="list-style-type: none"> • Many plants also have definite requirements for growth, flowering and fruiting. Azaleas require 3-4 hours of sunlight each day to promote flowering. • Seedlings commonly produce spindly growth due to insufficient light. • Parasitic diseases and pests are affected by light conditions, eg some fungi will only produce spores when there are sufficient ultra-violet wavelengths in sunlight.
Photo damage	<p>Photo damage may occur on some species of eucalypts, eg Tasmanian blue gum (<i>Eucalyptus globulus</i>) when there is a combination of strong light with low air temperatures both in field nurseries and after planting out (Aust. Hort. Aug 2003).</p> <ul style="list-style-type: none"> • Though seedlings are most susceptible to frost and photo damage after planting out, crop loss can occur in the nursery. Even those planted on comparatively mild sites where frost and low temperatures periodically occur can be damaged. • The nursery has since adopted an automated system in which the extendable shade cloth is moved into place once air temperature drops below 10°C. In the field on cold sites shade cloth has prevented photo damage by reducing exposure to sunlight after frost.
Photosynthesis	<p>Light is the basis for photosynthesis. Plant growth and development are subsequently influenced by the quality and quantity of light. Light levels vary, depending on where you are geographically and the time of year, ie shorter days and less power in the sun.</p> <ul style="list-style-type: none"> • Diffused light penetrates more deeply into crops and increases crop yield and quality. • Removable coatings are now available that convert direct solar radiation into diffuse light (diffused light is also available using expensive special glass), eg <ul style="list-style-type: none"> • ReduSol® and ReduHeat® products enable growers to optimize the regulation of climate conditions in their greenhouses. • ReduCondens® eliminates light loss and prevents <i>Botrytis</i> caused by condensation droplets.

Wind

<p>Protecting plants</p> <div style="border: 1px solid black; padding: 2px; width: fit-content;"> <p>Desertification sand storms have occurred since biblical times</p> </div>	<p>Wind affects transpiration of leaves and so more water is required to sustain growth.</p> <ul style="list-style-type: none"> • Young fruit trees such as avocados are particularly susceptible to wind damage so special care should be taken in windy areas. • Trees are commonly used to provide wind breaks when establishing properties. • Suitable trees for natural windbreaks include <i>Casuarina cunninghamiana</i> and evergreen poplars (low suckering species). • Wind may cause trees to lean in a windward direction, slow crop growth, cause young leaves to wrinkle and tear, fruit to drop, cork and callus (Fig. 5 below). • Excess movement of tree tops reduces shoot growth up to 20%. <p>Parasitic diseases and pests.</p> <ul style="list-style-type: none"> • Wind may reduce the effectiveness of some biological control agents. • Casuarina buffer zones could be a first line of defense against windborne insects.
---	---



Fig. 5. **Left:** Very young citrus fruit with abrasion damage due to wind. **Right:** Mature citrus leaves wrinkled and malformed by wind injury when young. Photo©NSW Dept. of Industry & Investment.

Predictive weather stations

Weather stations help growers make better decisions

<p>Pest, disease and weed predictors</p>	<p><u>There is now a good understanding of the weather conditions</u> under which most of the key disease and pests of economic crops develop. Computer models have been developed to measure weather parameters and assess the crop risk from some diseases, eg downy mildew of grapes, apple scab. Historical records indicate seasonal variability in crop quantity and quality and in the timing of certain growth stages and harvest dates.</p>
<p>Abiotic factors</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.</p> </div>	<p><u>These include:</u></p> <ul style="list-style-type: none"> • Temperature. Is it too hot or too cold? <ul style="list-style-type: none"> • Frost is an increasing challenge in some areas; many monitoring systems have frost alerts built into them which send a message to the grower to turn on fans or sprinklers. Some are automated, ie may trigger a frost control system. • Coated seeds can delay germination until after the likelihood of frost. • Evapotranspiration measurements are also quite common. <ul style="list-style-type: none"> • Moisture probes are installed on-farm. • Results of waterlogging are complex because it not only impacts crop growth but also the soil environment, making some nutrients less available to the plant. • Wind can damage a range of crops. <ul style="list-style-type: none"> • Trees can be blown down, leaves and fruit blown off trees, flowers damaged.
<p>Why needed?</p>	<p><u>For many reasons</u>, including:</p> <ul style="list-style-type: none"> • Suitable weather for spray applications, eg to avoid rain and reduce spray drift. • Crop quality and quantity. Assessing insect damage on emerging plants before deciding whether to spray, rather than relying on calendar insurance sprays. • Warning services are conducted in the principal apple growing districts so that the application of fungicides can be timed more effectively, using post-infection curative fungicides rather than on a calendar basis (see page 407). • Deciding on planting and harvesting dates. • Analysis of pest outbreaks, assessment of the impact of climate change, timing of control measures and the interpretation of in-field trapping data can be forecast. • Predicting the flowering of weeds to prevent seed set. • Indicating when the pest, disease or weed is likely to be around, so that monitoring can be carried out to check on thresholds, eg codling moth. • Cotton pests thrive in the wet. It is essential to monitor crops from an early stage for pests and beneficial populations. The number of insect pests surviving on weeds and other crops over winter and then moving onto cotton depends largely on seasonal conditions. • Early warning systems can automatically monitor and record a wide range of data, eg temperature, humidity, rainfall, hours of sunshine and leaf wetness. • Warning messages are displayed when critical conditions are reached for infection. • Growers reduce pesticide usage and minimize environmental and health risks. • Electronic control systems can automatically trigger irrigation, reducing the need for direct action from the grower.
<p>Weather programs plant indicators, plant trials</p>	<p><u>Weather programs</u>, eg</p> <ul style="list-style-type: none"> • Weather Wizard 111 provides information on inside and outside temperatures, wind speed, wind direction, wind chill, time and date, highs and lows alarms. • Spraywise decisions predict weather up to 14 days in advance for choosing when and how to spray to achieve optimum results. • Weather station / Disease Predictor (The Model T MetStation) help growers make better decisions in control of weather-driven diseases and pests in some crops (SARDI). • Climate Kelpi 2011 is a one-stop shop for climate risk management information and tools. It provides links to the best available tools and information about climate, helping farmers and advisors to make farm business decisions. • Some are designed for special diseases, eg downy mildew of grapes (see page 407). <p><u>Interpreting plant trial results</u>, eg</p> <ul style="list-style-type: none"> • National Variety Trials (NVTs) of the grains industry. Frost detection is one of the most important factors when monitoring individual sites as frost can significantly influence quality and yield results and alter a varieties general performance. • District maps of specific weather parameters or disease risk are now a reality and can forecast individual regions. • Remote sensing is already in use in many districts – mapping disease outbreaks, vigor, missing vines as well as water table issues and soil temperatures. <p><u>Plant Efficiency Analysis (PEA)</u> is a convenient system for investigating plant photosynthetic efficiency without damaging the plant.</p> <p><u>Drought alarms.</u> Scientists have found a molecular signal in plants which may act as a drought alarm, allowing them to adapt to drought conditions. Such plants survived 50% longer in drought conditions (<i>Plant Drought Alarm Signal</i>. Aust. Hort. March 2012).</p>

Choosing the crop or the crop site

Disease or pest-free zones	<p>Area freedom. Many plants are grown in countries or parts of a country where certain diseases and pests are still absent (page 191).</p> <ul style="list-style-type: none"> • Pest-free zones in Australia include Fruit Fly Exclusion Zones (FFEZs) and areas free from dodder weeds and grapevine phylloxera. • Palm plants may be grown in areas where palm leaf beetle (<i>Brontispa longissima</i>) is not known to occur.
	<p>Macroclimate</p> <p>The region for crop / plant production is usually selected on:</p> <ul style="list-style-type: none"> • Climate and features favorable for crop growth, eg temperature, rainfall, soil type. Many IT programs are available which indicate climatic zones, eg plant hardiness maps by CSIRO, plant guides such as Arbordata, Plant Growers Australia (PGA). Growers may alter conditions, eg provide shelter from hot sun or frost. <ul style="list-style-type: none"> • Drought also affects crop selection for break crops; risky break crops like canola may be dropped. www.spraywise.com.au • Avoid planting frost-sensitive perennials in frost-prone areas, drought-sensitive species in unirrigated nature strips and sunloving species in shady areas. • Conditions unfavorable to the activities of certain pests, diseases or weeds. • Choosing the correct site applies to protected crops and indoor plants as well as to outdoor plantings.
<p>Microclimate</p> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; font-size: 0.9em;"> <p>This information is useful for predictive systems</p> </div>	<p>The microclimate in the immediate vicinity of the crop means different things to different people and different microorganisms. Temperature and humidity inside of a greenhouse may vary widely from side to side and from floor to roof. So specify exactly the piece of the microclimate referred to, eg root, fruit, or a whitefly sucking sap from a leaf.</p> <ul style="list-style-type: none"> • Pest and disease activity is mostly influenced by the microclimate in the immediate vicinity of the crop. Depending on their size microorganisms and insects live on a leaf in their own individual ecological niche. Understanding this is the key to escaping many of them by avoiding microclimates they prefer, without compromising plant growth. <ul style="list-style-type: none"> • Fungal spores and bacteria have to withstand a range of temperatures, humidities and UV rays in sunlight before coming to rest on a leaf. Those splashed on by water or deposited by sticky fingers and sappy tools get a free ride. Once there, virtually all of them depend on a water droplets or a wet wound to begin infection. • Flying insects go through the same environments as airborne fungal spores but some of their life cycle is spent on the leaf. Cabbage white butterfly eggs are on the leaf undersurface, which might have a quite different environment from the top. • The microclimates of biocontrol agents (bacteria, fungi, predators and parasites) are close to those of their specified pathogens and pests. Many biocontrol fungi and bacteria need a wet host microclimate too. Know the life cycles of the biocontrol agents as well as that of the pest, eg how many eggs are laid by spider mites and how long do they take to hatch at a particular temperature. • The microclimate can be modified, eg relative humidities can be changed by reducing rates of sowing, pruning, irrigation and mulching, protecting plants from sun, wind and hail by hail netting, climate control in greenhouses can be varied. • Crops highly susceptible to particular diseases when grown in humid areas can be grown relatively free from disease under surface irrigation in more arid regions.
	<p>Selecting plants Selecting sites</p> <p>Crop choice is an important decision which is determined by the markets, condition of the crop area and the outlook for the season ahead. Sometimes a crop choice has to be changed quickly, eg if an area doesn't come up the way required. Choose:</p> <ul style="list-style-type: none"> • Varieties suited to the particular site. Be realistic. Choose plants which are tolerant of a range of rainfall conditions. Look for plants that have adaptations that enable them to withstand both drought and wet feet. Areas designed to cope with ever decreasing amount of water may become awash with water. • New varieties and products are being released all the time • Passionfruit in cold areas must be sheltered from frost in winter but exposed to many hours of sun in summer, otherwise they will not fruit satisfactorily. • Sometimes it is possible to move small plants, which have been sited incorrectly. • Container plants can be moved readily from one location to another, eg they can be moved outside during summer. • Melbourne's urban forest renewal. A lack of species diversity leaves the urban forest vulnerable to threats from pests, disease, and climatic stress. Many of Melbourne's trees were planted at the same time and are reaching the end of their useful life expectancy. Myrtle rust and sycamore lace bug are also contributing to problems. A greater range of species will provide greater resilience and long-term stability as a whole. Species diversity is a basic rule for reducing risk www.melbourneurbanforestvisual.com.au/ <p>Melbourne's urban forests - lack of species diversity</p>
<div style="border: 1px solid black; padding: 2px; margin-top: 5px; font-size: 0.9em;"> <p>The right plant for the right site</p> </div>	<p>When selecting sites for plants avoid areas with:</p> <ul style="list-style-type: none"> • Poor drainage, soil compaction and other undesirable features, with species which are very sensitive to these problems. If possible remedy problems prior to planting. • Infested soil. Avoid planting disease-tested or apparently disease and pest-free plants, tubers and seed in contaminated soil. Carry out preplant soil tests. • Crop debris which may carry diseases and pests from a previously infected crop.

A changing climate

From time immemorial the world has been changing, eg getting colder or hotter etc. However, today we are faced with an accelerated rate of change. Rising temperatures will exceed some species tolerance, especially in alpine regions, while increases in frost and drought will alter vegetation, favoring grassland over trees and woodlands. Provided climate change is not too rapid or large, most Australian agriculture and horticulture enterprises are likely to develop the necessary coping strategies. The **NGI's Climate Change and Variability Policy Position** document outlines the Australian nursery and garden industry's role in managing the effects of climate change and variability in urban natural environments and how governments and authorities can assist.

Climate change and economics

Higher temperatures substantially reduce economic growth and these reductions occur in **rates of growth, not just annual levels of output**. It has been estimated that a **1°C** rise in temperature reduces economic growth rates by **1 to 1.5 percentage points**. The negative impact of climate change was almost completely limited to poorer countries. Rich countries showed no signs of decreased economic growth as a result of higher temperatures (Dell et al 2011).

Effects of climate change

Climate variability for grapevines:

- Will it be wetter, hotter, how significant will drought be?
- Will there be changes in distribution?
- Will there be changes in vine and pest phenology so that more damaging interactions will potentially occur?
- Are there potential changes in vines that make them more vulnerable to attack?

The direct impacts of climate change will be the result of the combined effect of CO₂ increases, rises in temperature, changes in evaporation and in rainfall averages, variability and intensity. They are likely to lead to changes in climatic patterns across the continent; frequency of storms, floods, droughts and frost may increase.

- **Crops.** Carbon dioxide is the staple food of plants. **The predicted increase in CO₂ concentration** could influence future crop productivity; it may increase growth and yield of some crops in some regions and increase demand for soil nutrients.
 - Some fruits such as cherries require winter chilling, but new varieties can be bred.
 - Longer seasons for lawns may make them more costly to maintain, so there is a need for more drought-tolerant, coarser grasses.
 - Changing production regions (where the crops grow) or cropping cycles.
- **Weather.** Depending on location, climate change may affect horticulture through:
 - Increased crop water needs and reduced water availability.
 - Greater crop damage due to frosts and heat stress.
 - Increased damage from extreme weather events.
- **Habitat loss and other threats to Australia's ecosystems,** extinction of some species.
- **Weeds.** With climate change we can expect that the geographic range of some weeds may change, some that prefer cooler climates may be reduced.
- **Pests and Diseases.** The likely impact of climate change on key pests, diseases and weeds has been researched and is available online, eg Qld fruit fly.
 - Warmer, wetter weather may increase plant susceptibility to diseases and favor the spread of water-transmitted diseases, eg *Phytophthora*.
 - Increased activity of some pests.
 - Some pests dormant in winter may remain active.

Adapting to climate change

Crop choice, inputs and opportunity cropping.

New strategies, eg new equipment, diversifying crops, storage.

Many adjustments to climate change will be extensions of current practices.

- **Flexible planning.** Decisions may need to be more opportunistic, taking into account environmental conditions, eg soil moisture, seasonal climate forecasting and market conditions, routine record keeping of weather, production, degradation, pests, diseases, weeds, also improved efficiency of water distribution systems to reduce leakage and evaporation; improved irrigation practices and moisture monitoring. Greenhouse gas (GHG) mitigation options for agriculture are being investigated.
- **Integrate more accurate weather forecasting into management.** Internet tools help growers integrate climate information into their management systems, eg
 - **Next generation of internet-based weather forecasting tools** in development, are able to provide accurate "multi-week" and improved "seasonal predictions, eg CropMate[®], Climate Kelpie www.climatekelpie.com.au, Climag www.managingclimate.gov.au
 - **Climex is widely used around the world** to examine the distribution of insects, plants, pathogens and vertebrates for a variety of purposes including invasive species risk analysis, pest incursion management, biological control, quarantine, and biogeography, vulnerability to pests, vector-borne diseases, climate change, education and policy.
- **Crop choice** and expectation of crop yields vary according to seasonal conditions.
 - **Opportunity cropping,** eg if it rains a good crop can be expected.
 - **Cropping rotations** primarily depend on climate outlook and rain events (Cole 2012).
 - **Crop varieties** with resilience to drought, frost, heat stress will enable continued productivity, irrespective of climate change, eg selecting a shorter season variety and planting later in the season, prune grapevines earlier to encourage late budburst, zero-tillage to retain soil moisture and maintain soil temperatures.
- **Managing inputs via precision agriculture (PA)** enable nutrient, soil, weeds and water variations in a field to be efficiently mapped and managed leading to reduced inputs of fertilizer, water and herbicides (page 372). The biggest source of **greenhouse gases (GHGs)** from cropping is nitrous oxide produced by microbial activity in the soil breaking down nitrogen fertilizer that has **not been utilized** for crop growth. Matching a crop's nitrogen needs to avoid a surplus can reduce the later production of **GHGs**.
- **Double-cropping** is producing 2 crops on the same land within the same year, eg growing a winter and summer crop following one another to improve the profitability and water use efficiency of irrigated cropping.

PA

PLANTING, SPACING, PRUNING, ETC

Planting



Select planting times to provide weather conditions, such as temperature and moisture that are **favorable for growth and development of the crop** but **unfavorable for the disease or pest**. Sowing on time is critical to profitability.

- **Time sowing** to avoid the period of main disease, pest or vector activity.
 - **Damping-off** is more common in seeds planted **early**, when **low soil temperatures** are more suited for the development of damping-off than the growth of the seed.
 - **Tomato spotted wilt virus** is particularly serious in **early tomatoes**. Seek advice, either delay planting, replace infected plants or spray regularly to control insect vectors?
 - **Autumn plantings** should be confined to frost-tolerant species because young plants tend to be more prone to frost damage.
 - **Greatest variation in sowing times is possible in greenhouses** where considerable manipulation of crop microclimates is practicable.
- **Depth of planting**, eg potato seed pieces are more readily attacked by *Rhizoctonia* if planted too deeply.
- **New cultivars** which are adapted to the selected growing period may be required.

Appropriate spacing

Appropriate spacing is necessary for:

- **Correct growth and development** of seedlings, cuttings and mature plants.
- **Preventing diseases and pests** favored by poor air circulation and high humidity.

Close plantings.

- **Some diseases**, eg bacterial gall of oleander (*Pseudomonas syringae* subsp. *savastanoi* pv. *nerii*), *Phytophthora* root rot (*Phytophthora* spp.), and **some pests**, eg twospotted mite (*Tetranychus urticae*) and cyclamen mite (*Phytonemus pallidus*) will **spread slowly through plantings** if individual plants touch one another. It may be possible to have a greater number of smaller plantings rather than a single large planting of susceptible plants. This may be recommended for urban tree plantings.
- **Beneficial insects** can move more freely on plants grown close together to form dense hedges or groups.

Crop density can be manipulated by spacing, seeding rates, fertilization, water regimes, pruning, thinning, trellising, staking and harvesting plants or plant parts.

- **Vigorous, fast growing crops**, eg turf, will compete effectively with weeds.
- **Controlling insect pests and diseases** can give the crop a competitive edge over associated weeds.

Harvesting



Time and method of harvest and marketing is paramount in the production of all quality produce, whether it is food, plants, or cut flowers.

- **Flower buds picked too early** may not open; fruit may not ripen properly.
- **Early ripening fruit** may escape serious attack by **brown rot and fruit fly** in some cooler areas of Australia and reduce the need for pesticide applications.
- **Selective harvesting** for specific quality has paid dividends in the grape industry and other crops, researchers are now investigating this potential for grain crops.
- **Grading, packaging, labeling, marketing**
 - **Grading**, eg size and color of flowers and fruit, length of flower stem.
 - **Packaging**, eg individual packaging and wrapping, size of total package to avoid bruising, inclusion of small packets of items to increase the vase life of flowers, maintaining appropriate temperatures to prevent deterioration.
 - **Labeling**, eg information leaflets on care may accompany some products, products must be correctly labeled.
 - **Minimize mechanical damage** when harvesting produce as damaged fruit is susceptible to postharvest infections.

Pruning



Plants should be pruned correctly at the correct time of year for each variety or situation.

- **Minimal** pruning techniques can lead to improved quality of some crops, eg grapes. Computer-based pruning production models are being developed.
- **Severe pruning** of old woody shrubs such as rosemary may cause them to die.
- **Pruning** is widely carried out in sanitation exercises (page 69).
- **Root prune** well ahead of transplanting mature shrubs and small evergreen trees. Make vertical slits perhaps 1/3 to 1/2 metre from main stem. Bonsai management is the ultimate in root pruning.
- **Dead flower heads of pansies** are pinched out to further flowering.
- **Older plane and citrus trees** may be pruned to rejuvenate them.
- **Plant growth regulators**, eg Regalis[®] (prohexadione-calcium) can reduce summer pruning costs in apples (page 31).

SOIL AND SOIL ORGANIC MATTER (SOM)

Soil is back on the agenda after 50 years

By and large Australian soils have low levels of organic matter

Soil is a living body, essential to sustain quality of life on the planet. **The upper 0-20cm of soil** is the most active and important zone, but also the zone most vulnerable to erosion and degradation.

- Most environmental functions and services that are essential to support terrestrial life on this planet are concentrated in the fauna and flora which live and interact in this zone.
- It is also the zone where human activities have the most immediate and potentially the greatest impact.
- By protecting this critical zone, we ensure the health, vitality, and sustainability of life on this planet.
- Omnivorous and predatory nematodes may be useful indicators of soil health.

Australian standards

AUSTRALIAN STANDARDS

Some soils must comply with Australia standards (AS):

- AS 3743.2003. *Potting Mixes*.
- AS 4419.2003. *Soils for Landscaping and Garden Use*.
- AS 4454.2012. *Composts, Soil Conditioners and Mulches*.

Soil conditioners vary greatly in their composition, application rate and expected or claimed mode of action. Claims for various products include, but are not limited to:

- Improved soil structure and aeration.
- Increased water-holding capacity and increased availability of water to plants.
- Reduced compaction and hardpan conditions.
- Improved tile drainage effectiveness.
- Alkaline soil reclamation.
- Release of “locked” nutrients.
- Better chemical incorporation.
- Better root development, higher yields and quality.

Environmental Best Practice Guidelines Soil management

Environmental Best Practice Guidelines Soil Management are available for different types of soils and situations, eg acidic soils, they generally include:

- Monitoring soil conditions.
- Avoiding traffic on wet soils, mechanization (soil compaction by heavy machinery).
- Improving organic matter content.
- Weed, pest and disease management.
- Nutrition and irrigation management, including nutrient budgeting and mapping.

The Soil Biology Initiatives 11

There are 3 key themes:

1. Monitoring soil quality for better **IPM** decision-making (page 333).
2. Management systems for **enhancing nutrient availability**.
3. **Suppressive soil traits and transferability**. In seasons when waterlogging has been common across high rainfall zones, soil health is a major problem (page 120).

Rhizosphere



The rhizosphere is the narrow region of soil around **living roots**.

The rhizosphere is the narrow region of soil that is directly influenced by **root secretions** and associated soil **microorganisms** (bacteria, nematodes, protozoa, etc).

- **Living organisms only make up about 1% of soils**; even so soils contain millions of organisms per gram.
- **The concentration of microorganisms** in turf is at its greatest in the **top 5cm of soils**. This area, known as the rhizosphere, is home to a thriving ecosystem of beneficial fungi, bacteria and actinomycetes, nematodes, protozoa, algae and yeasts (Geary 2010). Beneficial soil microbes such as *Trichoderma* spp. play an important role in decomposition of thatch and other organic matter, clippings, dead roots and stems.
- **Biostimulants**. In the last 10 years there has been sharp increase in products aimed at promoting soil microorganisms to turf and horticultural markets. The vast majority of micro and microorganisms play a vital and beneficial role in soils (pages 53).
- **Organic matter and humus**. Only **4-8%** of the total volume of Australian agricultural soil is made up of organic matter, it is eventually broken down and converted to brown / black structureless material called **humus**. Humus is important in soil biology as it contains organic carbon and nitrogen needed for microbial development and is the major food reserve of microorganisms (page 45).
- **Larger microorganisms**, eg earthworms, protozoa and nematodes also play a role.

Permanent soil cover

Maintaining permanent soil cover and promoting minimal mechanical disturbance of soil through zero tillage systems, ensures there is sufficient living and / or residual biomass to enhance soil and water conservation and control soil erosion. Permanent soil cover is maintained during crop growth phases as well as during fallow periods, using cover crops and maintaining residues on the surface.

- **Promoting a healthy, living soil** through crop rotations, cover crops, and the use of **IPM** technologies (page 333). These practices reduce requirements for pesticides and herbicides, control off-site pollution, and enhance biodiversity. Crop rotations and associations can be in the form of crop sequences, relay cropping, and mixed crops.
- **Promoting legume fallows** (including herbaceous and tree fallows where suitable), composting and the use of manures and other organic soil amendments improves soil structure and biodiversity, and reduces the need for inorganic fertilizers.

Efficiency and flexibility	<p>Precision agriculture (PA) enables targeted management of subsections of large areas. PA enables nutrient, soil, weeds and water variation in an area to be efficiently mapped and managed leading to reduced inputs of fertilizer, water and herbicides. PA consists of observation, evaluation and interpretation, targeted management and review (page 372).</p>
Soil structure <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-left: 20px;"> Spread Delve Spade Invert </div>	<p>Soil compacted by cars, machinery, walking, sport and other activities will result in poor water penetration and root development.</p> <ul style="list-style-type: none"> • Controlled-traffic farming is a way of optimizing soil structure. • Remediated sandy soils with clay-rich soil can generate substantial crop yield improvements provided appropriate methods are followed, eg spread, delve, spade, invert. Best Practice Guides are available. • Ground-penetrating radar (GPR) can accurately maps the depth of clay in duplex soils in the Esperance region of WA. • Parasitic diseases and pests: <ul style="list-style-type: none"> • Root knot nematode populations are favored by sandy soils which have large soil pores permitting adequate aeration. • The rhizosphere immediately around plant roots is where most subsoil disease and pest activity occurs. It can be modified by manure, irrigation and sowing depth. • Testing soils for disease potential before planting can assist disease management by indicating when rotation or other treatments are needed.
Adding organic matter to sandy and clay soils	<p>Organic matter improves sand's ability to retain moisture and nutrients while adding organic matter to clayey soils improves drainage and better aeration of plant roots.</p> <ul style="list-style-type: none"> • Compost is one of the most favored forms of organic matter for soil improvement. • Animal manures are particularly valuable because as well as supplying some bulk to the soil, they contribute useful fertilizer elements. <ul style="list-style-type: none"> • There may be some situations where animal manures are not permitted, eg poultry manure can only be used if composted as it is a breeding medium for stable flies. Some shires have banned its use. Beware of introducing weeds in manure.
Fit-for-purpose products for horticulture <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-left: 20px;"> Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen </div>	<p>Composts, mulches, biochar, humic acids, manures, etc.</p> <ul style="list-style-type: none"> • Innovation in production technologies including composting, pyrolysis, anaerobic digestion are developing new products and application techniques, social, economic and other drivers of Soil Organic Matter (SOM) management (University of Adelaide 2011). • Used in vegetable production, fruit and berry growing, amenity horticulture, landscape and land rehabilitation, turf production and maintenance, protected cropping, potting and container mixes, viticulture, flower production, tree cropping. • Soils for Landscape Development (Leake and Haeghe 2014).
Organic amendments	<p>Organic amendments incorporated into soil may suppress soilborne diseases by increasing microorganisms that are antagonistic to them. Points to note:</p> <ul style="list-style-type: none"> • Decomposing organic amendments stimulate the activity of parasites and predators of root knot nematodes, produce nematotoxic compounds and may increase the tolerance of plants to nematode damage (Pattison et al. 2011). • Recycled organic material including animal manures can provide alternatives to mineral fertilizers. The addition of organic matter can: <ul style="list-style-type: none"> • Improve soil structure. • Increase soil microbial activity. • Have over-all long term benefits. • Some cow manures and other amendments are guaranteed weed and chemical free. • Deep banding of organic amendments, a practice known as subsoil manuring, can increase crop yields, improve the physical properties of the subsoil and increase the Plant Available Water Capacity (PAWC). Improvements may still be present 4 years later after the initial placement of the organic matter in the subsoil. • Some soil organic amendments reduce nutrient leaching and water losses in sandy soils. This reduces fertilization and irrigation expenses, improves soil fertility and fertilizer utilization. Organic amendments stimulate microbial activity, are biodegradable, environmentally safe, nontoxic and non-contaminating. • Organic amendments may not meet the plant's needs for nutrients and lead to deficiency in the plant and in the soil. <ul style="list-style-type: none"> • Intensive animal production systems, particularly pigs and poultry as well as meat processing plants, produce organic waste products high in nutrients. • These nutrients may require treatment to be converted to plant available forms. In addition these wastes are often mixed with liquids, so large volumes have to be spread to achieve even low levels of nutrient additions. • Another problem is that nutrient content can vary between each load. It is important to have them tested. • Salts, especially sodium, in raw animal manures can be high enough to cause problems for plant growth. Raw manures often contain weed seeds and pathogens. • Some organic amendments bio-degrade very slowly, eg eucalypt leaves.

Carbon

C

Organic matter is described as plant and animal residues in varying stages of decomposition

Carbon is part of productive growing systems. Plants take carbon dioxide (CO₂) from the air for growth and add it to the soil through plant debris. Microorganisms break down plant debris and convert it into soil carbon (Baxter 2012). Many think that there is a need to reassess the amount of carbon being absorbed by plants and the implications for trying to measure the capacity of crops and forests to soak up carbon dioxide.

The **Soil Carbon Research Program** will provide a nationally consistent assessment of soil carbon conditions across major land-use / soil-type combinations used for agricultural production across Australia (Soil Biology Initiative). www.soilquality.org.au

Five types of carbon are found in soils (Baxter 2012)

1. **Microbial biomass carbon** (living fungi, bacteria) which decomposes plant residues to release CO₂ and nutrients into forms available for plants.
2. **Easily decomposable organic carbon**, ie plant shoot and root residues, stay in the soil for a few days to a few months and are a source of food for soil organisms.
3. **Particulate organic carbon** – individual pieces of plant debris (**0.05 to 2mm in size**). Plant residues and particulates improve soil structure and can affect the availability of nutrients to growing plants. The decomposition of **high nutrient content residues** such as legumes will initially increase the availability of nutrients to plants; while the decomposition of **low nutrient content residues**, such as stubble will initially reduce the availability of nutrients to plants.
4. **Humus (soil organic matter)** – well decomposed materials **smaller than 0.05mm** which are dominated by molecules stuck to soil minerals. Humus is one of the most important ingredients for maintaining and improving soil fertility and plant growth. It is mainly derived from the natural decomposition of plant and microbial matter over a **prolonged period** (many years) and is an important part in:
 - Improving the efficiency of water use by increasing water retention properties of soils.
 - Promoting development of better soil structures allowing greater plant root growth in soil.
 - Stimulating beneficial microbial activity by providing a good source of carbon and nutrients. Most Australian soils contain **less than 1% humus content**, with very few soils having more than **2-3%**. Soils with very low humus content usually have poor water holding and nutrient retention abilities, very poor physical structures and unfortunately low fertility and productivity.
5. **Resistant organic carbon** – dominated by pieces of **biologically resistant** charcoal, which lifts the soil's cation exchange capacity in sandy soils and its ability to hold water. May be thousands of years old.

Each type of soil carbon plays a different role in contributing to a soil properties:

- **Chemical**, eg minimizes pH change, immobilizes pollutants, and buffers soil temperature.
- **Biological**, eg energy for soil microbes, large store of nutrients such as N, P, K, S, Ca, Cu, Zn.
- **Physical**, eg improves soil structural stability, influences water retention, and reduces water and soil loss.

The activities that most improve the carbon content in the soil are

- Conservation tillage
- Recycling of crop residues and
- Improved soil fertility

Biochar

Biochar is a fine-grained, highly porous charcoal substance that is used as a soil amendment. Soils throughout the world contain biochar deposited through natural events, such as forest and grassland fires.

- **Biochar is a stable form of charcoal** produced by heating natural organic materials (crop and other waste, woodchips, manure) in a high temperature, low-oxygen process known as pyrolysis.
- **Different biochars** are derived from different materials and produce many different crop responses depending on the type of biochar applied.
- **It is chemically a more stable form** of carbon than the material from which it was produced making it more difficult to break down; in some cases it can remain stable in soil for hundreds or thousands of years.
- **Biochar may influence** the leaching and rate of breakdown of herbicides such as simazine and thereby affect future crop rotations.
- **There is potential** for biochar to assist with soil nutrition and lift yields in some crops.
- **It has been proposed** that a carbon-oriented agricultural revolution could double world food supplies while simultaneously building soil fertility and lowering atmospheric and oceanic concentrations of carbon (Bates 2010).

MULCHES

Mulches are full of contradictions

Australian Standards	<p>Mulches are materials placed on the surface of the soil to conserve water, suppress weeds and be decorative.</p> <ul style="list-style-type: none"> • There is an Australian Standard for mulches: AS 4454-2012. <i>Composts, Soil Conditioners and Mulches.</i> • Biodegradable materials used for mulching include straw, autumn leaves, grass clippings, various composted materials and biodegradable polymer films. • Manufactured products are also available including weed mats.
AUSTRALIAN STANDARDS	
Benefits of mulches	<p>Reduces weed problems, especially annual weeds, reducing the need for herbicides and hoeing around the roots of plants. Plants grow better with greater root lengths. Mulches:</p> <ul style="list-style-type: none"> • Reduce soil water evaporation, aid water retention and conservation; reduce loss of water from the soil, increase infiltration and absorption of water. • Reduce temperature fluctuations, eg lowers summer soil temperatures by up to 5°C. In cool climates mulches can trap summer warmth extending the growing season. • Reduce mud splash onto plants. • Reduce water splash spread of bacterial and fungal spores. • Protect seedlings from the impact of rain, hail and wind. • Prevent newly transplanted plants from drying out. • Prevent leaves, fruit and flowers from directly contacting the soil and any disease organisms in the soil. • Reduce soil compaction and erosion. • Some deter snails and slugs which prefer to move over smooth surfaces. • Some enrich soil by supplying nutrients and organic matter as they decompose. • Improve soil texture by keeping it slightly moist. • Increase populations of beneficial insects by providing shelter. • Surface-mulching of salt-affected bare surface areas around young seedlings reduces surface evaporation and salt concentration.
Challenges	<p>Soil temperatures under mulches in spring can be as much as 5°C lower than in unmulched soil. Even in some warmer climates the lower soil temperature beneath mulches may slow growth of early spring crops.</p> <ul style="list-style-type: none"> • Apart from damping off and general rots associated with excessive moisture, mulches can also carry specific disease, pests and weed risks which can be reduced by ageing or composting and avoiding stem contact. <ul style="list-style-type: none"> • Avoid mulches made from the same / similar plant species. • Crop residues used as a mulch can provide some diseases and pests with a food source as well as an environment in which to live and reproduce and so may increase some disease and pest problems, eg <i>Sclerotium</i>, <i>Armillaria</i>, termites, vermin. • It is not uncommon to have the fruiting bodies of fungi appear on eucalypt mulches after it has been applied. These are not usually harmful but are merely biodegrading the mulch. • Mulches which are too deep or packed down prevent moisture penetration, exacerbate drought, and absorb light rain preventing it reaching the soil. Roots which grow into the mulch layer seeking moisture are vulnerable to drying out and damage. Hydrophobicity (a tendency to repel water) associated with certain fungi may itself be a consequence of not keeping the compost sufficiently moist. Adding wetting agents to mulch can enhance performance. • Some mulches biodegrade quickly, eg newspaper, pine needles, often have only a temporary effect unless put on thickly. • Cost of transporting mulch is high, only on-site mulches are practical for field crops. • Nitrogen drawdown. Temporary withdrawal of soil N by microorganisms is common when nitrogen-deficient organic materials are incorporated into the soil (page 50). • Phytotoxicity occurs when substances leach into the soil and affect young plants. More and more unfamiliar materials are incorporated into mulches. Appropriate composting techniques are required to minimize such toxic chemicals. Green waste and compost can be contaminated with herbicides, etc. • Mulches can trap too much moisture which could be important in regions or episodes of high rainfall or sites with poor drainage; germinating seeds and seedlings are particularly vulnerable. • Keeping mulch clear of trunks is important, even if it means some weed growth. • Problems with mulches on sloping surfaces; land could be contoured before application. • Soil pH. Acidifying effects of mulch on soil pH are unlikely to be serious or prolonged but some mulches can raise the pH due to high Ca and K contents. • Some mulches can be a fire hazard. • Health effects and allergies to mulch, eg use of recycled crumbed rubber tyres.
<p>Mulches could insulate against the warming of cold soil in spring</p>	
<p>Recycled green or garden waste must be properly composted prior to using as a mulch to prevent introduction of weed seeds and plant disease.</p>	
<p>Nitrogen drawdown</p>	
Ground cover	<p>Carefully chosen groundcover plants in ornamental horticulture can effectively compete with weeds for space, light and nutrients.</p>

Different types of mulches

Mulches can be composed of organic materials (compost, wood chips, etc), stones or gravel or synthetic landscape fabric. Landscape fabric is preferred over black plastic as it allows air and water to move through it to benefit plant roots and it can be covered with bark, stones, etc to improve the aesthetic appearance and reduce degradation of the fabric by sunlight and to hold it in place. To be effective mulches should be applied immediately after plants are installed. Mulches range from 3-10cm deep depending on the type of mulch.

- **Hydromulching is a 1-step application** of the precise balance of seed, fertilizer and mulch for turf seeding, erosion control and re-establishing native species. **Enviroguard** bonded fibre matrix is a spray-on growmat and weedmat which holds seed and fertilizer. **Aquaseeding** is a similar system for turf seeding. It is applied hydraulically and dries to form a porous, ground-hugging mat which holds seed and fertilizer, preventing soil loss during rainfall or irrigation.
- **Cosmetic mulches** such as pebbles, colored pine bark, are used in ornamental landscapes for decoration, they often last indefinitely but leaves and debris have to be removed. Mulches may have to be removed and disposed of when no longer required. Dyed wood can disguise scrap wood of uncertain origin and treatment.
- **Plastic film** is out of favor but still widely used for the management of crops, eg strawberries and vegetables. **Woven plastic fabrics** allow air to circulate and water to seep through. They are used for crops such as blueberries and strawberry, and help to conserve moisture and warm soil temperatures. Weeds that do germinate under mulches soon exhaust the food stored in the seed and die from lack of light. **Current research into colored plastic** exploits growth responses to different wavelengths of light and on increasing yield and flavors.
- **Lucerne / barley straw** intensively cleaned of weed and grass seeds, provides better soil aeration, ease of handling and spreading. Compressed products saves water, controls weeds, are environmentally friendly and suitable for gardens and pots.
- **Mulching mowers** double cut grass and force it down into the thatch of the lawn making it available as "food". Benefits include not needing to get rid of clippings and reduces amount sent to landfill and fertilizer needs. Used on dedicated areas but is not so effective with turf varieties with a horizontal matting growth habit.
- **Tree based mulches** benefit plant growth and survival by maintaining greater soil moisture, decreasing competition from weeds, and moderating soil temperatures.
- **Composted garden waste** (lawn clippings, prunings and leaves) is applied as a mulch to a variety of plants, fruit trees and nut crops (page 71).

On-site (in situ) mulches and vegetables



Living mulch

'Clever clovers' (subterranean or other varieties with a short term growing season) are grown during winter to a height of 30cm, shading out competing weeds. The clover dies back naturally at the beginning of summer, setting seed below ground level, then collapses to form **3cm thick in-situ mulch**. Summer crops such as tomatoes seedlings are planted directly into the mulch. After the vegetable crop is harvested in autumn, the clover regenerates from the seed reserves and the cycle continues (Stirzaker 2010).

- **Field trials conducted** with capsicum at Bowen and Bundaberg and with broccoli at Gatton demonstrated **lower growth and yield** of the **vegetable crop** in soil covered by killed in situ mulch than in uncovered soil.
- **Biodegradable living mulches**, disease-suppressing (biofumigant) cover crops, crop rotation and semi-permanent irrigation could be integrated into a permanent bed vegetable management system.

Biodegradable mulches

Read, N. A. 2013. *Plant Residues and Newspaper Mulch Effects on Weed Emergence And Collard Performance*. Thesis. The Ohio State University.

The use of plastic mulch in agriculture has increased dramatically in the last 10 years throughout the world due to benefits such as an increase in soil temperature, reduced weed pressure, moisture conservation, reduction of certain insect pests, higher crop yields, and more efficient use of soil nutrients. However, removal and disposal of conventional polyethylene mulches remains a major agronomic, economic, and environmental constraint (reduced landfill capacity and legislation). Some **photo- and bio-degradable mulches** can be tilled into the soil following harvest.

- **Biodegradable polymers** as agricultural mulch films have become more available.
 - More information is needed on the effect of biodegradable mulches on crop growth, soil biota, soil fertility and yields (Kasirajan and Ngouajio 2012).
 - The source of **polymers and additives** may limit use of some in organic production as inputs are restricted.
- **At Gatton College in Queensland**, a large range of mulches were tested **for weed suppression, soil effects and crop response**.
 - **Paper film, biodegradable polymer film and 7.5cm layers** of sugarcane trash, sorghum hay, or waxed fiber cartons **provided weed suppression** equal to that of plastic mulch.
 - **Also the similar weight of marketable fruit of capsicum plants** grown in the biodegradable polymer film, paper film and plastic mulch indicated that biodegradable polymer and paper films had the agronomic potential to replace plastic mulch film. The costs of the biodegradable material trialed were in excess of that of the plastic mulch.
 - **Provided practical difficulties can be overcome** and the high cost of biodegradable polymer is reduced, these materials seem to be the best of the biodegradable alternatives to plastic mulch film.
 - **However**, 7.5 cm layers of composted vegetable mulch, bagasse or sawdust, a 3cm layer of recycled newspaper or hessian fabric were not so successful.

NUTRIENTS

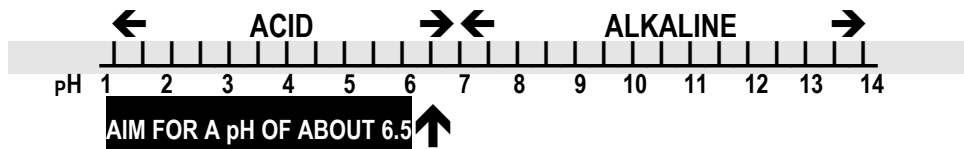
Acidity and alkalinity

Availability of nutrients

pH

Growers should know the pH of their soil / media and irrigation water

The pH is a measure of the acidity or alkalinity of a solution. Below pH 7 is said to be **acid** and greater than pH 7 is said to be **alkaline**:



- **Many products are available to modify** the pH of soil and growing media.
- **The pH of soil can alter the availability of certain nutrients** and indirectly cause plant deficiencies and excesses.
 - **In alkaline soils**, some nutrients become unavailable, eg iron; manganese and zinc **deficiencies** occur on azaleas, citrus, camellia, and many Australian native plants.
 - Iron deficiency caused by high pH is a common landscape problem and appears as interveinal chlorosis in young leaves.
 - A high pH can make phosphate sensitive plants even more sensitive leading to severe chlorosis as well as reddening, stunting and deformity of young leaves.
 - People quite often give their plants a high pH inadvertently, eg mushroom compost.
 - **In acid soils, deficiencies** of molybdenum occur on legumes. Lime lovers include plants in the legume families such as peas, beans and hardenbergas that find it easier to fix nitrogen (N) at higher pHs.
 - Another consequence of acidity is the production of **toxic levels** of soluble aluminum (Al) and manganese (Mn) in the soil solution. As the pH drops to below 5, Al and Mn become increasingly soluble and unless plants have some resistance to these toxic elements growth can be affected.
 - Legumes do not grow well in acid soils as they are intolerant of Al and Mn. Some eucalypts appear extremely tolerant of Al and can grow in highly acidic soils as low as 3.5.

pH testing

- Check pH of media when made.** Lime added later may alter the pH.
- **With long-term crops and stock plants**, the pH tends to become more acid over time due to continuing fertilizer applications. Acidity can result in land degradation.
 - **Most fertilizers tend to have an acidifying effect** and in the case of controlled release fertilizer the effect is increased with increasing rate of application.
 - **The pH of water** can seriously affect media pH.
 - Most common problems arise from high pH in water associated with bores or dams.
 - Mains water has a high pH from treatment chemicals. Because the water is usually relatively pure, the effect on the media is minimal.
 - If other salts, eg bicarbonates, are present the effects can be severe.

Parasitic diseases and pests

- Soil pH affects pathogenic and beneficial soil bacteria and fungi.**
- Club root (*Plasmodiophora brassicae*) of brassicas is favored by acid soils.
 - Common scab (*Streptomyces scabies*) of potatoes is favored by alkaline soils.
 - Crown gall (*Agrobacterium* spp.) is thought to be favored by alkaline soils.

Australian standards

AUSTRALIAN STANDARDS


Tips for retailers:

- Offer in-store pH testing service.
- Familiarize yourself with the pH of different materials, have information sheets to hand out.
- Ask customers where they live, if the area is known to have a difficult pH, etc.

- Various standards apply to soil and potting mixes**, eg
- **Always check** the pH of soil and potting mixes to make sure they meet the standards:
 - AS 3743.2003. *Potting Mixes*.
 - AS 4419.2003. *Soils for Landscaping and Garden Use*.
 - **There are various Australian Standards for water.**
 - **Potting mix pH** is rarely a concern for potted flower growers because it is produced and sold so quickly that pH is unlikely to change.
 - **Longer-term container stock** should be checked about every 2 months so that drifts in pH can be checked and addressed.
 - **One potential problem in mixes** is the acidification of mixes caused by the use of acidifying fertilizers.
 - **A common situation** for a landscape contractor presented with a list of plants by the client which is not compatible with the soil pH. The landscaper has two options – amend the list or amend the soil. Acidity can be neutralized or the soil acidified as required. Plant pH guides are available.
 - **Test pH** either with a glass electrode pH meter or with a calorimetric test kit. The latter is available to home gardeners but has limitations and is not suitable for grower use.

Fertilizers

Global fertilizer demand is set to grow 11% in the next 5 years.

<p>National Code of Practice</p> <p>CODES OF PRACTICE</p> 	<p><u>The National Code of Practice for Fertilizer Description & Labeling (2011)</u> provides information on content and form that enables informed decision making on use rates, application methods and timing. The Code also addresses Work, Health & Safety issues, eg covers labeling, naming of fertilizers, basis of analysis, and minimum level for inclusion of nutrients, product tolerances, impurities (maximum permissible concentrations, statement of concentrations, warning statements, weight and volume, physical description, etc).</p> <ul style="list-style-type: none"> • <u>State / Territory legislation</u>, etc. <ul style="list-style-type: none"> • WA has introduced regulations to half the concentration of phosphorus in garden fertilizers to minimize phosphorus leaching to the environment from residential sources. This aims to protect the health of WA's waterways and ground water. The P content in fertilizers set by the new regulations closely matches the nutrient requirements of plants, thereby reducing waste and leaching. www.slp.wa.gov.au/ (Aust. Hort. Feb 2011). • The Agricultural and Veterinary Chemicals (Control of Use) (Fertilizers) Regulations 2005 prescribe the requirements for fertilizer labels and advice notes, as well as standards for maximum levels of contamination in fertilizers sold in Victoria. • Companies may have little choice about phosphorous additives even in the organic product blood and bone; Qld regulations stipulate a phosphorous minimum, eg the addition of rock phosphate in blood and bone to get the P level up to Qld's requirements. • <u>Fertilizer residues in food</u>. There are standards (maximum permitted concentrations) for heavy metals (cadmium, mercury and lead) in fertilizers. Cadmium in food comes from phosphate fertilizer, poultry manure and soil derived from phosphate rock.
<p>Ferticare accreditation</p>	<p><u>Courses are offered by the fertilizer industry</u>, eg Australian Fertilizer Services Association (AFSA) and the Fertilizer Industry Federation of Australia (FIFA).</p> <ul style="list-style-type: none"> • <u>Ferticare</u> provides training to assist industry understand the food safety and environmental risks involved in handling, transporting, storing and spreading fertilizers, eg <ul style="list-style-type: none"> • Ferticare Training (page 282). • Ferticare Accredited Advisor. • The Accu-Spread program assesses and certifies the spreading width and uniformity of fertilizer spreading machinery. There is also Accu-Spread accreditation for contractor equipment for liquid application through boom sprays.
<p>Phytotoxicity</p>	<p><u>Practically all fertilizers are capable of causing damage to germinating seeds</u> if they are in close proximity to each other and in a concentrated band.</p> <ul style="list-style-type: none"> • <u>Often additional N and P fertilizer is needed at sowing</u>, but placing it too close to the seed or using high rates can burn new seedlings. Chance of fertilizer toxicity depends on the concentration of fertilizer near the seed, soil moisture, sowing equipment, soil type, crop species and fertilizer choice. <ul style="list-style-type: none"> • <u>The sensitivity of the plants</u> is probably the most important factor. Some species of plants and even varieties won't tolerate excess fertilizer, eg <ul style="list-style-type: none"> • Phosphorus, eg many natives especially those in Proteaceae or pea families, or • Ammonium, eg impatiens, gardenia, snapdragon, poinsettia. • <u>Plant growth retardants</u> resulting in slower growth means the plants need less fertilizer. • <u>Tube stock</u>, both those almost starved to those with luxury supplies, are at risk. • <u>Controlled Release Fertilizers (CRFs)</u> are commonly affected by temperature more than any other factor. High temperatures soon after potting up are a risk; temperatures in small pots are likely to heat up more than in large pots. • <u>Water regimes</u>. Plants in larger pots may suffer more on capillary systems compared with those on other forms on irrigation where excess fertilizer can be leached out. • <u>Over-fertilization</u> occurs most commonly when plants are young.
<p>Disease and pest resistance</p> <p>Balanced resistance</p> <p>Key factors to consider are the:</p> <ul style="list-style-type: none"> • Type of plant. • Age of the plant. • Periods of nutrient demand. • Interaction with other nutrients. 	<p><u>Plants receiving a balanced nutrition</u> in which all nutrients are supplied in the correct amounts are likely to be as resistant as possible to moderate attack by disease. This of course won't protect them from a major or virulent attack. However, the same conditions that favor crop growth may also favor some diseases and pests, eg</p> <ul style="list-style-type: none"> • <u>Too much or too little are obvious areas of concern</u> but generally all disease / nutrient associations are tenuous. <ul style="list-style-type: none"> • Deficiency or excess of a particular element depends on the particular type of plant and the attacking pest or disease, the nutrient element, its form and concentration, method and time of fertilization and environmental conditions. • Only when one of these remains extreme does the association become a problem. • Growers need to know which elements affect the diseases and pests in their plants. • <u>Abundant new succulent growth</u> caused by over-fertilization, overwatering or severe pruning may make some plants more susceptible to some diseases and pests, eg <ul style="list-style-type: none"> • Oriental fruit moth (<i>Graphita molesta</i>) of stone fruits. • Powdery mildew diseases of apples and other plants. • Virus diseases, where vectors are attracted to soft new growth. • <u>General plant stress</u> due to overwatering, poor light or high temperatures, over-supply or under supply of nutrients, can result in plants becoming susceptible to pests or diseases. Trees in poor vigor are susceptible to borer attack. Fertilizing, irrigating and pruning affected trees, usually improves their vigor.

Nitrogen Use Efficiency (NUE)

N

Nitrogen leaching may occur during high rainfall periods, and burning

Generalizations are difficult - the effect of nitrogen is used as an example.

Nitrogen application is the most important factor for yield. Growers must be flexible with **N** and cautious with how much and when it is applied. If it is too wet there is the risk of de-nitrification and run-off. If soil moisture is marginal, use a soil nitrate test to determine how much fertilizer is required.

- **Excess nitrogen** is often associated with disease susceptibility because it tends to produce soft tissue with weak cell walls especially when nitrogen is supplied on its own without the balance of other nutrients.
 - **Excess nitrogen** prolongs vegetative growth, delaying maturity. Such plants are more susceptible to diseases and pests which prefer to attack young succulent tissues, eg powdery mildews and rusts and may also be more susceptible to frost.
 - **Ammonium toxicity** in nurseries may be accompanied by root damage which results in easy entry for root pathogens such as *Rhizoctonia*, *Chalara*, *Pythium* and *Fusarium*; leaf damage and other causes also encourages secondary invasion by *Botrytis*.
 - **Nitrogenous fertilizers** can affect spread of disease by modifying crop environments.
 - **Can lead to lodging** (breaking or bending over of young plants).
- **Low nitrogen** makes plants weaker, slower growing and faster ageing so they are more susceptible to diseases and pests which are most able to attack such tissues, eg bacterial diseases, eg *Xanthomonas*, fungal diseases, eg *Alternaria* and *Fusarium*.
- **The form of nitrogen** available to the host may be more important than concentration of nitrogen. Literature is full of contradictions about the effect of the form of nitrogen on diseases such as *Phytophthora*. There is no clear cut picture.
- **Nitrogen Use Efficiency (NUE)**, eg improved **N** efficiency and plant uptake.
 - **NUE** will reduce **GHG** emissions associated with global warming and climate change and **N** pollution in waterways.
 - Nitrogen fertilizers can be volatile and lost as nitrous oxide etc.
 - Plant breeders are laying the foundation for **nitrogen efficient crops**.
 - **Nitrogen e-Tools** such as **Yield Prophet**® can help growers review water-limited crop potential and match nitrogen to that potential.
- **Responses to nitrogen** are a combination of species, variety, seeding date, plant population, form of nitrogen and soil moisture. A plant's **N** status contributes directly to how much and how quickly water is used. Too little **N** results in poor utilization of light for photosynthesis and crop growth slows.

Phosphorus Use Efficiency (PUE)

P

Most Australian soils are naturally nutrient deficient

Prices and demand for **P** have increased; high quality sources are finite

The **P** content in fertilizers as set by the new regulations closely matches the nutrient requirements of plants, reducing waste and leaching

Phosphate is central to the productivity of Australia's farms. Pasture systems have a very low **PUE** of **13-30%**; most broad acre grain operations average around **50-60%**.

- **Phosphorus** is considered to promote resistance to diseases.
 - Phosphates can **lessen severity** of some diseases and **increase incidence** of others.
 - Phosphorus hastens crop maturity, so that young susceptible tissues are not exposed to powdery mildews for long.
- **Phosphorus Use Efficiency (PUE)** means improved **P** efficiency and plant uptake, eg
 - Applying the right amounts of **P** fertilizers at the right times.
 - Reduce **P** without sacrificing yield.
 - **Phosphorus banking** is a term used to describe a buildup of unusable **P** in soil, particularly in soils with high iron and aluminum.
 - **Select varieties** that can take **P** from soil and save costs.
 - **Breeding plants** that can more efficiently take up **P** from the soil or grow better in lower-**P** soils. **Ideally 1 kg of P applied as fertilizer should produce 1kg of P in the plant.** At present for **every kg of P** that ends up in farm products usually **2-4 kg of P** has been added to the soil in fertilizer – this is because most Australian soils tend to hold onto **P** when they are fertilized and plants can't access it.
 - **P-solubilizing strains of Penicillium spp.** make **P** more available to the crop while preventing / minimizing nutrient run-off. The fertilizer JumpStart® contains strains of the naturally occurring soil fungus (*Penicillium bilaii*) which grows along plant roots. www.bioag.novozymes.com
 - **When P escapes to a surface water body**, growth of green and blue-green algae which can produce toxins, compete with desirable aquatic organisms for oxygen in the water and change the aquatic environment by shading lower water layers. **P** can also end up in surface water through the movement of clippings, dirt particles, and fertilizer. Dust blowing from bare ground, erosion by wind or water, movement of mud on machinery, leaves falling from trees, washing down of fertilizer application equipment (page 61).
- **Low availability of soil P limits organic grain production in Australia.** Organic growers cannot use superphosphate which is a major input to non-organic grain production (they may use compost made with rock phosphate).
- See also page 55 (phosphorus placement).

Potassium

K

Potassium may increase resistance by strengthening outer walls of epidermal cells, eg it:

- Inhibits **development** of some parasites, eg wilt fungi, bacteria, viruses, nematodes.
- Promotes **wound healing**, reducing infection by wound parasites such as *Botrytis*.
- **Postpones senescence**, reducing risk of infection by diseases that attack such tissue.
- Helps **strengthen** the leaf and stem cuticles if applied prior to winter.
- Reduces the effects of **frost damage**.
- Reduces some disadvantages of **excessive N applications**. There are other interactions with **N** and other cations such as **Ca** which also have disease preventative properties.

Calcium, silicon, trace elements

Concentrate fertilizer investments on the best areas and the most profitable crops

Key factors to consider are the type of plant, age of the plant, periods of demands and interaction with other nutrients.

- **Calcium** is also involved with cell formation, lack of calcium can lead to disorders such as dieback and may affect stock plants grown for >12 months in the same mixture. There is a strong relationship between calcium deficiency and:
 - **Disease organisms** which break into plant tissue by producing enzymes which dissolve pectin. **Ca** increases pectin concentrations and hence resistance to these enzymes.
 - **Breakdown of storage structures** such as bulbs, corms and tubers which invites invasion by disease organisms.
- **Silicon** is one of the most abundant materials found in soil, however much of the silicon found in soils is present in insoluble forms and not available for plant uptake.
 - **Silicon** is documented as reducing fungal attack by increasing cell wall thickness to stimulate the plants own defense mechanisms to deter pathogen attack. Silicon has been show to “moderate effects of some environmental stresses and reduce the severity of some fungal diseases and pest attacks”.
- **Trace elements** can have a positive and negative effect on plant disease.
 - **Copper, zinc, and manganese** are common components of fungicides when applied as sprays, they are not necessarily as effective when applied through the root zone as plant nutrients (Nichols 2003).
 - **Trace elements** are wasteful if they are applied when they are not really necessary.

Nutrient tests for soil, water and plant tissue

Testing kits are available or samples can be sent to a professional laboratory for analysis

Keep good records. Testing programs gain enormously in value if current test results can be compared with earlier results obtained on samples taken from the same area by identical sampling procedures. **Seek advice** on how tests should be done and what needs to be measured; make sure they are done properly and learn how to interpret the results.

- **Soil / media tests** are done initially **before planting** to determine the amount of nutrients that are **potentially** available to plants.
 - **Most recommendations for soil sampling deal with only the top 10-15 cm of the soil profile** which is usually adequate for routine work with annual crops.
 - **With long lived tree crops, sample to a depth of 1 meter initially and at 7-10 year intervals.** This allows monitoring of the long term effects of soil management practices, distributions of nutrients with depth, soil layering and waterlogging.
 - **Laboratory tests** include pH, available nutrients, salinity levels, nitrogen content and phosphorus content (if working with native plants).
 - **Interpreting soil tests** (Hazelton and Murphy 2007).
 - **Monitoring container nutrition** allows growers to make important fertilizer decisions.
 - **In-field soil tests** are becoming quicker and easier all the time, eg MIMS (multi-ion measurement system) records the location and analysis of soil samples on-the-go.
- **Water quality** as a minimum needs to be tested for salinity, alkalinity and nutrient status. Recycled water, eg laundry detergents may contain high levels of sodium, phosphorus, etc. www.lanfaxlabs.com.au/
- **Plant analysis** provides information on the nutrient status of plants, eg
 - **Indicates the amount of nutrient that plants actually take up** and can be used as a maintenance guide or a diagnostic technique to confirm visual deficiency symptoms. In most cases symptoms appear well after something should have been done about them.
 - **Evaluates fertilizer programs**, ie are they performing according to expectations.
 - **Protects the environment** from over-fertilization of crops and pastures, etc.
 - **Quality of plant products**, estimates the overall nutritional status of regions or soil types.
 - **For each species** there is a concentration range of nutrients for optimal growth.
 - **Regular tissue analysis on stock plants in the ground or held in large containers** for more than 1 year ensures adequate nutrients for cuttings and the establishment of scions during grafting and budding.

SOIL ANALYSIS

WATER ANALYSIS

PLANT ANALYSIS



Fig. 6. Deficiencies on citrus leaves.

Left: Iron deficiency, leaves have a fine network of green veins on pale background tissue.
Centre: Magnesium deficiency, leaves develop green V-patterns on pale yellow background tissue.
Right: Zinc deficiency, leaves are small and narrow with a yellow mottle between veins.
 Photo©NSW Industry & Investment.

Liquid fertilizers

Customized blends

Diagnosing deficiencies and toxicities from visual symptoms is a trap.

Tissue analysis can be used to verify symptoms but mostly symptoms appear well after something should have been done about them.

Plants can have different symptoms for similar deficiencies on different species and on certain varieties.

Symptoms may have other causes; damage caused by herbicide, pesticides and pollution chemicals can resemble nutrient deficiencies or toxicity symptoms.

Best Management Practices

Efficient use of fertilizers

Every plant system loses nutrients.

- Aim not to eliminate but to minimize losses.
- The more nutrient taken up by the plant the more soil water it uses, the less is lost.

PA

Financial decisions
Monitor soil moisture prior to sowing and during the growing season to determine yield potential, so that fertilizer expenditure can be reassessed and modified as appropriate without affecting profits.

Right fertilizer
Right rate
Right time(s)
Right place

With fertilizer prices rising, liquid fertilizers are widely regarded as one of the next major steps for Australian horticulture and agriculture providing controlled and highly targeted nutrient management. **Custom blends are available**, and can be tailored for a grower's specific crop and environmental conditions (Sustainable Liquid Technology Pty Ltd) (SLTEC). Regulations apply to packaging. www.sltec.com.au

- **Seek advice before planning crop nutrition programs** incorporating liquid fertilizers which may be applied at seeding and in-crop, often in mixtures with herbicides or fungicides.
- **Split and variable rate applications of fertilizer**, particularly of **N** may be applied where about 66% of **N** is placed upfront and the rest supplemented later in the season with variable rate applications.
- **Carbon-based liquid products** enhance earliness, minimize disease susceptibility and improve nutrient use efficiency in cotton (Bionutrient Solutions, Qld).
- **Foliar sprays** with the correct nutrients can be the most efficient method of feeding a plant if applied at the proper stage of crop growth, the proper time and correct application practices. Usually they are applied as **frequent low concentrations** as applications of larger amounts can easily burn them (Nichols 2007).
 - Most research has been carried out on **fruit and vegetables**; little is known about the vast number of ornamentals species.
 - **Golf course management** is an exercise in **managing plant stress** due to low daily mowing, shade, traffic, etc and they mostly survive. Foliar feeding is common practice.
 - **Foliar-applied sprays of calcium** are much more efficient in solving calcium deficiency in poinsettia bracts than using high levels of calcium in the media.
 - **GreenStim® (glycine betaine derived from sugar beet molasses)** promotes normal growth and productivity of field vegetables and fruit under conditions of **environmental stress caused by heat, cold, salinity and drought**.

Crop nutrition is part of a whole agronomy package and should not be considered in isolation from costs, soil type, region, soil preparation, crop type and variety, crop protection, equipment available, yield potential and other issues.

- The **International Plant Nutrition Institute (IPNI)** estimates that fertilizer is responsible for 40-60 % of world food production. It aims to improve crop nutrition management, fertilizer use efficiency and profits. **Fertilizers can be made** (after a soil test) to suit your requirements.
- **Best Management Practices (BMPs)** aim to use fertilizers efficiently, reduce run off and minimize their impact on the environment and improve profitability, eg
 - **Keep records**. Calibrate application equipment.
 - **Use** controlled-release fertilizers, slow release fertilizers.
 - **Spread out applications** over a season and tighten control of irrigation practices.
 - **Minimize fertilizer use**, aim to maximize use of available water.
 - **Grow varieties** which are more nutrient efficient.
 - **Precision agriculture (PA), Variable Rate Application**. GreenSeeker^R-fitted machinery assesses whether the target being observed contains live green vegetation or not. Using **PA** in fertilizer management can save \$ by just optimizing **P** application (page 372).
- **Many programs aim to help growers make better fertilizer decisions**, eg
 - **National and regional soil test-crop response calibrations** for assessing the nitrogen, phosphorus, potassium and sulphur status of soils used for production of up to 35 different cereals, pulse and oilseed crops.
 - **An online searchable national database** of crop micronutrients response trials conducted throughout Australia.
 - **Training resources and publications** to communicate soil-test-crop responses to grain growers, fertilizer industry and scientific community.
 - **National Fertilizer database for the grain industry** to help growers improve profitability. Data collected will be dates of sowing and harvest, location, crop type and variety, experimental design, fertilizer treatments, crop yields, soil test, growing conditions, tillage and sowing system (multiple till, reduced till, no till, zero-till or raised beds) and row spacing, crop area, history and grain quality attributes.
- **Environment**. Efficient use of fertilizer is critical in the capture of nutrient by crops and the reduction of losses to the environment (Branagh-McConachy 2010). It is important to **balance a crop's need for nutrients with its ability to take up nutrients from soil water**. – by using the right amount of fertilizer at sowing and monitoring throughout the season growers can ensure **nutrient-rich water** doesn't escape into nearby rivers. The 2 nutrients that threaten waterway health are **nitrogen and phosphorus**. Even small amounts of both exported from agricultural and urban environments can promote algal blooms and degrade water quality (page 61). Targets have been set for **P** and **N** in waterways.
- **Soil and tissue tests** determine nutrient requirements; only apply amounts required to maximize profitability. Soil tests **before planting** assess nutrient supply and guide fertilizer rates, and assess subsoil nutrient supply.
- **Adopt a flexible fertilizer program**. Allow the season and testing to dictate the timing and frequency of fertilizer applications to actual crop needs.
- **Improve soil structure** to trap water for plant growth via reduced tillage, stubble retention; control weeds.
- **Avoid fertilizing in waterlogged areas** which may leach more mobile nutrients such as **N, S** and **K** deeper into the profile.
- **Fertilizer buffer zones** between waterways and crop operations should be **at least a 10m**.

Biostimulants

Biostimulants are used as supplements to conventional fertilizer programs

What are they?

Bioactive materials, Biofertilizers, Biostimulants, Enhancing products and Soil conditioners, etc, can be defined in different ways but to some extent they are used interchangeably and can be confusing. Always explain exactly what you mean when using these terms.

- **If used appropriately** biostimulants provide a promising management tool for promoting plant health but effectiveness may vary, depending on environmental factors and how the products are applied.
- **Not all products may be as effective** as anticipated and results may be depend on the:
 - Plant species or variety.
 - Physiological condition of the plant.
 - Formulation, composition, application rate.
 - Timing of the application.

Biostimulants

Turf uses a lot of enhancing products:
To cope with stress when grass is just not green enough, needs fast recovery, when roots and shoots need to be stimulated, eg Reinforce

Agricultural biostimulants include diverse formulations of compounds, substances and other products that are applied to **plants or soils** to regulate and enhance the crop's physiological processes, thus making them more efficient.

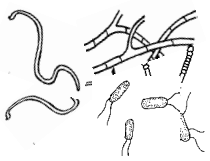
- **Biostimulants act on plant physiology** through different pathways / mechanisms to synthetic nutrients to improve crop vigour, yields, quality and postharvest shelf life / conservation (EBIC - European Biostimulants Industry Consortium, 2011).
 - They do not have any direct actions against pests or disease (unlike pesticides).
 - They are thus complementary to crop nutrition and crop protection products.
- **They are increasingly used in crop production** around the world and their availability stimulated by pressure from environmental groups and government agencies for growers to justify management practices regarding pesticide and nutrient run-off.
- **Biostimulants foster plant growth and development** throughout the crop life cycle from seed germination to plant maturity in a number of ways, including:
 - Enhancing yield increases and crop quality.
 - Increasing plant tolerance to and recovery from abiotic stresses, eg drought, heat, wind.
 - Facilitating nutrient assimilation, translocation and use.
 - Enhancing quality attributes of produce, eg sugar content, colour, fruit seeding, etc.
 - Regulating and improving plant water balance.
 - Enhancing certain physicochemical properties of the soil and fostering the development of complementary soil microorganisms.
 - Increasing water-holding capacity in the soil.
- **There is some debate regarding their perceived benefits.** More research is needed on their effect on plant nutrition, abiotic stresses, plant disease responses, plant growth and development as well as aspects of legislation on these products.

Ingredients



Uplift contains:

- Seaweed
- Bio-Activ™ beneficial soil microbial technology
- Fulvic acid
- Natural wetting agent



Fungi, bacteria, nematodes

Common commercial biostimulants contain many ingredients, including:

- **Plant hormones** regulate growth and development processes in the plant, eg stem elongation, root initiation, etc. Only small amounts are needed.
- **Humic substances.** Humic acid and fulvic acid both positively affect shoot and root growth, seed germination and seedling establishment, etc.
 - **Humus** (soil organic matter), is one of the most important ingredients for maintaining and improving soil fertility and plant growth. Humus is essentially derived from the natural decomposition of plant and microbial matter over a prolonged period of time. It improves the efficiency of water use by increasing the water retention properties of soil, promotes better soil structures which allow greater plant root growth and stimulates microbial activity by providing a good source of carbon and nutrients.
- **Kelp and / or manure extracts** contain many organic and mineral compounds and are rich in plant hormones, sugars, protein sugars, enzymes and amino acids.
 - **Kelp extracts** (seaweed materials) increase root mass in treated plants. Seaweed contains high concentrations of cytokinins, auxins, amino acids, vitamins, simple and complex sugars, enzymes and proteins, as well as inorganic nutrients such as **NPK** and **Fe**.
 - **Seaweed feeds** the beneficial biological organisms already present in the soil.
- **Many commercially available materials are "bioactive"**, that is they also contain living organisms that add a microbial level to their activity (MacCartney 2005). A biofertilizer is a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant.
 - **Beneficial soil organisms**, eg *Bacillus* bacteria and *Trichoderma* fungi are introduced to assist with the decomposition of organic residues in the soil, releasing nutrients into the soil for plant use. Some think that these introduced strains of microbes may in fact stimulate the activity of the indigenous organisms resulting in increased benefits.
 - **Some also contain nematode deterrents** and neem oil, or other oils, eg eucalyptus or tea tree oil and saponin.
 - **AgSafe® Tree and Shrub 20-10-5 Fertilizer Planting Tablets with Humates & Mycorrhizae**, consists of a special polymer-coated fertilizer tablet formulation containing micronutrients, humates, organics, sea kelp extracts to supply 75 trace minerals and natural growth hormones, yucca extracts to supply natural saponins to help with transplanting and environmental stress, and mycorrhizae for expanding rooting systems.
 - **TurfVigor contains** *Bacillus* and *Paenobacillus*, kelp extract and macro and micronutrients.

CONSERVATION TILLAGE (CT)

Reduced tillage and residue retention is an essential component of Conservation Agriculture (page 374)

Reduced tillage

CT



Weed control is replaced or supplemented by the use of herbicides

Conservation tillage (CT) is a general term for crop production systems in which regular cultivation is reduced, and weed control is replaced or supplemented by the use of herbicides. The system aims to produce a satisfactory environment for seed germination and growth with minimal or no cultivation. Crop stubble is retained undisturbed for maximum protection of soil structure, and maintained weed-free to conserve moisture and increase organic matter. **Weed control is usually achieved:**

- Totally by the use of herbicides and no tillage, or
- By the use of herbicides and limited tillage.
- **To avoid confusion** always say exactly how many cultivations are carried out, eg
 - **No-till or zero-till.** The only cultivation is for low disturbance sowing using either a disc seeder or knife points (less than 20% soil disturbance) (Baxter 2012).
 - Zero tillage, is now applied on more than 95 million ha worldwide, primarily in North and South America (Derpsch, 2005).
 - No-till practices in Australia have exceeded 90% in some regions and less than 5% in some other regions. Less than 5% of growers now practiced multiple cultivations. However, most no-till growers still cultivated up to 30% of the cropped area. 88% used knife points for sowing instead of discs.
 - **Minimum till** includes at least one cultivation before sowing.

Adequate residue retention and management



Conservation tillage protects the surface of the soil preventing erosion

Most of the agricultural benefits of zero tillage relate to **increased organic matter** in the soil due to increased yields **resulting in more crop residue on the soil surface**, which is eventually converted to stable soil organic matter. Retained stubble can:

- **Reduce** run-off and if rainfall is intense more water can be stored.
- **Slow** evaporation.
- **Improve** soil structure, soil stability and reduce soil erosion.
- **However**, high stubble minimizes sunlight reaching the soil reducing soil temperature and photosynthesis, slowing crop establishment and early crop growth.
 - **There is no single solution** to managing heavy stubble but management is essential.
 - Plan an **IWM** program ahead to include crop and herbicide rotations.
 - **N** inputs require careful management to keep stubble load down. Seek advice.
 - **Rate of stubble decomposition** is influenced by fragment size, degree of contact with soil, temperature and moisture, also whether soil is light or heavy.
 - **Stubble can be burnt** but its use might eventually be restricted because of concerns about the impact on air quality.
 - **Grazing** stubble following harvest or cutting before sowing.
 - **Stubble crunchers** knock down and split open the heavy stubble and allows moisture and microbes in to speed up the breakdown process. Also by laying the stubble down you will seal in moisture and minimize soil disturbance.
 - **Investing** in sowing equipment that can deal with dense stubbles.

Other long term benefits of reduced tillage

Zero tillage, including controlled traffic (where all in-field traffic traverses only specified wheel or foot tracks), is highly compatible with precision treatment of field conditions

The fundamental driver behind no-till or zero-till, and controlled traffic is extra plant-available water; **CT** conserves soil moisture (Freebairn 2012). Prompt killing of weeds by herbicides is essential to retain moisture in soil. Stubble through the summer is not so much about reducing evaporation but more to do with helping the capture and infiltration of water from rain.

- **Improved availability** of nutrients to plants and improved soil fertility, improved carbon content of soil, improved nutrient cycling.
- **Comparable** or increased yields, saves time and fuel, reduced cropping costs.
- **Less greenhouse gases.** When the soil is ploughed the carbon in the soil is exposed to oxidation and CO₂ is released into the atmosphere. The more soil is disturbed, the more CO₂ is released.
- **Greater biodiversity.** A combination of **CT** or **ZT** and stubble retention increases soil microflora and microfauna in **the top 5 cm of soil** due to:
 - Increased soil aeration,
 - Cooler and moister conditions,
 - Less fluctuations of temperature, moisture, and carbon content in surface soil favors soil beneficial microflora and activates biological control mechanisms such as mycorrhiza, fungal-feeding nematodes and protozoa which are competitors or antagonists of soilborne diseases. Earthworm populations increase (Page et al 2013).
 - Weeds are more prevalent and provide much of the plant diversity within a crop.
- **Less compaction** due to fewer tractor passes during cultivation to control weeds and to apply pesticides which restricts root growth, affects water drainage, etc.
- **Compatible with controlled traffic** (where all in-field traffic traverses only specified wheel or foot tracks), and to **precision agriculture**, including differential fertilizer applications according to nutrient requirements, spot spraying for weed control.
- **Water bodies**, habitats, and streams in agricultural areas can be better protected as no-till reduces the nutrients and soil lost to run off by 90% thus quality of water moving downstream through the catchment is significantly cleaner.

Challenges, limitations

CT



The green bridge



Increased cost of glyphosate

CT

- Increases soil moisture
 - Lowers soil temperature
 - Changes crop nutrient uptake patterns which:
- DIRECTLY INFLUENCE:**
- Pathogens
 - Beneficial soil microflora and activates biological control mechanisms

Weed control is more difficult (Freebairn 2012).

- **Flushes of green weeds and volunteer crop plants** use available soil moisture and nutrients and create a green bridge for pests and diseases if not controlled (Ground Cover Mar-April 2010. Fact sheet: Green Bridge).
- **CT depends on the availability and success of effective and efficient herbicides.**
 - **Large inputs of herbicides** may be required.
 - Herbicide **residues** may be a problem, eg herbicides used in previous crops.
 - Herbicide **resistance** can be a problem (pages 303, 427).
 - **Reducing tillage affects herbicide incorporation** and increased stubble can reduce soil penetration or foliage contact, possibly reducing efficacy of certain herbicides.
- **Increases the threat of some soilborne diseases and pests, eg**
 - **Stubble provides food and shelter** for snails and slugs, mice and similar pests in high rainfall seasons (Fig. 7 below).
 - **Stubble retention may increase** certain soil and stubble-borne pests and diseases. Insects, nematodes and fungal hyphae parts are not buried deeply. They are not broken down by cultivation or exposed to degradation by desiccation, solarization and predations by birds, eg *Rhizoctonia*, *Fusarium*.
 - **Diseases and pests that were previously economically unimportant**, may survive between seasons on plant debris and may become more important.
 - **More insecticides and fungicides** may be required to control pests and diseases.
 - **Increased use of herbicides for weed control** may increase or decrease the severity of some diseases; some herbicides may inhibit spore germination of some fungi.
 - **During wheat stubble decomposition**, immobilization of **N** can be common, reducing the immediate availability of **N** to the emerging crop.
- **Management**
 - **Greater level of skill** needed to make the system productive. More things can go wrong. Appropriate equipment is required to plant seed into untilled ground.
 - **Potential problems** such as herbicide resistance and stratification of nutrients in surface soil are becoming apparent in some established systems.
 - **Allelochemicals** are thought to either leach from the stubble or be produced by microorganisms during the early stages of stubble decomposition and are affected by seasonal variability. This may inhibit growth of newly sown plants.
 - **No-till systems have not been embraced** in some areas.

Strategic tillage

Root diseases and pests and weeds

Phosphorus placement by precision tillage

- The fundamental driver behind no-till or zero-till and controlled traffic** was **extra plant-available water**. The reality facing many mixed growing systems across Australia is the requirement sometimes for strategic tillage due to diverse soil and seasonal variations, eg **weeds** and during wet years to control **root diseases and pests** (Freebairn 2012).
- **Knowing when to cultivate** is the secret and requires skilled judgement derived from long experience with the crops and weeds involved.
 - **Check how deep to plough** to control weed seeds, weed parts, and diseased stubble. The mouldboard plough controls weeds by placing weed seeds to a depth from which they cannot emerge. Some weed seeds must be left at a depth for at least 10 years for them to decay. A one-off inversion of sandy soil with a mouldboard plough every 10 to 15 years can be a very profitable and effective method of quickly decimating a seed bank of resistant weeds.
 - **Strategic tillage and residue reduction** had proven necessary to overcome productivity constraints in mixed systems.
 - **Precision tillage**. Phosphorus is an immobile nutrient that tends to remain in the top 10cm of the soil profile where it is placed using conventional practices for applying fertilizers. Tillage machines designed to cultivate the seedbed and place fertilizer down to a **depth of 20cm in the soil** tackles this constraint (Collis 2012).

Mouseoff® is used for large scale mouse infestations in crops. In some States supply of Mouseoff® may be restricted to approved contractors and/or landholders who have special permits.

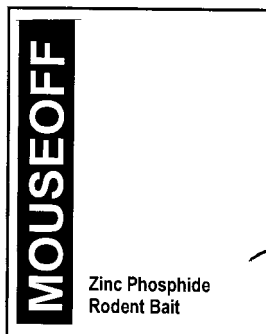


Fig. 7. CT may increase populations of mice necessitating the application of rodenticides.

CROP ROTATION (CR)

Crop rotation is an essential component of Conservation Agriculture (page 374)

<p>Why rotate crops?</p> <p>CR</p> <p>Plan the right rotation</p>	<p>CR is the successive planting of different crops in the same area. The value of break crops in rotations is substantial for many reasons including:</p> <ul style="list-style-type: none"> • Assisting in controlling weed populations. • Reducing diseases and pests. CR is more successful against bacterial and fungal diseases and nematodes than against insects. • Improved soil fertility and availability of plant nutrients. • Some break crops are N-fixing providing long term overall soil improvements. • Help replenish the soil organic matter (green manuring) and beneficial microbes. • Increasing water use efficiency, eg water retention if stubble is retained. • Clever rotations may optimize long-term profit from available soil water and nitrogen levels, eg sowing crops into existing pasture (pasture cropping), under-sowing crops with pastures that do not germinate until the next year (twin sowing). • Maximizing income.
<p>Features</p>	<p>Most frequently used with short-lived host plants such as annuals and biennials, eg field crops, flower beds and vegetable crops.</p> <ul style="list-style-type: none"> • Planning and keeping records is the key to success with crop rotation. • CR can include a fallow period (page 58). • Testing soils for disease potential can assist disease management by indicating when rotation (or another treatment) is required. Rotations differ depending on the results.
<p>A disease break</p> <p>Practice crop rotation where practical, for vegetables, annual and herbaceous flower crops</p>	<p>Crop rotation plays a major role in controlling soil-borne pathogens. Soilborne pathogens that infect plants of one or a few species or even families of plants can sometimes be reduced in the soil by planting (for 3-4 years) crops belonging to species of families not attacked by the particular pathogen. Rotation crops break the life cycles of root diseases.</p> <ul style="list-style-type: none"> • Some pathogens only survive in the presence of a specific host, or its residues. <ul style="list-style-type: none"> • For soilborne pathogens crop rotation with non-susceptible crops produced the best result for pathogens that survive only on living hosts or on host residues. • Intervals between susceptible crops must be longer than the known survival period of the pathogen. • A disease break can be provided by growing a non-host or a resistant variety. Weeds and volunteer hosts must be controlled during the rotation. • Avoid double cropping or cropping after crops in the same family. <p>Field crops</p> <ul style="list-style-type: none"> • Probably the most widely used rotations are to control soilborne diseases of cereals. <ul style="list-style-type: none"> • Canola is considered one of the best break crops for cereal production – the benefits come from the root disease break a broadleaf crop provides. • Disease breaks and moisture retention. Wheat for 2 years, then a pulse usually chickpeas also sometimes lucerne, lupins or faba beans. • The Crop Sequencing Initiative (CSI) aims to improve on-farm crop sequencing decisions across the grain belt by facilitating training. <p>Diseases and pests of potatoes.</p> <ul style="list-style-type: none"> • Growing potato crops more than once every 3 years can lead to an unacceptable reduction in quality, due mainly to build up of diseases. • Brassica green manure crops are being researched for use in an integrated pest management (IPM) system for whitefringed weevil (<i>Graphognathus leucoloma</i>) which is a serious insect pest of potatoes in WA. <p>Nematode diseases in crops.</p> <ul style="list-style-type: none"> • The effective use of cover crops for providing some control of plant-parasitic nematodes has been described by (Penfold and Collins 2012). • Some rotations may include a crop which inhibits the development of a specific pathogen, eg forage sorghum, pinto peanut, watermelon, Rhodes grass and cowpea which host few root knot nematodes (<i>Meloidogyne</i> spp.). Following crops show little sign of nematode damage. • Levels of root knot nematode (<i>Meloidogyne</i> spp.) can be reduced by growing susceptible crops in rotation with a trap crop (page 105). • Rotation crops can reduce numbers of host specific organisms which helps to reduce numbers of pathogenic organisms, eg cereal cyst nematode (<i>Heterodera avenae</i>). • Soybeans offer widespread areas of eastern Australia a valuable rotational crop not just for cereals but also for cotton, sugarcane. <p>Virus diseases of bulbs</p> <ul style="list-style-type: none"> • It is difficult to remove all bulbs at the end of a season; some may remain in the soil. They may be infected with virus, and become a source of infection for virus-tested bulbs planted the following season. After the leaf blades have emerged through the soil, aphids transmit the virus diseases from the old infected bulbs to the new bulbs.

Insect control	<p>Redlegged earth mite (<i>Halotydeus destructor</i>) populations on canola can be reduced if lupins, chickpeas and lentils are grown in rotation before canola. Mites can attack canola seedlings and may kill many plants before they establish.</p> <ul style="list-style-type: none"> • The crop must be kept relatively free from weeds and a border spray can be used to prevent mites invading from crop edges. Seek advice. 			
When crop rotation is unlikely to be successful	<p>Crop rotation is not likely to be successful when:</p> <ul style="list-style-type: none"> • The disease is a soil inhabitant and <ul style="list-style-type: none"> • Produces long-lived spores or • Lives as a saprophyte for > 5 years, eg damping off and root rot fungi such as <i>Aphanomyces</i>, <i>Fusarium</i> spp., <i>Sclerotinia</i> spp. and <i>Macrophomina phaseoli</i> or • Has a wide host range and is a strongly competitive saprophyte, eg bare patch (<i>Rhizoctonia solani</i>). • Insects with a wide host range can fly further afield. • Pests with exceptional powers of dispersal or are normally migratory, eg locusts. 			
Challenges	<p>Challenges include:</p> <ul style="list-style-type: none"> • Crops such as canola and mustard may reduce mycorrhizas in the following crop. • Some crop rotations may include allelopathic crops which release chemicals into the environment which interfere with surrounding plants (page 59). • Tying up the land may be costly for the producer. • Costs associated with establishment, land preparation, green manuring, etc. • If susceptible crops are chosen there can be a buildup of diseases, nematodes. • Need for evaluation of cover crop mixtures in many crops, eg vegetables. 			
Conservation agriculture (CA)	<p>Like conservation tillage, crop rotations must be used within a broader system of conservation agriculture to help overcome many of these limitations, eg</p> <ul style="list-style-type: none"> • Diverse crop rotations. • Effective fertiliser and herbicide management. • Minimum or no tillage. • Full stubble retention. • See also page 374. 			
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; padding: 2px;">BQmulch™</td> </tr> <tr> <td style="text-align: center; padding: 2px;">FUMUS®</td> </tr> <tr> <td style="text-align: center; padding: 2px;">Nemfix</td> </tr> </table>	BQmulch™	FUMUS®	Nemfix	<p>Biofumigation involves growing certain crops such as some <i>Brassica</i> spp. as biological fumigants ahead of crop production to reduce the need for chemical fumigation especially in tight rotations (Reddy 2011, 2012). Seek advice if attempting biofumigation.</p> <ul style="list-style-type: none"> • These biofumigant crops are then incorporated into the top soil; as the material decomposes it releases isothiocyanates (ITCs) compounds which are toxic and may suppress some soilborne plants diseases. • Potential exists to select or develop brassica varieties with enhanced potential for particular target organisms. • The effectiveness of biofumigation in vegetable crops has been trialed in Australia using various <i>Brassica</i> spp., eg BQmulch™, FUMUS®, Nemfix. • These green manure crops have benefits other than as biofumigants, eg increased organic matter, beneficial soil mulches and long term overall soil improvements (Matthiessen and Kirkegaard 2003). • Some brassica crops, eg canola (<i>B. napus</i>), and Indian mustard (<i>B. juncea</i>) are also valuable rotation crops.
BQmulch™				
FUMUS®				
Nemfix				
Cover crops	<p>Cover crops are also called "green manure", "living mulches", etc depending on their many different uses. Cover crops are types of plants grown to suppress weeds, to help build and improve soil, prevent soil erosion and control diseases and pests. Once grown, cover crops are usually mowed and then tilled into the soil.</p> <ul style="list-style-type: none"> • A green manure is a cover crop incorporated into the soil while still green, to improve soil fertility. Green manures are used primarily by organic growers and home gardeners. • Cover crops can serve as short-rotation forage crops when used for grazing or harvested as immature forage (green chop). • Living mulches are similar to cover crops and are interplanted with a cash or commodity crop but stay alive throughout production of the main crop. They are typically used with specialty crops, including orchard and nursery crops. 			

Rotate crops, Rotate crop varieties

FALLOWING

What is traditional fallowing?



Traditional fallowing is land ploughed and harrowed but left uncropped for a year or more to destroy weeds, rest the soil and build up available moisture.

- **In some cropping systems** the field is cultivated and left fallow for a year or part of a year and the area kept free of all vegetation and weeds either by herbicides or by cultivation about once a week after each period of rain.
 - **A series of shallow cultivations during seed-bed preparation** encourages successive germinations of annual weeds whilst destroying emerged weed seedlings. Cultivation is detrimental to some pests and pathogens and also to at least some the predators of nematodes and other pests.
- **Cultivation is just as effective as chemical weed control** in conserving summer rain for use by winter crops.
- **Summer weed control stands out as the most effective way** to conserve summer rains and soil nitrogen for use in subsequent crops. Aim to control weeds as early as possible.
- **Controlling summer weeds** is a priority as they provide a **green bridge** for pests such as aphids, mites, snails and diamondback moth to survive over the hot summer months. The overwintering populations give rise to new generations the following autumn which can then move onto emerging crops.

Advantages include:

- **Fallowing can be used to store moisture under some conditions** from the preceding winter, spring and summer for the needs of a crop in the following growing season, eg where there is insufficient rainfall **in cereal growing seasons** to consistently produce an economic crop. Conserving summer rain is most valuable in low rainfall areas when subsequent growing season rainfall is low.
- **Fallowing is a cheap and effective means of reducing the populations of soilborne diseases** such as root knot nematodes (*Meloidogyne* spp.) and weeds. Root knot nematode eggs hatch as usual but as they are without a food host, the young nematodes die. It is essential that fallowed areas be kept free of weed growth.
- **In areas with hot summers**, fallowing allows greater heating and drying of soil which leads to marked reduction in nematode and some other disease organisms.

Disadvantages include:

- **Bare soil** increases risk of soil erosion compared with retained stubble.
- **Cultivation** also increases the risk of soil erosion compared with retained stubble. However, cultivating to create a slightly rough surface can reduce soil losses compared with a smooth, bare paddock.
- **Beneficial insects** are reduced when weeds are destroyed during fallowing.
- **Loss of income.**

Summer fallow with retained stubble

Variations of traditional fallowing include utilizing herbicides and reduced tillage (sometimes called an eco-fallow).

- Retained stubble reduces evaporation and prevents wind and water erosion.
- More than **5t / ha of stubble** is needed to reduce soil evaporation significantly.
- Summer grazing can damage soil in the surface layers but should not reduce crop yields provided summer weeds are properly controlled and 70% stubble is retained.
- Modeling studies show the highest return on investment in summer weed control is on lighter soils or where soil water that would support continued weed growth is present.
- Zero tolerance of weeds in a summer fallow may require more than one herbicide spray.

Greenhouses

A **greenhouse** may be 'rested' from use between crops.

MIXED PLANTINGS

When humans started to grow food plants in monocultures to increase their food supply, the balance of nature was inadvertently upset. **Some diseases and pests**, which were insignificant before, became widespread.

Crop diversity

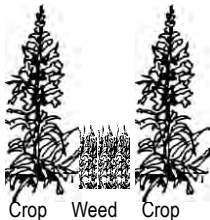
The Pros and Cons of growing mixed species crops

General nurseries are the ultimate in mixed cropping

The implications of growing mixed species include:

- **Crop choice is an important decision** and is determined by markets, condition of the area and the outlook for the season ahead. Sometimes a crop choice has to be changed quickly, eg if an area doesn't come up the way you wanted it to.
 - **Mechanization** of growing and harvesting mixed crops can be difficult. Yields from mixed plantings are often reduced so may not be suitable for commercial production.
 - **Tall plants** may act as a wind break and provide barriers for movement of both pests and beneficial insects. They also shade smaller plants and provide frost protection, but these plants may be shaded to the extent that flowering and growth are reduced.
 - **Aesthetically pleasing** in garden or landscape plantings.
 - **Repellent, bait and trap plants** which assist in disease and pest control are often included in mixed plantings.
 - **There is a perpetuation of some natural controls** because of the mixed crops, eg predators and parasites of insect pests, but this is not necessarily so.
 - **In the competition for nutrients** mixed plantings tend not to deplete the soil of particular nutrients to the same extent as monocultures. Deep rooted plants may bring essential minerals to the soil surface so that they can be used by other plants.
 - **The crop itself** must be made more hospitable to natural enemies.
- **Crop diversification** can be provided by margin planting, growing a crop or crops between the rows of another crop. Strip farming separates areas of one crop by intervening strips of another crop. To be successful:
 - **Weeds must be controlled** so they are not alternative hosts for pests and diseases.
 - **Crops should not share** common pests or disease organisms.
 - **Crop rotations should be carefully chosen.**
 - **Incidence of pests and disease may be less** because the distance between similar plants is greater than in more intensive growing systems, making it less likely that propagules or vectors of pathogens will successfully move from one host to another. The intervening plants pose physical barriers to the dissemination of aerial pathogens or their vectors. The rates of spread of more specialized parasites are also restricted because of the discontinuous distribution of suitable hosts.
- **Habitat manipulation or ecological engineering** (Moody 2004, also page 106).

Allelopathy



Broccoli residues interfere with growth of other cruciferous crops that follow

Successfully planted legume cover crops can suppress weed growth by competition for:

- Nutrients.
- Light.
- Water.
- Also possibly through release of allelochemicals.

Allelopathy refers to the **beneficial or harmful effects** of one plant on another plant, both crop and weed species, by the release of chemicals from plant parts by leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems (Ferguson and Rathinasabapathi 2003).

- **Effects of allelopathy** include reduced seed germination and seedling growth. Allelochemicals may affect cell division, pollen germination, nutrient uptake, photosynthesis, various enzymes, etc. It involves the interactions of many different chemicals, physiological and environmental stress, pests and diseases, solar radiation, herbicides, nutrient supplies, moisture, etc.
- **Allelopathy can affect many aspects of plant ecology** including growth, plant succession, and the structure of plant communities, dominance, diversity and plant productivity. Also observations of crop damage, yield reduction, replant problems for tree crops, occurrence of weed-free zones, etc have been observed.
- **Different plant parts can be affected**, eg flowers, leaves, leaf litter and leaf mulch, stems, bark, roots and soil. Soil leachates can vary over a growing season. They can persist in the soil affecting neighboring plants as well as plants planted in succession.
- **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. Foliar and leaf litter leachates of *Eucalyptus* spp. are more toxic than bark exudates to some crops.
- **Root exudates from some plants may be toxic to other plants and pests, eg**
 - **Black walnut (*Juglans nigra*)** roots secrete a toxin (juglone) which has a toxic effect on plants such as tomatoes, potatoes, lucerne and birch trees.
 - **Asparagus** roots secrete a substance into soil which is toxic to root knot nematodes. When interplanted with nematode-susceptible plants, asparagus decreases the numbers of nematodes in the soil and in the roots of the susceptible crops. Antagonistic plants, however, are not used on a large scale for practical control of nematode diseases of plants for the same reasons that trap plants are not used (page 104).
- **Weed control.** Allelopathy can be exploited to benefit production systems by utilizing natural phytotoxins leaching from plant residues which inhibit the germination of seeds and growth of many weeds (page 93).
- **Repellent, bait and trap plants** which assist in disease and pest control are often included in mixed plantings may also be allelopathic (page 105).
- **Pest suppressive landscapes** may be developed (page 106).

MANAGING CULTURAL METHODS

Due to public concerns about the use of chemical pesticides and the development of pesticide resistance, there is more emphasis today on cultural and other non-chemical methods.

- Cultural methods are usually preventative and compatible with other methods of control and useful in **integrated pest management (IPM)** and other management programs.
- Cultural practices should **favor crop growth** and beneficial agents but not pests, diseases or weeds.

Phytophthora and environment

Approximately 16,000ha of forest in WA collapsed during the summer of 2010. Nearly half the sites were located on shallow soils. A high proportion of dead trees had resprouted by spring 2011 (Batini 2012).

- Some of the deaths, particularly of banksia, were no doubt caused by *Phytophthora*.
- Most of the jarrah sites that collapsed were considered disease-free and this was confirmed by extensive sampling.
- The low winter rainfall followed by a record dry summer, the pattern of deaths and recovery in the overstory, the healthy understory and the timing of the collapse all point to **sudden and severe drought stress as the primary driver**.
- Is this an unusual, one off event or a sign of more frequent and severe drought in these forests? These forests are valuable for their water supply, conservation and biodiversity, for minerals, for recreational activities and for timber production.

Phytophthora and high levels of nitrogen

A survey of a dieback-affected urban bushland reserve on the foreshore of Sydney Harbor found that deaths of native trees and increased weed density were associated with **high levels of nutrients, particularly nitrogen (N)** and *Phytophthora cinnamomi (Pc)* (Kelly et al 2013).

- **Under low N conditions**, inoculation with **Pc** reduced the health of *Angophora costata* and *Corymbia gummifera*, and reduced the root biomass of *Eucalyptus botryoides*. *A. costata* and *C. gummifera* displayed signs of phytotoxicity with elevated levels of inorganic N.
- **The presence of Pc, in combination with elevated N** reduced the health of all species, but the symptoms were more severe in *Angophora costata* and *E. piperita*. The results suggest that the effect of elevated N application and susceptibility to **Pc** is **species specific**. Mitigating soil nutrient loading in urban bushland areas by redirecting stormwater flow and surface runoff away from vulnerable bushland may assist in managing dieback caused by **Pc**.

Elm leaf beetle

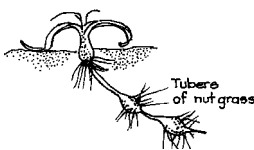
An epidemic of elm leaf beetles could kill hundreds of century old elm trees and cause millions of dollars of damage in Adelaide. The beetle's tiny larvae feed on the leaves, destroying their ability to absorb sunlight and produce reserves of energy. Trees have been injected with a special solution that kills the larvae that feed on the leaves.

- **Not all species are susceptible**. The larvae were not a threat to the common Dutch elm but would kill other elm trees if not treated. The elm trees in SA have been **under stress from recent years of drought and water restrictions** which makes them more vulnerable to attack from pests (Pryor 2011).

Integrated Weed Management (IWM)



Noxious Weed Acts provide for the mowing, slashing, hoeing, digging, ploughing, grubbing and burning of noxious weeds.



Using both non-chemical and control methods.

- **Cultural methods**, eg
 - Rotate crops. Rotate varieties, choose more vigorous crop varieties.
 - Increased seeding rates will provide better weed competition from the crop.
 - Conservation tillage and controlling weeds with herbicides.
 - Cultivation is an effective means of weed control during fallow periods on arable land.
 - Dig out then mulch. Mulches must be weed-free.
- **Biosecurity**
 - Make sure that soil and weeds are not spread on machinery.
- **Weed-tested seed**
 - Make sure seed is weed-free.
- **Physical methods**, eg
 - Reduce the weed seedbank (pages 236, 427).
 - Mowing or cutting tall weeds prevents seed set and is used in conjunction with herbicide applications.
 - Special mowing machines can be used around fruit trees and vines.
 - Digging out, hand pulling, hoeing, cutting and brush cutting are efficient means of controlling scattered weeds and small patches of annual weeds. The nut grasses or sedges, *Cyperus esculentus* and *C. rotundus* produce underground tubers or nuts. Unless all of these are removed including the very small ones, they will resprout. Dig around and under each weed and discard it, do not compost.
- **Herbicides**
 - Target problem weeds at the correct stages in the rotation to minimize the threat of herbicide resistance.
 - Rotate mode of action groups of herbicides to reduce risk of resistance.

Management techniques

Wine grape growers can reduce the severity of frost by electing to prune earlier to encourage later budburst, using overhead spraying to insulate plants from effects of frost or using fans and hovering helicopters to mix air and retard cooling effects of the atmosphere.

Reducing soil-borne diseases

To reduce soilborne disease risk, growers with successful stubble retention systems, stress the importance of forward planning by:

- Testing soil before planting and monitor to ensure early detection of diseases and pests.
- Using cultural methods, eg
 - Crop rotations
 - Timely sowing
 - Good nutrition
- Planting disease resistant varieties and disease-tested material.
- Implementing biological and chemical controls where appropriate.

Preventing a blooming mess

Preventing phosphorus pollution (Hull, J. 2011)

There is unlikely to be "one-size fits-all" solutions.

P is relatively insoluble in most natural soils and will not leach through. **P** binds to or reacts with many soil constituents such as iron, aluminum, calcium, magnesium, and organic matter. Dissolved **P** can leach very rapidly through sandy soils due to lack of the above substances.



Primary nutrient sources for algae are phosphorus and nitrogen with **P** being the main one for fresh water and **N** for salt water. When **P** escapes to a surface water body it allows for the growth of green and blue-green algae and other undesirable aquatic organisms which can produce toxins, compete with desirable aquatic organisms for oxygen, deplete the oxygen in the water and change the aquatic environment by shading lower water layers. Minimize **P** movement from soils into waterways by:

- **Minimizing** dust blowing from bare ground, erosion by wind or water, movement of mud on machinery, leaves falling from trees, washing down of fertilizer equipment.
- **Reduce P levels in fertilizers.** In WA the concentration of **P** in fertilizers for home gardens has been reduced in the Swan Basin.
- **Only add P** when testing indicates that it is required.
- **Management options for reducing nutrient inputs** can be constructing artificial wetland or simply manually netting or skimming out leaves falling from trees.
- **Sunlight reduction**, eg planting non-invasive plants in and around the pool especially those with floating leaves such as lilies will reduce the amount of sunlight on the surface water and help with nutrient uptake. Chemical dyes are available to turn water various shades of blue and reduce the amount of sunlight available to plants and algae (make sure it is registered for use). **UV light and ozone** are proven methods of algal control but not suitable for large systems.
- **Straw bales** have been used by farmers for years. Bales are thrown into the dam but it only half works. As it breaks down many small organisms feed on the algae and the bales end up as lots of rotting straw at the bottom of the dam. Barley straw or lavender breaks down to release hydrogen peroxide which is particular effective at stopping the growth of filamentous algae (not the ones that discolor the water).
- **Several chemicals are registered** to control algae but many are not economically viable.
- **Biological treatments.** Blends of beneficial bacteria or enzymes that support beneficial bacterial are already found in the environment which breakdown organic sludge into basic elements. Biological filtration with bacteria can control nitrogenous nutrients.
- **Water movement by circulation or aeration** (pumps are costly to run and maintain); some are used in nurseries, etc. Aeration reduces sludge and nutrients in sediment, introduces oxygen to assist biological processes and reduces need for chemical treatments.
- **Leave buffer zones** around water bodies if possible. Avoid clippings or granular fertilizers reaching water bodies. **Limit silt movement from construction** sites by using barriers.
- **Stabilize bare soil** by keeping it damp especially during windy conditions. Keep a solid cover of turf where possible.
- **Intercept drainage from sandy or P saturated areas.** Re-use nutrient-enriched water where possible.
- **Monitor sensitive water bodies** to establish the source of any pollution. **P** in water bodies can in favorable conditions, be precipitated or fixed so that it is removed from the water at least temporarily.
- **Lake Burley Griffin, Canberra.** The people of 3 jurisdictions (Federal, ACT, Queanbeyan City) all fertilize their gardens and the catchment causing many problems, eg rampant carp, redfin perch, nutrient, phosphorous and the occasional sewage contamination.

Grey mould

Botrytis cinerea




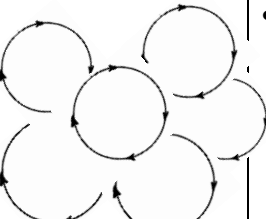
Grey furry *Botrytis* spores on strawberries



Pink spots on rose petals caused by germinating *Botrytis* spores.

Like other fungi, Botrytis has ranges of temperature and relative humidity (RH) that are necessary for spore germination, infection and disease development.

- **Botrytis occurs most often in spring and autumn**, because warm days followed by cool evenings results in condensation on plant surfaces.
 - **Spore germination and infection depends on a film of moisture for 8-10 hours, RH of 93% or greater and temperatures between approximately 12-18°C** with colonization of plant tissues at temperatures up to 21°C.
- **Once Botrytis develops, it cannot be effectively controlled with fungicides alone.** Suppress *Botrytis* by keeping the plant canopy dry especially from dusk until dawn.
 - **Using drip irrigation** or watering plants at the base instead of sprinkling or watering overhead will help prevent *Botrytis* and many other leaf spot diseases.
 - **Increasing plant spacing** to provide a less dense canopy will also help by allowing more air circulation and better fungicide coverage.
 - **In the greenhouse**, reducing humidity as a whole and in the microclimates around plants is also important. Water just enough to prevent excess water on the floor and water early enough in the day to allow plant surfaces to dry before evening reduces the humidity will help manage *Botrytis*.

<p>Vegetables and minimum till</p>	<p>Horticulture Australia (HAL) is investigating the management of nematodes in vegetable crops to determine:</p> <ul style="list-style-type: none"> • Whether losses from root-knot nematode can be reduced by integrating minimum tillage, crop rotation and organic amendments into the vegetable farming system. • The impact of planting date on damage thresholds for root knot nematodes on potatoes. • A claim by a seed company that there is a "fumigation effect" when certain forage sorghum cultivars are incorporated into soil.
<p>Focusing on the weed seed bank</p>	<p>Weed Seed Wizard is an interactive, computer-based system which gives Australian grain growers insight into the hidden seed bank and allows them to co-ordinate their long-term management of weeds by focusing on the weed seed bank, eg</p> <ul style="list-style-type: none"> • It integrates current knowledge of weed biology and through incorporating the effects of herbicides and a range of other control strategic options; the Wizard will help design a truly integrated weed management system. • Targets the major crop weeds for each state, eg annual ryegrass (<i>Lolium</i> sp.). • Shows how management techniques can simulate and predict annual weed populations and how weed management effects crop yield. • Take into account CT systems and strategic use of other methods including: <ul style="list-style-type: none"> • Soil inversion, by placing weed seeds to a depth from which they cannot emerge. Some weed seeds may need to be left at a depth for at least 10 years for them to decay. A one-off inversion of sandy soil with a moldboard plough every 10 to 15 years can be a very profitable and effective method of quickly decimating a seed bank of resistant weeds. • Autumn tickle. • Crop competition. • Crop rotation. • Selective and non-selective herbicides. • Seed catching and burning, an innovative baler design can harvest and bale the residue including weed seeds in one go – it was developed to counter the proliferation of herbicide-resistant weed populations. • Weed Seed Destructors crush seeds and return them to the site (page 236). • Grazing for stubble management.
<p>Conservation agriculture (CA)</p>	<p>Conservation agriculture (CA) is a combination of reduced tillage, adequate retention of residues on the soil surface and crop rotation (page 374). Crop residue retention resulted in increased populations of beneficial microflora under both ZT and CT.</p> <ul style="list-style-type: none"> • No-till is proving an essential part of plant-early strategy. Preserving crop residues stops the soil surface drying out, preserves soil moisture and expands the sowing window. • The combination of ZT with residue retention is responsible for increased microflora. The increased microbial activity produced under these conditions would create an environment more antagonistic to pathogens due to competition effects. • Crop rotation complements no-till strategy and helps manage diseases and weeds; no-till is pointless without strategies to prevent disease build-up. • Controlling weeds is a vital part of preserving moisture in the soil. Aerial herbicide applications can be made over large areas if the ground is too wet. • Timing is critical in summer weed control. A late spray means weeds are bigger and more costly to control, may already have used critical soil moisture and tied up nitrogen. • Yields are increasing with practices such as no-till fallows (retained stubble, herbicides to control weeds), the use of disc seeders to minimize soil disturbance and skip rows to save some inter-row soil moisture for seed fill (Gascoigne 2011). • Remember: Improvements are often due more to good practice than new varieties.
<p>Suppressing weeds with competitive crops</p>  <p>Bedding pansies mound and quickly crowd out weeds</p> 	<p>Efforts by CSIRO to improve water use efficiency in bread wheat has resulted in lines that in trial, also reduces weed seed-set while yielding within a few per cent of top commercial varieties (Braidotti 2012). Key points include:</p> <ul style="list-style-type: none"> • Selection for early vigor has resulted in large-leafed wheats that shade out weeds. • Early-vigor traits improve the root's ability to find water and nutrients, while shading from broad leaves helps conserve soil moisture. • Competition for nutrients has a major negative effect on crop productivity, particularly for current Australian wheat varieties which compete poorly with weeds. This is of special concern where weeds are herbicide resistant. • The buildup of weed seedbanks is also a serious management issue, even with the use of herbicides. • In weed-competition trials, the wheats reduced weed seed-set by 50-60% and matched the yields of commercial varieties. Improved competitive ability has the potential to improve wheat yield and restrict weed seedbank increases. • The Resistance and Integrated Management (RIM) tool evaluates the performance of different integrated weed management practices over many crop cycles. <ul style="list-style-type: none"> • RIM measures the effect of early vigor wheat lines with different levels of suppression on the build up of the weed seedbank. • Early vigor achieves sustainable levels of weed control of ryegrass when used as part of an integrated weed package, eg sowing at high seed rate, but using a wheat cultivar with 30-50% additional weed suppression and combined with windrow burning after barley.

PROS, CONS AND CHALLENGES

PROS

- Cultural methods are preventative, non-polluting.
- Compatible with other methods of control. So can be used in **integrated pest management (IPM)** programs.
- Usually an essential part of **IPM** programs.
- Cultural methods are an increasingly important means of **reducing reliance on chemicals**.
- **Australian Standards** are available for potting mixes, soils for landscaping and garden use, composts, soil conditioners and mulches.
- **Conservation tillage** prevents erosion of soil.
- **Resistance to herbicides** may be minimized by periodically changing the system of land use and using **non-chemical control methods** where possible, eg mulching, ground cover, denser plantings, hand weeding, hoeing.
- Facilitates the **selection of plants** to suit a site.
- Using **predictive weather services** so that early warnings of diseases and pests are available to growers so that pesticides are only applied when necessary.
- **Genetic engineering** is providing new varieties with improved nutrient uptake and other benefits, eg tolerance to drought, frost, prolonged shelf life, etc.

CONS

- Often it is difficult to measure their effectiveness.
- They are often indirect and must be employed far in advance of the problem occurring.
- Often **they do not provide complete control**, may not satisfy customer or biosecurity requirements.
- Some, eg repeated cultivation, may **facilitate soil erosion**.
- **Excessive use of fertilizers**, over-irrigation, etc may cause environmental pollution, promote salt toxicity in containers and outdoor cropping areas. Excessive accumulations of some animal manures may result in nitrate pollution of the environment.
- In **monocultures and fallow situations**, the species and overall numbers of beneficial insects and other biocontrol organisms, are reduced.
- High cost of labour may prohibit cultural methods.
- Crop rotation may not be a practical option.

CHALLENGES

- Current agriculture and horticulture is in a transition towards reduced tillage and less chemical use.
- Precision agriculture has been slow to be adopted in Australia. The need to match inputs with plant needs.
- Diversification and opportunity cropping helps hedge climate risk.
- **Weeds in zero or minimum till are a major challenge**, resulting in more dependence on herbicides for weed control and risk of weed resistance.
 - Glyphosate is getting more expensive.
 - Alternative management strategies are needed to reduce dependence on herbicides and minimize risks of herbicide resistance.
 - Need to **integrate multiple tactics** and to evaluate long-term effects of non-chemical weed management on cropping sustainability.
 - Breeding crops / cultivars for weed suppression.
 - Crop residue can play a role in suppressing weeds by mulch effects on emergence and seed predation.
 - Optimizing crop rotations.
- How we might grow more with existing rainfall.
- Unpredictable rainfall and limited irrigation have encouraged the adoption of the latest water use efficiency practices and more crop options.
- Opportunity cropping.
- Extending the development of GM crops to combat, drought, heat etc.
- Climate variability slows technology's ability to lift yields.
- Greater use of nitrogen-fixing crops in non-legumes.
- Offering incentives to encourage mini-till, etc.
- The need to lift fertilizer production possible by as much as 30% to cater for food security demands.
- Exploring techniques for enhanced nutrient uptake brought about by many biocontrol agents which improve growth and suppress disease by increasing nutrient availability. This could explain why treated plants are larger than untreated plants even when a pathogen is absent. By altering the pH or by exporting enzymes that dissolve insoluble elements, these biocontrol agents increase the availability of certain fertilizers.

REVIEW QUESTIONS AND ACTIVITIES

- Name 1 common problem of the following plants associated **with insufficient or irregular soil moisture**:
 Tomato French bean
 Conifers Crop of your choice
- Describe **cultural conditions which favour the following diseases and pests**:
 Black spot (rose) Salinity
 Oriental fruit moth Etiolation
 Damping off *Phytophthora* root rot
 Twospotted mite Oedema
- List 3 fertilisers which **make the soil more acid** and 3 which **make the soil more alkaline**.
- List 2 deficiencies **common in alkaline soils** and 2 deficiencies **common in acidic soils**.
- List at least 4 cultural conditions you should consider when **siting plants**.
- Explain how **planting and / or harvesting times** can affect the incidence of the following diseases:
 Damping off Fruit fly
 Tomato spotted wilt virus (TSWV) on tomato.
- Name 1 disease of annual flowers, vegetables or field crops that **crop rotation** could be used to control.
- Describe the **advantages and disadvantages of conservation tillage (CT)**.
- Describe how **weeds** can be controlled in **CT systems**.
- List 2 reasons why, from a disease and pest point of view, **spacing of plants** can be important.
- Describe cultural methods which may **contribute to the control** of the following problems, discuss their effectiveness:
 Damping off *Phytophthora* root rot
 Twospotted mite Problem of your choice
- Describe how cultural methods can be used in **IPM** programs.
- Describe the **advantages and disadvantages** of using cultural methods of disease, pest and weed control.
- Perform **practical exercises** in disease, pest and weed control using cultural methods.

SELECTED RESOURCES

- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- Australian Fertilizer Services Association. *FertCare Accreditation Program*.
- Australian Standards
AS 3743. *Potting Mixes*.
AS 4419. *Soils for Landscaping and Garden Use*.
AS 4454. *Composts, Soil Conditioners & Mulches*.
- Baker, S. 2006. *Rootzones, Sands and Topdressing Materials for Sportsturf*. STRI, UK.
- Bates, A. K. 2010. *The Biochar Solution. Carbon Farming and Climate Change*. CSIRO Pub.
- Batini, F. 2012. *Major Vegetation Collapse: Northern Jarrah Forest, Western Australia*. The Forester, Vol 55 March 2012.
- Baxter, N. 2012. *Soil Carbon: Easy to Misunderstand, Vital to Have*. Ground Cover Jan-Feb.
- Braidotti, G. 2012. *Old Fashioned Wheats reveal Competitive Vigour*. Ground Cover Jan-Feb.
- Branagh-McConachy, M. 2010. *Fertilizer "Win-Win" from Limiting its Use*. Ground Cover May-June.
- Brown, J. F. and Ogle, H. J. 1997. *Plant Pathogens and Plant Diseases*. Rockvale Pub. Armidale, NSW.
- Brunton, V. 2013. *AgGuide: Using Compost in Agriculture*. NSW DPI.
- Cole, S. 2012. *Climate Driving Change*. Ground Cover. Jan-Feb.
- Collis, C. 2012. *Deep Fertilizer Placement to Restore Productivity*. Ground Cover. Nov Dec.
- Cresswell, G. C. and Weir, R. G. 1997. *Plant Nutrient Disorders. 5. Ornamental Plants and Shrubs*. Inkata Press, Port Melbourne.
- Davis, C. 2011. *Phosphorus Fertilizer Research Aims for Multiple Benefits*. Ecos.
- Dell, M., Jones, B. and Olken, B. 2011. *Temperature Shocks and Economic Growth: Evidence from the Last Half Century*. American Economic Journal: Macroeconomics. 2012:4(3):66-95.
- Derpsch, R. 2005. *The Extent of Conservation Agriculture Adoption Worldwide: Implications and Impact*. Proc. of the Third International Congress of Conservation Agriculture, Nairobi, Kenya.
- Dumanski, J., Peiretti, R., Benetis, J. R., McGarry, D., and Pieri, C. 2006. *The Paradigm of Conservation Tillage*. Proc. World Assoc. Soil and Water Cons, P1: 58-64.
- Duncan, R. R., Carrow, R. N. and Huck, M. T. 2008. *Turfgrass and Landscape Irrigation Water Quality: Assessment and Management*. CRC Press.
- Ferguson, J. J. and Rathinasabapathi, B. 2003 (reviewed 2009). *Allelopathy: How Plants Suppress other Plants*. Florida Coop. Ext. Service, Uni. of Florida.
- Freebairn, B. 2012. *Can Tillage Save No-Till in Wet years?* Ground Cover. Jan-Feb.
- Gascoigne, T. 2011. *Farm Evolving to Preserve Moisture*. GRDC May-June.
- Geary, J. 2010. *The Biology of Turfgrass Soils*. Australian Turfgrass May-June.
- GRDC. 2010. *Adapting to Climate Change*. Ground Cover Climate Supplement. July-Aug.
- GRDC 2011. *Suppressing Weeds with Competitive Wheat Cultivars*. 2010-2011. GRDC Annual Report.
- Handreck, K. and Black, N. 2010. *Growing Media: For Ornamentals Plants and Turf*. 4th ed., UNSW Press, Kensington, NSW.
- Hazelton, P. and Murphy, B. 2007. *Interpreting Soil Test Results*. CSIRO Pub.
- Hüberli, D., Hardy, G. E. J., White, D., Williams, N. and Burgess, T. I. 2013. *Fishing for Phytophthora from Western Australia's Waterways: A Distribution and Diversity Survey*. Aust. Plant. Path. 42:251-260
- Hull, J. 2011. *Phosphorus in the Turf Environment*. Keeping it Green. Dec.
- Illingworth, J. 2004. *Investigating Turf Wetting Agents*. Golf & Sports Turf Australia. Oct-Nov.
- International Symposium. *Organic Matter Management and Compost*. University of Adelaide 4-7 April 2011.
- Kasirajan, S. and Ngouajio, M. 2012. *Polyethylene and Biodegradable Mulches for Agricultural Applications: a Review*. Agro. for Sus. Dev. 12 Jan. April, 501-529.
- Kelly, S., Guest, D. and Daniel, R. 2013. *Elevated Soil Nitrogen Increases the Severity of Dieback due to Phytophthora cinnamomi*. Aust. Plant Path. 42(2):55.
- Lake, J. 1998b. *Irrigation Expo Reaffirms Water is Gold*. Aust. Hort., July.
- Leake, S. and Haegi, E. 2014. *Soils for Landscape Development: Selection, Specification and Validations*. CSIRO. Pub.
- Lintz, H. E., Huso, M., Stanley, K. C. and Taylor, T. 2011. *Composting One Invasive Species to Control Another*. Restoration Ecology, 19: 1-4.
- MacCartney, R. 2005. *Biostimulants: Their Place in Turf Management*. Golf and Sportsturf Australia Feb-Mar.
- Matthiessen, J. and Kirkegaard, J. 2003. *Brassica Green Manure Crops appear to Improve Soil Properties*. Hort. Biofumigation Update. 18. CSIRO.
- McCarthy, A. 2001. *Avocado Culture in Western Australia*. Bull. No. 4484. Agriculture WA.
- Moody, H. 2004. *Exploring the Potential of Companion Planting*. New Frontiers. Aust. Hort. Dec.
- Moody, H. 2004. *Ecological Engineering for Pest Management*. Habitat.
- NGIA. *Nursery Production Farm Management System*. Online Manuals Portal: User Manuals for the NIASA, EcoHort and BioSecure HACCP programs.
- Nichols, D. 2003. *Nutrient Stress can Increase Disease Risk*. Aust. Hort. July.
- Nichols, D. 2007. *Foliar Sprays: Value and Use*. Aust. Hort. Oct.
- NSW DPI (Collaborative Project). 2010. *Making Better Fertilizer Decisions for Cropping Systems in Australia*. Industry & Investment NSW.
- Nursery Industry Accreditation Scheme Australia (NIASA). 2010. *Best Management Practice Guidelines*. 4th Edit. NGIA. Includes *Water Management Best Practice Guidelines*.
- Page, K., Dang, Y. and Dalal, R. 2013. *Impacts of Conservation Tillage on Soil Quality, including Soil-borne Crop Diseases, with a Focus on Semi-arid Grain Cropping Systems*. Aust. Plant Path. 42(3):363.
- Pattison, A.B., Badcock, K. and Skora, R. A. 2011. *Influence of Soil Organic Amendments on Suppression of the Burrowing Nematode, Radopholus similis on the Growth of Bananas*. Aust. Plant Path. 40:386-396.
- Penfold, C. and Collins, C. 2012. *Cover Crops and Plant-Parasitic Nematodes*. Factsheet June. GWRDC.
- Pritchard, F. 2011. *Crops, Carbon, Climate and the Future: Grain Scientists Pitch In*. Ground Cover Sep-Oct.
- Pryor, L. 2011. *New Pest: Trees under Threat from Invasion*. Adelaide Advertiser 8/1/2011.
- Read, N. A. 2013. *Plant Residues and Newspaper Mulch Effects on Weed Emergence and Collard Performance*. Thesis. The Ohio State University.
- Rebeck, M. A. and Knell, G. 2007. *Managing Frost Risk: A Guide for Southern Australia Grains*. SARDI.
- Reddy, P. P. 2011. *Biofumigation and Solarization for Management of Soilborne Plant Pathogens*. Scientific Publishing India.
- Reddy, P. P. 2012. *Recent Advances in Crop Protection*. Springer India.
- Reuter, D and Robinson, J. B. (eds) 1997. *Plant Analysis: An Interpretation Manual*. 2nd Edn. CSIRO Pub.
- Rolfe, C., Yiasoumi, W. and Kesikula, E. 2002. *Managing Water in Plant Nurseries*. 2nd ed. NSW DPI.
- Smith, M. L., Smith, J. P., and Stirling, G., R. 2011. *Integration of Minimum Tillage, Crop Rotation and Organic Amendments into a Ginger Farming System: Impacts on Yield and Soilborne Disease*. Soil & Tillage Research 114: 108-116.
- Stirling, G. R. 2014. *Biological Control of Plant-parasitic Nematodes: Soil Ecosystem Management in Sustainable Agriculture*. CAB International, Wallingford.
- Stirzaker, R. 2010. *Out of the Scientist's Garden: A Story of Water and Food*. CSIRO Pub.
- Sustainable Liquid Technology (SLTEC) www.sltec.com.au
- Sutherst, R. W. 2000. *Pests and Pest Management: Impact of Climate Change*. No.00/16. RIRDC, ACT.
- Whelan, B. and Taylor, J. 2013. *Precision Agriculture for Grain Production Systems*. CSIRO Pub.
- Windust, A. 2012. *Waterwise House and Garden*. Landlinks Press.





SANITATION



INTRODUCTION	66
DISEASED AND INFESTED PLANT MATERIAL	67
Crop residues	67
General litter and debris	67
Picking off pests	67
Fallen leaves	67
Loose bark	67
Propagation material	67
Fruit	67
Over-seasoning	68
Host removal, eradication	68
Tree surgery	68
Pruning off shoots, branches	69
Rogueing	69
Washing fruit, seedling roots, potato tubers	69
DISPOSAL AND RECYCLING	70
Legislation	70
Contaminated waste	70
Chipping trees and shrubs	70
Grazing and mowing	70
Green waste	70
Composting	71
Recycling animal manure	72
Recycling water	72
Nursery run off	72
Burning	73
Burying	73
HANDS, EQUIPMENT, CONTAINERS, SOIL	74
Handling plants	74
Shoes, boots	74
Pruning tools	74
Storage bins, packing sheds	74
Movement of staff, plants, machinery	74
Containers	75
Trolleys, machinery, benches, floors, walls	75
Disinfectants	75
MOWERS, HARVESTERS, BRUSHCUTTERS	76
Mowers in urban areas - weeds	76
Machinery and vehicles, on-farm biosecurity	76
Grape harvesters	76
Seed Destructors	76
Brushcutters	76
MANAGING SANITATION	77
PROS, CONS AND CHALLENGES	81
REVIEW QUESTIONS AND ACTIVITIES	82
SELECTED RESOURCES	82

INTRODUCTION

Sanitation is of increasing importance

<p>What is sanitation?</p> <p>Practice good hygiene from propagation to harvest</p>	<p>Sanitation includes:</p> <ul style="list-style-type: none"> • The elimination or reduction of disease organisms, pests and weeds in a nursery, glasshouse, storage or packing facility or other horticultural or agricultural situation. It reduces the likelihood of spread to other produce, healthy plants, containers, farms, especially at the beginning of a new season. Examples include the prompt removal of diseased fruit and thoroughly cleaning packing facilities and equipment with a suitable disinfectant, etc. • Generally used in conjunction with other methods of control. • Often overlaps with physical methods.
<p>Why sanitation?</p>	<p>With the development of “wonder” disinfectants, pesticides and other innovations in the 20th century, sanitation was neglected. However, it has regained its importance due to:</p> <ul style="list-style-type: none"> • Pesticides and disinfectants don’t work against everything! • The development of resistance by some pests, diseases and weeds to certain groups of pesticides. • The availability and expense of developing new products. • Consumers wanting a cleaner, greener environment. • Its ability to reduce reliance on pesticides in nurseries and storage areas, etc. • Being a powerful control tool for some diseases, eg soilborne fungal infections. • Being preventative, usually non-polluting and is a central component of many Integrated Pest Management (IPM) and Best Management Practice (BMP) programs, eg Nursery Industry Accreditation Scheme, Australia (NIASA) and Biosecurity Best Practice for on-farm hygiene. • Many industries and situations need excellent hygiene, eg the seed industry, benches and containers in nurseries, weed control inside and outside glasshouses, machinery moving from farm to farm.
<p>Legislation, Standards, etc</p>  <p>AUSTRALIAN STANDARDS</p>	<p>Sanitation procedures may be prescribed by legislation, codes of practice, standards.</p> <ul style="list-style-type: none"> • Noxious Weeds Acts aim to prevent the spread and build-up of specific weeds and provide for the mowing, slashing, hoeing, digging, ploughing, grubbing and burning of noxious weeds. • Plant Diseases and Plant Protection Acts may prescribe sanitation practices. • Biosecurity Acts may prescribe sanitation measures during eradication campaigns. • Standards: www.standards.com.au AS 3743 – 2003. <i>Potting mixes</i>. AS 4454 – 2012. <i>Composts, soil conditioners and mulches</i>. AS 4419 – 2003. <i>Soils for landscaping and garden use</i>. <p>Legislation, Accreditation schemes, eg</p> <ul style="list-style-type: none"> • Environment Acts. • Plant Diseases Acts. • Plant Protection Acts. • Nursery Industry Accreditation Scheme Australia (NIASA). • Australian Garden Centre Accreditation Scheme (AGCAS). • Tree Protection Acts.
<p>Training</p> 	<p>There is a range of agriculture and horticulture courses which include units dealing with weed movement, machinery inspection and cleaning, greenhouse hygiene, processing areas, etc.</p> <ul style="list-style-type: none"> • Some of these nationally accredited units can be undertaken separately in workshops and a Certificate of Attainment achieved. • “WeedStop” courses provide training and accreditation in the fundamentals of hygiene practice to both growers and consultants. • Registered training organizations and Commonwealth and State / Territory providers deliver such courses. 
<p>Timing</p> 	<p>Sanitation must be practiced at the right time, eg there is a need to know the life cycle of the disease, pest or weed, where it overwinters, how it spreads, etc.</p> <ul style="list-style-type: none"> • Twospotted mite has a wide host range and survives over winter on weeds and perennial ground cover. • Greenhouses can be emptied and cleaned between crops. • Secateurs should be disinfected between plants. • Harvesters and mowers should be cleaned before moving them from property to property; defense vehicles are cleaned on returning to Australia.

DISEASED AND INFESTED PLANT MATERIAL



<p>Crop residues</p> <p>Conservation Tillage Check benefits page 54</p>	<p><u>Destruction of diseased and infested plant material</u> reduces inoculum and minimizes spread of many foliar diseases and pests.</p> <ul style="list-style-type: none"> The effect of destroying crop debris in situ will vary depending on the crop and the problem(s) it causes. Some residues which harbor diseases and pests can be destroyed as soon as possible after harvest / flowering, eg <ul style="list-style-type: none"> Tomato plants, eg early blight or target spot (<i>Alternaria solani</i>). Indoor plants, eg grey mould (<i>Botrytis cinerea</i>), mealybugs (Pseudococcidae).
<p>General litter and debris</p>	<p><u>Many insects pupate in litter and debris surrounding trees.</u></p> <ul style="list-style-type: none"> Destruction of these materials reduces numbers of emerging insects, eg <ul style="list-style-type: none"> Codling moth (<i>Cydia pomonella</i>) Oriental fruit moth (<i>Graphita molesta</i>)
<p>Picking off pests</p>  <p>Collecting insects by hand</p> <p>Swatting insects</p>	<p><u>This is probably the first kind of pest control measure ever used.</u></p> <ul style="list-style-type: none"> Only useful on a few plants in a small area, such as in a home garden. Large easily seen, slow-moving insect pests such as caterpillars can be handpicked and destroyed. A few scale or mealybugs can be rubbed or washed off from infested shoots. Aphids could be hosed off. Leaves with various leaf spotting fungi can be removed early in the season. Parasitic weeds, eg dodder (<i>Cuscuta</i> spp.), can be pulled from host plants. Cutworms (Noctuidae, Lepidoptera) can be carefully dug up and killed. Hand weeding is probably the best example. Weeds can be dug out. Snails can be collected or stomped on at night with the aid of a torch. Flying insects such as flies and mosquitoes may be swatted. Vacuum cleaners have been used to monitor and control insects and mites. Overseas small, hand-held, battery-operated vacuum cleaners suck up adult whiteflies from leaves. Vacuum when cool and whiteflies sluggish, ie in the early morning. Insects can be killed by placing the vacuum bag in a plastic bag and freezing overnight.
<p>Fallen leaves</p>	<p><u>Some fungal diseases</u>, eg black spot (<i>Marssonina rosae</i>) of rose, overwinter in fallen leaves and it is often suggested these infected leaves be raked up. However, it is impossible to rake up every single leaf. Raking up and destroying infected leaves, does not, on its own, provide effective control.</p>
<p>Loose bark</p>	<p><u>Caterpillars of codling moth</u> (<i>Cydia pomonella</i>) spin their cocoons under loose bark on trunks and limbs of trees. Brushing these cocoons away and destroying them will reduce numbers of adult moths to some extent but will not, on its own, provide effective control.</p>
<p>Propagation material</p>	<p><u>Propagation programs should be planned and managed</u> so that propagation areas are regularly emptied for cleaning and disinfecting.</p> <ul style="list-style-type: none"> Cuttings, rootstocks, bulbs, corms and seeds may be infested with pests or infected with diseases (page 208). Stock / parent plants held for a long period in greenhouses and outdoor areas are often the source of pests and diseases in cuttings, bulbs, etc.
<p>Fruit</p> 	<p><u>Collection and destruction.</u></p> <ul style="list-style-type: none"> Sanitation may be prescribed by legislation to reduce codling moth and fruit flies. Essential measures for the control of many diseases and pests include the removal and destruction of all fallen fruit and infested fruit on the tree, eg <ul style="list-style-type: none"> Fruit fly - Every 3 days Codling moth - Every 7 days



Fig. 8. Removal and destruction of all fallen fruit and infested fruit on the tree which reduces the numbers of insects and disease organisms to attack the next crop.

Over-seasoning

Over-wintering
Over-summering



Volunteer hosts and weeds are often hosts to pests which may later move onto cultivated crops.

Check that they really are a problem before destroying them as they are part of the ecology.

The term 'green bridge' describes the role of weeds and crop volunteers in providing 'between season' hosts for insects and diseases that pose a serious threat to future crops and can be expensive to control later in the season. The destruction of these alternative hosts can reduce disease and pest inoculum for the following season.

- **Diseases and insects can quickly spread from the green bridge** jeopardizing crops and current control methods including the effectiveness of chemicals and genetic breeding for resistance. Weeds and volunteers can be controlled, either by cultivation or by herbicides.
 - **Volunteer potato plants** in the field which are infected allow diseases to overwinter, and in the spring such tubers produce infected plants.
 - **Volunteer bulbs** in new crops are usually infected with virus diseases
 - **Volunteer tomato plants** may grow during the period between tomato crops in warmer climates and act as reservoirs of infection.
- **Weed growth during summer and autumn** depletes soil moisture and nutrients that would otherwise be available to following crops.
- **Check areas are weed-free** before cropping so there is no carry over of pests.
- **Know the host range of your diseases and pests**, eg
 - Tomato spotted wilt virus (TSWV) Annual and herbaceous perennial plants, including flowers, vegetables, weeds.
 - Root knot nematodes (*Meloidogyne* spp.) Many dicotyledonous plants and weeds
 - Twospotted mite (*Tetranychus urticae*) Wide host range, weeds, groundcover.
- **Effective control of the pest and disease risks requires neighbors** to work together to simultaneously control weeds and crop volunteers.
- **Sanitation assumes particular significance** when used in conjunction with crop rotations. There is little point in growing a **non-host crop in a crop rotation** to reduce the level of diseases or pests, if weeds which act as alternative hosts grow unchecked. Weeds along fence lines may act as sources of reinfestation.
- **Perennial plants of all types** can harbor certain pests and diseases, eg scale insects.
- **Alternate hosts.** Overseas, some rust diseases must develop on 2 kinds of plants to complete their life cycle. Eradication of the wild or economically less important alternate host interrupts the life cycle of the rust disease and leads to control of the disease. In Australia in the absence of alternate hosts for wheat rusts (*Puccinia graminis*, *P. coronata*), these rusts survive on volunteer plants.

Host removal, eradication



Eradication is usually associated with biosecurity measures and may be mandated.

Because eradication is so costly to growers and land managers, alternative strategies are preferred



Severely diseased or infested plants or crops may have to be destroyed.

- **Indoor plants** severely infected with powdery mildew or *Botrytis*, or infested with mealybugs (Pseudococcidae), may be destroyed.
- **Prunus spp.** Young *Prunus* trees severely infected with **bacterial canker** (*Pseudomonas syringae* pv. *syringae*) can be removed.
- **Wood rot.** If there is extensive rot or fruiting bodies on the main trunk, the tree is best removed.
- **Tree Protection Acts** may prevent certain trees from being removed.

Host eradication to eradicate a disease, pest or weed.

- **After the outbreak of either a new disease in an area** or an **old disease in a new area** in spite of biosecurity, a plant disease epidemic may follow. **Eradication** is the **removal of all infected plant material**, ie removal and destruction of all host plants infected or suspected of harboring such a disease to eliminate the pathogen and prevent greater loss from spread to additional hosts.
 - **Citrus canker** (*Xanthomonas campestris* pv. *citri*) in the NT and Queensland has been eradicated.
 - **Apple scab** (*Venturia inaequalis*) has been the subject of vigorous eradication campaigns in WA. However, it is now established in some areas of that state and is being appropriately managed.
 - **Phytophthora dieback** (*Phytophthora cinnamomi*) has been successfully eradicated in some areas of WA by clearing contaminated bushland of living hosts (2014).
- **The period between the introduction of a disease, pest or weed and its detection** can allow spread to the extent that attempts to eradicate or contain it are not possible, eg some **rust diseases** in Australia, eg
 - Myrtle rust (*Puccinia psidii*)
 - Poplar rust (*Melampsora* spp.), willow rusts (*Melampsora* spp.).
 - White chrysanthemum rust (*Puccinia horiana*).

Tree surgery



Tree surgery is the chiseling out and trimming of wood from a tree that is damaged by **wood rot, borers, termites, sunscald, vehicles** or other agents. If the tree is taller than 3 meters consult a qualified tree surgeon. Although Fact Sheets describing how to perform tree surgery are available from websites it is suggested that you seek advice as it may be necessary to remove the tree for safety reasons.

- **The larvae of some fruit-tree borers live in short tunnels** on trunks and branches, commonly in branch forks (page 79 photo). Loose bark and debris can be removed and any larvae exposed destroyed. Probe any exposed holes under the removed bark with a length of flexible wire to kill any larvae.

Pruning off shoots, branches



Pruning depends on the type of plant.

A successful program for control.

- **Pruning** inevitably influences the microclimate within the tree canopy indirectly affecting any subsequent disease and pest development.
- **Pruning out infested or diseased shoots** prevents spread onto healthy parts and may be carried out in winter or during summer, depending on the plant and the problem.
- **Avoid pruning in wet weather** and large pruning cuts where possible.
- **Cut at the collar of a tree** to encourage callusing.
- **Fertilize to promote vigor** to ensure callusing of cuts and a speedy recovery.
- **Some plants**, eg agapanthus can be pruned after flowering to remove seeds to prevent spread.

Indoor plants.

- **Stems and shoots which are severely infested** with insect pests such as **scale**, or infested with **powdery mildew**, may be pruned out.

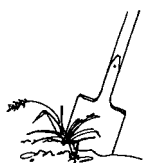
Fruit trees.

- **Brown rot** (*Monilinia* spp.), **shot-hole** (*Stigmia carpophila*). Pruning out infected small branches, shoots, twigs and brown rot ‘mummies’ on stone fruit trees is usually carried out during winter pruning.
- **Powdery mildew** (*Podosphaera leucotricha*) of apple. Unless infected shoots are pruned out and destroyed during winter pruning and during the growing season, fungicides may not bring about effective control on susceptible varieties.
- **Citrus gall wasp** (*Bruchofagus fellis*). Removing gall-infected shoots at least 1 month prior to wasp emergence (ie before September) helps to reduce adult populations. Hedging, pruning and skirting operations are best undertaken immediately after gall emergence is completed to reduce the amount of new growth suitable for egg laying (Creek and Hardy 2010).

Small trees and shrubs.

- Branches and twigs infested with **scale**, **borers** and **wood rotting fungi** may be removed and destroyed to prevent spread.

Rogueing



Dig out weeds and diseased plants

What is rogueing?

- **Rogueing is the removal of an infested or diseased plant**, known as a ‘rogue’, from an otherwise healthy crop and destroying it so that the pest or disease cannot spread from it to neighboring plants or through its seeds to the next generation. **Weeds** may be rogued from annual and herbaceous perennial plantings.
- **To minimize spread**, diseased plants need to be removed as soon as possible after symptoms are observed.
- **Rogueing may need to be repeated regularly** as newly diseased plants appear. To reduce spread of banana bunchy top virus, both affected plants and adjacent apparently healthy plants are removed and destroyed.

Which problems is rogueing effective against?

- **Rogueing is only practical where the disease or pest is at a low level**, eg when only a few iris or lily bulbs are infected with virus diseases. Some insect pests, eg chrysanthemum gall midge, build up populations on individual plants.
- **Rogueing is routinely carried out** in many nurseries, greenhouses and high value crops, to prevent spread of numerous diseases and pests by eliminating infected plants that provide a ready source of inoculum within the crop.

Which problems is rogueing not effective against?

- **Rogueing is of little value against soilborne diseases and pests.** The diseased or infested plant is removed but the problem-causing organisms remain in the soil. When plants infected with soilborne diseases are removed, where practical a spadeful of the surrounding soil should be carefully removed as well. However, the disease is likely to be still in the surrounding soil.
- **Most problems which attack the aerial parts** of plants.
- **Most fungal diseases and most insect pests.**



Washing fruit, seedling roots, potato tubers

Washing with or without sanitizers is used to removed soil, other residues and the pests and diseases from the surface of various plant parts, eg

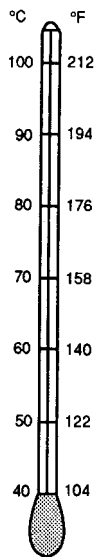
- **Post-harvest fruit and vegetable treatments.**
- **Potato cyst nematode (PCN)** (*Globodera rostochiensis*) is of serious biosecurity concern because its eggs, protected within cysts are long lived and are readily transported in soil adhering to tubers or less commonly as cysts that develop on the tubers themselves. Trials are underway to see if washing tubers of potatoes harvested from land infected with **PCN** until **less than 5% of tubers** had small visible soil patches, could be an acceptably low risk of carrying **PCN** on potatoes for processing.

DISPOSAL AND RECYCLING

Reduce, Reuse, Recycle

<p>Legislation</p> 	<p><u>For some pests and diseases</u>, eg fruit flies, the method of disposal is prescribed by law and may vary from one region to another within Australia.</p> <ul style="list-style-type: none"> • Fire blight (<i>Erwinia amylovora</i>) was found in the Royal Botanic Gardens, Melbourne in 1995. Host plants on properties within 250 meters of the gardens were destroyed under the then Plant Health & Protection Act 1995. • Guidelines for Best Practice are available for green waste. • Environmental Best Practice Guidelines are also available.
<p>Contaminated waste</p>	<p><u>Waste may be contaminated in several ways</u> including:</p> <ul style="list-style-type: none"> • Improperly composted green garden waste may spread pests, diseases and weeds, eg white rot of onion (<i>Sclerotium cepivorum</i>), oxalis seed, couch runners. There can be a high incidence of environmental weeds in the green waste stream. <ul style="list-style-type: none"> • This risk is somewhat reduced depending on the means by which weeds spread. • Treatments vary, eg degrees of shredding, and degrees of composting. • Crop residues may be contaminated with pesticides, eg cotton waste used for cattle feed which was contaminated with pesticides. • Grass clippings, tan bark, soil, crop residues may be contaminated with herbicides or weed seeds. • Bark and sawdust may contain toxins. • Treated timbers may be contaminated with timber preservatives. • Sewage sludge may be contaminated with heavy metals.
<p>Chipping trees and shrubs</p>	<p><u>Disease hazard from uncomposted tree mulch.</u></p> <ul style="list-style-type: none"> • Chipping tree parts is a common means of disposing of pruning waste. Chips are often sold for landscape mulch without composting. Beneficial fungi are important in breaking down the chips so that the nutrients they contain are recycled. Their fruiting bodies may appear on the mulch during the decomposition process for several years. • Chipped infested elm wood is considered unable to support development of the elm bark beetle (<i>Scolytus multistriatus</i>). Chipping is not recommended for bark which might be contaminated with Dutch elm disease (<i>Ceratocystis ulmi</i>). • It is considered unwise to use uncomposted or improperly composted chips from plants which are susceptible to serious diseases or pests. Such uncomposted chips may contain fungal pathogens which could infect similar species of trees or woody plants.
<p>Grazing and mowing</p>	<p><u>In mixed farming enterprises, stock can be used to graze off crop residues.</u></p> <ul style="list-style-type: none"> • Sheep or cattle may be used to remove crop stubble after harvesting. Sheep and pigs may also be used to remove fallen fruit in apple orchards. • Mowing is used to control weeds between rows in tree crops and vineyards. • Grazing and mowing may spread weeds. • Maintaining moderate herbaceous ground cover levels and using sheep to browse juvenile parkinsonia, offers a potential management strategy for limiting parkinsonia (<i>Parkinsonia aculeata</i>) invasion (Smith 2012).
<p>Green waste</p>  <p>AUSTRALIAN STANDARDS</p>	<p><u>Green waste refers only to items that are suitable for composting.</u> Various strategies have been developed to reduce and manage green and organic waste at both Commonwealth and State / Territory levels. Some branded products are available.</p> <p><u>Australian standards:</u></p> <ul style="list-style-type: none"> • AS 4454-2012. Composts, Soil Conditioners and Mulches. A framework for assessing the quality of organic materials. Due to inherent weed and plant disease potential of this material, shredded green waste (garden waste) is specifically excluded from standards specification unless it has been composted. • AS 3743-2003. Potting Mixtures. Green waste for potting mixes must meet prescribed criteria. The main problems may be variability, the potential for diseases, pests and weeds and unknown toxic contaminants. • AS 4419-2003. Soils for Landscaping and Garden Use. Specifies physical and chemical requirements such as organic matter, wettability, etc. <p><u>Local authorities or councils.</u></p> <ul style="list-style-type: none"> • Many have proposals to either reduce or ban green waste from entering landfill and to recycle it into soil enriching products. • Many have systems which collect green waste and compost it for resale. The composting must comply with the Australian standards to ensure that uniform heating of the stockpile kills most weed seeds.

Composting
Endogenic heat



AUSTRALIAN STANDARDS

All products are tested regularly by an independent specialist soil laboratory to ensure that products from garden and wood waste comply with the standards.

Handreck, K. A. and Neil D. Black, N. D. 2010. *Growing Media for Ornamental Plants and Turf*. 4th Ed. NSW University Press, Sydney.

Compost will hold moisture like a sponge and as nutrients are also water soluble it enables them to be taken up by plant roots; the nutrients are also retained within the compost until required. Compost improves soil conditions by adding organic matter and increasing its water-holding capacity. It also helps prevent top soil being lost and reduces the effects of erosion.

- **Compost Australia (CA)** says that organic material diverted from landfill could abate 2 million tons of CO₂ equivalents every year (Aust. Hort. 2011). A South Australian project aims to link urban green waste producers to organic farmers.
- **An International Symposium on Organic Matter Management and Compost Use in Horticulture 2011**, presented options for using compost and other organic soil amendments for horticultural soils and production systems.

Fit-for-purpose compost products are tailored to particular end-users, eg

- **By adding the right nutrients**, eg for vegetable production, fruit and berry growing, protected cropping, turf production and maintenance, viticulture and tree cropping.
- **Selecting products that deliver desired outcomes**, including:
 - For enhancing crop yield and quality and improving profitability.
 - Suppressing soilborne diseases.
 - Improving physical, chemical and biological soil properties.
 - Improving **WUE** (infiltration, water holding capacity, reduced water loss).
 - Maintaining and improving soil carbon levels.
 - Determining the nutrient supply from composts and manures.
- **Composting one invasive species to control another** can be effective and merits trials. The mechanisms behind this is uncertain but may be related to weed seed burial or the allelopathic potential of the mulch (Lintz et al 2011).
- **Some branded composts have additives**, eg gypsum, dynamic lifter, wetting agents.

Crop residues and green garden waste must be composted before re-use.

- **Temperatures of 60°C or higher for 30 minutes** are required to kill disease and pest organisms, and weeds (page 240). Centers of properly constructed and managed compost bins will reach this temperature. However, it is difficult, even with regular turning of the contents to ensure that all the compost will reach 60°C. It is unwise to place residues from plants which often carry pests and disease organisms on poorly constructed compost heaps. Also avoid weed seeds and weeds such as couch or undesirable plants like ivy that will regrow from even a small piece of stem if not properly composted.
- **AS 4454-2912. Composts, Soil Conditioners and Mulches** provide an important framework for assessing the quality of composts.
- **Contamination.** There's a wide array of herbicides, pesticides, heavy metals and other chemicals as well as bacterial pathogens that can make their way into commercial compost. **Green garden waste** used for compost may be contaminated with herbicides, etc.

Most beneficial effects of compost are due to the activities of beneficial antagonistic microorganisms.

- **Composting temperatures, ie 60° C for 30 minutes**, are high enough to destroy disease organisms but not some antagonists. Composting encourages the development of *Trichoderma* and other antagonists.
- **Many compost batches tested** are deficient in antagonistic organisms and may need to be inoculated with specific biocontrol agents.
- **Few beneficial microorganisms survive high-temperature areas of compost.**
 - **Most survive in outer low-temperature layers** where they re-establish themselves if the moisture content is > 35% (preferably > 45%) in the organic matter fraction.
 - **Allow composts to cure** while maintaining moisture content of 45% to 55%.
- **Composts usually do not provide total disease control**, but under favorable conditions they can reduce many diseases to below critical threshold levels.
 - *Pythium* and *Phytophthora* root rots may be suppressed by composts.



Fig. 9. Left: Temperatures of 60°C kill many soilborne disease organisms. Right: Steam rising during turning of a free-standing compost heap. Diagram©CSIRO (Handreck 1994).

Recycling animal manures



Recycled animal manures can provide alternatives to mineral fertilizers to help improve soil structure and increase soil microbial activity, with over-all soil-health benefits in the medium to long term. Increasingly growers are looking to manures to reduce fertilizer costs but it must be managed properly.

- **Consult State Environmental Protection Authorities** for guidelines. In some States, as in SA, a license would be required to compost large amounts of material.
- **A chemical analysis of recycled organics** is essential to determine the potential nutrients available, calculating application rates and identifying potential benefits and risks. Test for key indicators including nitrogen, phosphorus and potassium to ensure that it is applied at an appropriate rate. **A fact sheet** details the risks and benefits of using materials such as pig, chicken and cow manure as broadacre fertilizer for crops (GRDC 2010).
- **Animal manure** can also carry weed seeds, pathogens and contaminants such as heavy metals.
- **Ongoing tests are important in monitoring and managing** the potential buildup of nutrients and other chemicals in the soil. A number of risks relate to agronomy, environmental pollution, public health and safety. Soil and water risks include:
 - **Heavy metals.** Limit application to ensure maximum in-soil limits of heavy metals as defined by relevant State / Territory guidelines are not exceeded.
 - **Nutrients.** Limit rate to ensure nutrients do not accumulate over time.
 - **Maintain vegetated filter strips in riparian areas** and do not store or apply manures within prescribed distances to sensitive areas, eg surface water, bores.
 - **Salinity and sodicity,** phytotoxicity,
 - **Human and animal health,** eg odor, dust and air quality.

Recycling water Get advice



Murdoch University's Environmental Technology Centre handles a total waste system of various types of water, eg

- **White water** (natural) is fresh potable water scheme or bore water.
- **Grey water** is the recycling of 'waste' water that is generated in homes and commercial buildings. Its gets its name from its cloudy appearance.
 - **It is collected from** sinks, showers, baths, washing machines, dishwashers.
 - **It is used** for a variety of purposes such as irrigation or toilet flushing.
 - **Seek advice** on setting up the system, storage and using it.
- **Black water** is wastewater from toilets and designated for sewage systems. Any water containing human waste is considered black water. Black water can be treated. If opportunity exists to reuse effluent from municipal treatment plants, **get advice**.
 - **There are various classes of treated effluent water** mostly concerned with public health and not necessarily to do with irrigation. Considerations though include water quality for irrigation, pH typically in the high range, certain negative elements, eg sodium, also salinity and total dissolved salts.
 - **Water storage** also needs to be addressed.
 - **Quality is inconsistent and harsh,** frequently causing a buildup of calcium, magnesium, carbonate and solid matter in sprinkler nozzles. Filters and equipment corrode quickly.
 - **Nutrient levels.** Treated effluent (black) water contains more N and P than scheme or bore water so **measuring nutrient levels is essential** so that fertilizer programs can be adjusted. Too much nutrient is just as bad as too little, with too much plants grow too quickly and more is lost to the environment.
 - Many ornamental plants are more salt-sensitive than turf grasses.
 - Treated effluent water could eventually be used in nurseries but there are concerns about the high nutrient percentages found in compost on vegetables gardens.

Sewer mining is increasingly being used around Australia to supply water to racecourses, golf courses and public gardens. Australia's first large-scale recycling scheme to source wastewater through sewer mining for irrigation and residential non-drinking uses was installed at Sydney's Olympic Park at Homebush Bay, NSW.

Utilizing storm water in verges is coming of age, ie redirecting storm water from street gutters to trees. There can be difficulties in putting it into practice. www.treenet.com.au

Nursery run-off

Significant levels of nutrients can leach from potting media during irrigation of containerised plants, overwatering of plants can be widespread.

- **Concentrations of nitrogen, phosphorus, iron and manganese** in the leachate, in some instances, particularly in the first few weeks after potting up, can regularly exceed water quality guidelines.
- **Nutrient losses are around 60% higher in summer,** due to more frequent and longer irrigation.
- **Recycling irrigation** water increases the risk of spreading some major waterborne root pathogens, *Phytophthora* spp. and *Pythium* spp. which can be present in water from nurseries.
- **Nursery run-off may also contain pesticides.**
- **Seek advice** regarding managing run-off water.

Burning
Check local legislation



Harvesting weed seed management is the No. 1. IWM tool

Burning is a very effective method of destroying contaminated plant material.

- **Local regulations** often restrict or prohibit burning.
- **Adverse effects of burning** include loss of nutrients, smoke contamination of the environment and the addition of carbon dioxide to the atmosphere.
- **The burning of sugar cane crops** prior to harvest is becoming a thing of the past. More than 80% of the nation's sugar crop is now cut green.
- **Trials of burning chrysanthemum crop residues** rather than treating with chemicals to control white rust, *WFT* (eggs laid in ground), red mite and weeds using gas-fired burners at different stages of crop preparation, had varying degrees of success.
- **Biosecurity legislation** may require that host plants are destroyed. Burning may be used in eradication campaigns to remove inoculum of newly introduced diseases to prevent an epidemic developing, eg citrus canker (*Xanthomonas axonopodis* pv. *citri*). As this incurs a great cost to the industry, alternatives are being researched.
- **Sometimes stubble is burnt to control snails and weeds** resulting in loss of stubble. Patchy stubble burning only provides snail survival rate of up to 50% survival. Cabling, rolling and slashing result in up to 90% control and the stubble is retained.
- **Weeds seeds.** Chaff is fed into a chaff cart which is emptied on-the-go at designated dumps located in a line across the paddock.
 - **Within 3 years of introducing the chaff carts**, problem weeds such as annual ryegrass, wild radish, brome grass and wild oats are diminished.
 - **Chaff dumps are burnt in the afternoon.** Dump locations are moved annually as poor crop germination underneath is considered to be due to high concentrations of potash.
 - **Some growers favor windrow burning.** Weeds can be concentrated in narrow harvest windrows, made by fitting a special chute to the rear of the harvester, and then burnt. Higher temperatures are achieved than whole paddock burning, greatly increasing control of a range of weed seeds while leaving most of the paddock with adequate stubble to minimize wind erosion.
 - **Post-emergence herbicide sprays** are still used.
 - **Other questions relate to bailing or feeding chaff to livestock.** About 6% of viable ryegrass seed will pass through the gut of sheep and about 12% through cattle.

Burying crop residues, weeds

Current trends are towards minimum tillage rather than deep ploughing (or burning).

Conservation Tillage
Check benefits page 54

Why bury or plough in residues and weeds?

- **Burying some crop residues** can reduce the level of disease and pest organisms at the commencement of the next season. Plant material and disease and pest organisms are destroyed by soil microorganisms, chemical processes and soil water.
- **Diseased and infested material or weed seeds must not be returned to the soil surface** by cultivation before it has decayed, otherwise the problem may become more severe.
- **Burying may be achieved** either by deep ploughing or burying vertically in soil or in a pit with at least 15 cm of soil on top.
- **Resistant weed seeds.** The mouldboard plough controls weeds by placing weed seeds to a depth from which they cannot emerge. Some weed seeds must be left at a depth for at least **10 years** for them to decay. A one-off inversion of sandy soil with a mouldboard plough every 10 -15 years can quickly decimate a seed bank of resistant weeds.
- **Crop residues can be buried as soon as possible after harvest.** This prevents the build-up of **some** diseased and infested plant material (seek advice).
 - **Diseases only partially controlled** include Sclerotium stem rot (*Sclerotium rolfsii*) which requires a food source near the soil surface and Verticillium wilt (*Verticillium* sp.) of mint (*Mentha* spp.). Plants with shallow root systems could escape infection.
 - **Plant debris which should not be buried** includes fruit infested with codling moth caterpillars and fruit fly maggots unless the pits are specially sealed or fruit has been treated with a recommended insecticide.

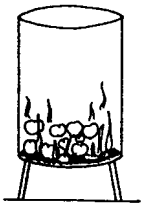
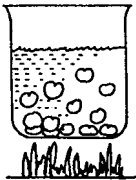
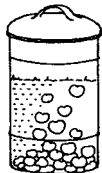
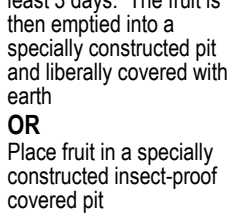

BURNING	BOILING	SOAKING IN WATER	BURYING	OTHERS
Local legislation often restricts or prohibits burning	Boil for at least 10 minutes until maggots and caterpillars are killed	Soak in water topped with kerosene for at least 7 days OR Soak inside a water-tight container for at least 7 days	Burying in specially constructed pits is only permitted after the fruit has been immersed in an approved insecticide for at least 3 days. The fruit is then emptied into a specially constructed pit and liberally covered with earth OR Place fruit in a specially constructed insect-proof covered pit	Secure fruit inside a plastic garbage bag and expose to sun for at least 3 days until the heat inside kills the maggots and caterpillars
				

Fig. 10. Examples of sanitation measures for fruit infested with fruit flies (Tephritidae) and / or codling moth (*Cydia pomonella*). Only practical in a garden situation.

HANDS, EQUIPMENT, CONTAINERS, SOIL

Weed seeds and parts and infected plant material are easily spread on vehicles, machinery, clothes. Diseases, pests and weeds are easily spread in soil and mud adhering to boots, vehicles and machinery.

Decontaminate before entering and exiting

Handling plants

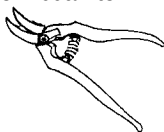


Handle healthy plants and sterilised containers before handling diseased plants, contaminated pots and other items.

- **Wash and disinfect hands** before handling clean planting stock to reduce spread of viruses which may be transmitted on hands, eg orchid viruses and tobacco mosaic virus (TMV) on tomatoes.
- **In many nurseries it is now standard practice** to wash and disinfect hands before commencing propagation activities.
- **Gloves** may be worn when handling propagation materials to prevent re-infection.
- **Soap**, nail brushes, recommended hand disinfectants and paper towels should be available. Soap decreases the surface tension between cells of microorganisms which can have detrimental effects.

Pruning tools

Disinfectants



Using clean secateurs which are never used on more than one plant at a time without disinfection, reduces spread of viruses in a nursery

Some diseases may be spread on pruning tools. A few diseases such as the fungal disease, *Eutypa gummosis* (*Eutypa lata*), **bacterial canker** (*Pseudomonas syringae* pv. *syringae*) of *Prunus* spp. and **bacterial gall** (*Pseudomonas syringae* subsp. *savastanoi* pv. *nerii*) of oleander, can be spread from pruning cut to pruning cut on secateurs, budding knives and other tools. Some **virus diseases** may also be spread on cutting tools. If diseases are present which are spread in this way, pruning tools, as a minimum should be sterilized between each plant.

- **Washing.** If dirty, secateurs, etc tools must be washed thoroughly prior to disinfection.
- **Tools may be sterilized** by dipping in 70% methylated spirit, the 30% water prevents fast evaporation and reduces flammability. Alternatively the blades may be wiped with a cloth moistened with methylated spirit.
- **Other disinfectants** are also available but many involve soaking the secateurs for a specified period of time. If these are used, it is important that this time be adhered to; otherwise the sterilization process is not effective.
- **It may be necessary to rinse the tools with clean water** after sterilization as some disinfectants may cause plant damage.

Storage bins, packing sheds



Careful picking and handling of perishable crops and **proper hygiene** in packing sheds effectively reduces the incidence of some postharvest diseases.

- **Postharvest fungi** may overwinter in fruit bins and packing sheds.
- **By washing produce**, containers, bins and the walls of storage houses, the amount of inoculum and infection may be reduced or contained.
- **With a lower incidence of disease**, there is a lower chance of resistant strains being selected.
- **Weed seeds** may re-contaminate open-stored potting mix ingredients.
- **Uncleaned grain headers** are a source of insect contamination entering bulk grain storages.
- **Crops infested with insect pests or infected with diseases** may introduce these problems to storage areas.
- **Soil or components of potting mix must be stored under cover** until used to prevent contamination by airborne weed seeds, diseases and pests.

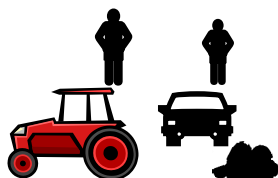
Shoes, boots



Soil adhering to shoes or boots may carry damping-off and other soilborne diseases.

- **Shoe baths** at the entrance to glasshouses and other 'clean' areas are used to disinfect shoes preventing spread of soil diseases to clean areas.
- **Biosecurity** has **cleaning protocols** for boots of visitors to properties.
- **Phytophthora Dieback Boot Cleaning Station.** In WA dieback (*Phytophthora cinnamomi*) is one of the biggest threats to biodiversity. The **Phyto Fighter 1000** is an ingenious wash-down station which aims to stop dieback from being brought into clean areas of bush and forest on hikers' boots. It provides a convenient scrubbing mat and a hand-powered squirt of disinfectant that cleans the walker's boots of any mud and kills the introduced *Phytophthora* dieback.
- **Other soil diseases, weed seeds and pests** can also be spread in soil attached to boots.

Movement of staff, plants and machinery



Restrict movement of staff, machinery and plants between propagation and production areas.

- **Restrict movement of workers and machinery from infected to disease-free crops** particularly when wet.
- **The color of clothes** can also affect spread of insects and insect vectors. **Yellow clothes** attract whiteflies and many other insects, both **yellow** and **blue clothes** attract thrips (pages 234, 247). It may be necessary to **brush insects from clothing** before entering 'clean' areas.
- It may be necessary to **drive cleaned vehicles** through 'disinfectant baths'. **In WA, vehicles** which may be contaminated with dieback (*Phytophthora cinnamomi*), must pass through disinfecting ponds on entering quarantine areas.

Containers



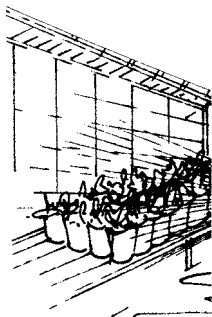
Phytophthora can be spread in soil in containers

New containers are considered to be '**clean**' provided they have not been stored in contact with soil or used containers. They should be stored in unopened cartons on shelves in a covered area prior to use.

Re-using containers may be uneconomical. It may be possible to re-use only some sizes and types.

- **Diseases and pests** associated with containers:
 - **Disease organisms** will rapidly multiply in '**dirty**' pots which have not been effectively disinfected and will infect successive batches of plants.
 - **Soilborne insects**, eg root mealybugs (*Rhizoecus falcifer*), are also spread from pot to pot in re-used pots.
 - **Fungal spores and most insect eggs and pupae** stick to the surface of pots where they are shielded by any remaining media. Once the media and any fungi present dry out they are very difficult to remove.
- **Identify** the diseases or pests problems associated with your particular crop.
- **Decide** if treatment is required.
- **Washing containers.**
 - Porous surfaces can be virtually impossible to disinfect in commercial operations. Dirty surfaces are harder to disinfect than washed surfaces.
 - Those to be re-used should be cleaned thoroughly with warm water and detergent prior to sterilizing. Washing may be all that is considered necessary, depending on the intended uses of the containers. Pot washing machines are available.
- **Some containers can be pasteurized** using steam.
- **Containers may also be disinfected** using bleach or other product. Label directions for use must be followed.
 - **Equipment** used for dipping or soaking containers and for measuring the disinfectant must be appropriately labeled.
 - **Sterilizing times must be adhered to.** It may be necessary to rinse containers after treatment prior to use to avoid plant damage.

Trolleys, machinery benches, floors, walls



Trolleys, vehicles, benches, floors can all become contaminated

- **Soil on equipment, etc.** Many diseases such as *Phytophthora*, *Rhizoctonia* and other damping off diseases, nematodes and crown gall are spread in soil. Washing off soil from trolleys and other equipment after working in diseased crops and before moving them to '**clean**' areas, can help to reduce the spread of such diseases. Sand heaters and capillary beds must be sterilized regularly. Washing and disinfecting floors, benches and lower walls also reduces infection sources and this is now standard practice in most large nurseries.
- **High pressure cleaners** are available for washing equipment, machines and vehicles and the regular cleaning of glasshouse floors, walls and benches. They may use cold, hot water or steam. Low toxicity cleaning detergents which do not damage plants are available for use. Pressure cleaners require extra care in their use to prevent injury to the operator and adjacent persons, glass structures and plants. Water consumption is reduced by up to 80% when compared with using an ordinary round garden hose.
- **Disinfectants are available for use in glasshouses.** Contact with plants must be avoided.
- **Greenhouses can be completely emptied** between crops, cleaned and sterilized if necessary.



Disinfectants

Some disinfectants are registered as pesticides

- **Wash** containers and equipment to remove soil and plant debris prior to disinfection.
- **Check that the disinfectant you propose to use is effective** against the disease or pest you want to control.
- **Make sure that the recommended sterilizing time** is adhered to. Research has shown that generally, when only short time intervals are involved, there is a wide variation in effectiveness.
- **Some disinfectants** may cause plant damage.
- Follow **label directions for use** and **safety directions.**
- **Sanitizers** for fresh fruit and vegetables are available.
- **Some disinfectants are deactivated** when contaminated with organic matter. Solutions should be changed regularly to ensure that disinfectant efficacy is maintained.

MOWERS, HARVESTERS, BRUSHCUTTERS

Weed seeds and parts and infected plant material are easily spread on vehicles, machinery, clothes. Diseases, pests and weeds are easily spread in soil and mud adhering to boots, vehicles and machinery. **Decontaminate before entering and exiting**

<p>Mowers in urban areas - weeds</p> 	<p>Machinery Guidelines for Roadside Managers are available online in most jurisdictions and some are available for specific weeds, eg Chilean Needle Grass. They include:</p> <ul style="list-style-type: none"> • Clean down areas. • Minimizing soil disturbance. • Clean down procedures. • Clean down types, eg manual on site, blowers, wash bays, portable facilities. • Clean down techniques, eg wash down, physical, compressed air and vacuuming.
<p>Machinery and vehicles, on-farm biosecurity weeds, pests and diseases</p>	<p>Procedures for inspecting and cleaning machinery between farms are available on the Biosecurity website. To help producers manage vehicle and equipment biosecurity on farms, the NSW Department of Primary Industries has prepared a handbook in the AgGuide series, Machinery hygiene: Inspecting and cleaning machinery to prevent the spread of weeds, pests and diseases. 2013. This book is about inspecting and cleaning machinery that may contribute to the spread of weeds, pests or diseases and includes:</p> <ul style="list-style-type: none"> • How weeds, diseases and insects are spread by machinery. • Inspection of machinery and support vehicles. • Identifying and reporting unusual weeds, diseases or pests. • Sampling procedures. • Cleaning machinery and support vehicles. • Disposing of contaminated soil and plant matter. • Preventing / controlling weeds, pests and diseases. • Keeping vehicle cleaning records. • Signage.  <p>Biosecurity farm fence sign. Photo©Plant Health Australia.</p> <p>The WeedStop Vehicle Hygiene Program offers training in the fundamentals of hygiene practice. This will raise the number of consultants with WeedStop accreditation in the industry and promote the principles of on-farm biosecurity and accountability.</p>
<p>Grape harvesters spread Phylloxera</p> <p>Designated zones Permit needed</p>	<p>In some vineyards the symptoms of phylloxera may not be recognized for 3-5 years after infestation, so phylloxera can be unwittingly spread to other vineyards unless good cleaning and hygiene procedures are followed.</p> <ul style="list-style-type: none"> • Phylloxera can be present in the grapevine canopy during the harvest period and lodge within machines, transported to other vineyards if machines are not cleaned. • Mechanical harvesters can spread phylloxera and other pests, diseases and weeds. All operators need to ensure they comply with regulations and follow good hygiene practices in order to minimize potential biosecurity risks. <ul style="list-style-type: none"> • Grape growers should inspect any harvesting machines as they arrive at their property to ensure sure they are clean and accompanied by a permit before commencing harvesting. • To avoid the potential transfer of phylloxera or other unwanted pests, diseases or weeds onto other vineyards, grape harvesters can only move between vineyards within designated zones accompanied by a permit. There are penalties for not following regulations.
<p>Seed Destroyers Reducing the weed seedbank</p>	<p>The Harrington Weed Seed Destructor (HWSD) and the later Integrated Weed Destructor (IWD) destroy the weed seeds contained in harvested chaff, reducing weed populations. Field trials by the WA Herbicide Resistance Initiative demonstrated little residual viable weed seed after treatment (see page 236).</p> <ul style="list-style-type: none"> • Seed destructors have a valuable role in IWM management, they: <ul style="list-style-type: none"> • Lower the weed seed bank, • Delay the onset of herbicide resistance, and • Aid in the management of herbicide-resistant weed populations.
<p>Brushcutters</p>	<p>Brushcutters are an efficient means of controlling scattered tall weeds and small patches of annual weeds preventing seed set; they are often used in conjunction with herbicide applications.</p> <ul style="list-style-type: none"> • Brushcutters and their attachments are constantly being improved, eg replaceable cords, easily replaceable flexible nylon blades and heavy duty steel blades and articulated blades each with its own advantages. The breakage and rapid wear common to nylon cord has been eliminated and blade replacement can be carried out in seconds.
<p>Others</p>	<p>Mechanical harvesters remove large amounts of water hyacinth (<i>Eichhornia crassipes</i>) in aquatic areas. Some machines can mechanically mow around fruit trees, vines, etc. The “Tournesol” is a new Pellenc rotary blade tool which works both sides of a tractor and up to the tree trunk; it should be ideal for growers wishing to reduce herbicide use.</p>

MANAGING SANITATION

Sanitation, like cultural methods is one of the central components of nearly all management strategies, eg Integrated Pest Management, biosecurity, environmental management, organic standards, Best Management Practice, Quality Assurance programs, etc. A few examples follow.

Orchard Biosecurity Manual for the Cherry Industry (Biosecurity Best Practice)

HIGH HEALTH
VIRUS-TESTED
ELITE STOCK



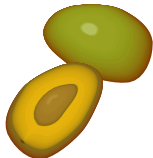
Exotic Plant Pest
Hotline
1800 084 881

Six easy ways you can reduce the threat of new pests impacting on your orchard. They reduce the risk of spreading pests, diseases and weeds. Each practice should be embedded in your orchard's everyday management.

1. **Be aware of biosecurity threats.** Make sure you and your orchard workers are familiar with the most important exotic cherry pest threats. Conduct a biosecurity induction session to explain required hygiene practices for people, equipment and vehicles in your orchard.
2. **Use pest-free propagation material.** Ensure all propagation material is from trusted sources and orchard inputs are fully tested, pest-free and preferably certified. Keep good records of your orchard inputs.
3. **Keep it clean.** Practicing good sanitation and hygiene will help prevent the entry and movement of pests onto your property. Workers, visitors, vehicles and equipment can spread pests, so make sure they are decontaminated before entering and leaving your property. Have a designated visitor's area and provide vehicle and personnel wash-down facilities.
4. **Check your orchard.** Monitor your trees and fruit frequently for early detection of any exotic plant pest threat. Knowing the usual appearance of your orchard and trees will help you recognise new or unusual events and pests. Keep written and photographic records of all unusual observations.
5. **Abide by the law.** Respect and be aware of laws and regulations established to protect the cherry industry, Australian agriculture and your region.
6. **Report anything unusual.** If you suspect a new pest – report it immediately to the Exotic Plant Pest Hotline. 1800 084 881



Orchard Biosecurity Manual for the Mango Industry



Steps in the Orchard Biosecurity Manual for the Mango Industry include:


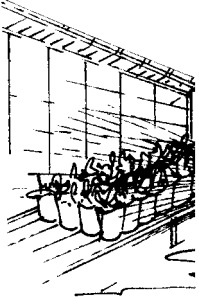

- **Check the origin of material** coming on or going off your property to assess it for the risk of disease or insects.
- **Use certified "free from pests"** seed or propagation material and use trusted suppliers.
- **Do not bring agricultural equipment** onto your property without ensuring it is **clean and free from soil, seeds and other contaminants.**
- **Do not bring plant material** (including seeds) from overseas without appropriate permits from biosecurity.
- **Apply high standards of personal cleanliness and disinfection** if handling suspect plant material or soil.
- **Where possible create a "buffer zone"** with your neighbor through measures such as double fencing and wind breaks.
- **Limit visitors** to your plants, crops and livestock.





Kauri dieback disease in NZ



About 27 km of popular walking tracks in the Waitakere Ranges will be closed in a bid to halt the spread of Kauri dieback disease (*Phytophthora taxon Agathis*) (**PTA**) (Thomson 2012).

- **Kauri dieback ID Field Guide 2010.** PTA was identified as a new disease of kauri in 2008. The disease is specific to kauri and spreads in soil, water, etc. Make sure shoes, tyres and equipment are clean of dirt before and after visiting kauri forest.
- **Officials have reported higher incidence** of kauri dieback in areas more often visited by walkers and survey work showed the need for more extensive measures to protect healthy kauri than the present **boot disinfection stations.** About 8 protection zones have been proposed to be reviewed in a year when scientists have learned more about the disease and its possible control measures.
- **Formation of protection zones** around unaffected kauri in the dense forest west of Auckland City has been requested by Auckland's City Council.
- **Clean shoes and any other equipment** that comes into contact with soil after every visit, especially if moving between bush tracks at all times. Any movement of soil around roots of a tree has the potential to spread disease.
- **Keep your dog** on a leash at all times. Dogs can inadvertently spread the disease if they disturb the soil around trees.
- **At this stage there is no plans to close parks** and recreation or reserves but it may have to be considered in the future. There is a **Kauri Dieback Response Team.**

<p>Removal of streets trees in Canberra</p>	<p>In 2011, 200 Eucalypt trees and other species infected with a wood rot fungus (<i>Phelinus</i> sp.) were removed from Northbourne Avenue, the main route into Canberra to preserve Canberra's green public spaces and protect motorists from falling branches (Cook 2011).</p> <ul style="list-style-type: none"> • Symptoms included knobby brown fruiting bodies of the fungus on the main trunks, dead leaves and sparse upper branches. • Equipment was sterilized to prevent it from spreading to the remaining 4,300 trees.
<p>Nursery Industry Accreditation Scheme Australia (NIASA)</p>	<p>The NIASA Best Management Practice Guidelines contain full colour photographs of "Best Practice" in production nurseries and growing media supplier businesses. They include:</p> <p>Water Management Best Practice Guidelines. Hygiene in propagation.</p>
<p>Greenhouse biosecurity</p>  <p>Hygiene</p> 	<p>Sanitation practices are very important in greenhouses.</p> <ol style="list-style-type: none"> 1. Abide by the law and support regulations protecting your industry. Check the nursery accreditations scheme manual in Australia and websites for up-to-date legislation. 2. Training and monitor training. Train everyone and follow up with refresher sessions. Monitor procedures and processes regularly, adjust them as needed. 3. Check / monitor your plants or crops routinely for pests and diseases. You should be able to identify the usual pests and diseases. Knowing the usual appearance of your crop will help you recognize anything new or unusual to ensure early detection and correct identification of problems. 4. Report anything unusual. If you suspect a new pest or see anything unusual, report it immediately to the EXOTIC PEST HOTLINE 1800 084 881. 5. Clean and disinfect the greenhouse. Before planting a new crop, remove everything from the production cycle, all debris, disinfest and bring in clean media, pots and plants and water. Keep algae at bay by avoiding standing water and scrubbing floors regularly to reduce algae-eating fungus gnats and shore flies. 6. Ensure seed and other farm inputs are fully tested, pest-free and preferably certified. Check the origin of material. All seedlings must be checked and found free from pests and diseases before they are planted out into a clean greenhouse. Keep records of your farm inputs. 7. Biosecurity. Isolate and separate disease-sensitive crops. Keep crops as separate as possible, keep workflow under control with single entrances to greenhouses, team employees with specific greenhouses and crops to keep the spread of disease to a minimum. Scout crops regularly. 8. Decision-making. Check information that is used for all decision-making including chemical, biological, whole crop and hot spot treatments.
<p>Contractors, fertilizer delivery, loading grain</p> 	<p>In WA, Biosecurity and GrainGuard go hand in hand to boost WA's biosecurity surveillance and emergency response capabilities with the primary purpose of identifying threats from endemic and exotic sources and to assess potential impacts to the local grains industry.</p> <ul style="list-style-type: none"> • People are much more mobile now and this increases the chances of spreading certain types of pests, diseases and weeds. You just have to set up everyday practices that reduce the risk to your property. Controlling weeds is the main day-to-day biosecurity threat, eg herbicide-resistant ryegrass and radish. Monitor surrounding areas for any new weeds sown by passing traffic. • Depending on the season, look out for any pest or disease symptoms, eg aphids, fungal diseases arising from late spring rains. • Other practices to reduce risk includes making sure that contractors coming on to the farm have cleaned their machines; making sure that trucks delivering fertilizer or feed and loading grain are properly cleaned before entering paddocks.
<p>Grain storage insects</p> <p>AUSTRALIAN STANDARD</p>	<p>There is too much grain left around silos and so most farms have a problem with storage insect pests, a bit like the flour moth in domestic kitchens. There are many steps in the process for keeping grain pest-free, but a starting point is:</p> <ul style="list-style-type: none"> • Removing residual grain from the base of silos to prevent unwanted insect pest incursions. Any spilled grain, weeds, rocks and other rubbish from the storage area must be removed. • Silo hygiene. GRDC runs on-farm workshops to facilitate better knowledge of silo hygiene, pressure testing and seal replacement. Silo manufacturers are improving factory sealing of silos with the introduction of the new Australian Standard: <p>AS 2628-2010. Sealed grain-storage silos - Sealing requirements for Insect Control</p> <ul style="list-style-type: none"> • A benchmark is now in place that buyers can refer to when buying silos; before buying ask manufacturers to perform a test run that the silo can be sealed on-farm. • The new standard ensures that gas-tight silos will slow down the development of phosphine resistance among grain storage pests and preserve grain quality.

<p>Best Practice washing fresh vegetables postharvest</p> <p>2</p>	<p>Growers generally recognize that a washing step can enhance the market quality of many fresh vegetables. Sanitizers are used to minimize the populations of microbes which could either cause food spoilage or be a health risk to humans. Sanitizers are effective in destroying up to 99% of harmful bacteria on fresh produce and most microbes in wash water. Best practice in the washing of vegetables and tomatoes includes:</p> <ul style="list-style-type: none"> • Knowing the principles and practices of effective disinfection. • Checking the comparative effectiveness, safety and registration of sanitizers. • Realizing that the performance of washing systems depends on the quality of the supply water. • Maintaining the temperature, pH and organic load of their water treatments, especially when contamination can occur from dirty water supplies or in recirculated systems. Analytical probes, thermostats, pH buffer and filtration aids can be used to enhance water quality. • Using appropriate methods for safe disposal of used sanitizers.
<p>Verge plantings, community gardens</p>	<p>Utilization of nature strips and other verge planting has taken off in recent years, particularly with the involvement of children. Concerns have been raised in relation to:</p> <ul style="list-style-type: none"> • Hygiene of vegetable verges to which dogs and cats have access. • Permissions. Check with your local council for their policies on nature strips, etc. • Verge plantings must be maintained appropriately after planting. • The Australian City Farms and Community Garden Network (ACFCGN) is an informal, community-based organization linking people interested in community gardening from around Australia. www.communitygarden.org.au • Many articles are available online, eg <i>Farmers of the Urban Footpaths: Design Guidelines for Street Verge Gardens</i> (Gray 2010).
<p>City rooftop farms</p> 	<p>Food waste from restaurants and commercial kitchens could be used to grow fresh vegetables in both high density urban environments and remote rural areas with poor soil and low rainfall.</p> <ul style="list-style-type: none"> • Although vermiculture (worm farms) and hydroponics technologies and other systems already exist, it is generally considered that the combined systems are several years away from being adopted on a large scale. • Potential stumbling blocks include: <ul style="list-style-type: none"> • Collecting the organic waste. • Distributing it to individual vermiculture and hydroponic set-ups. • Sanitation, dumping, etc. Could have the same problems as charity bins.
<p>Cotton hygiene Soilborne diseases</p> 	<p>Hygiene key to soil disease containment of disease in cotton, eg</p> <ul style="list-style-type: none"> • Black root rot (<i>Thielaviopsis basicola</i>) and <i>Fusarium</i> spread have been slowed down by the growing of varieties with some resistance to <i>Fusarium</i>, resulting in populations taking longer to build up. Many farms still do not have either of these diseases. <ul style="list-style-type: none"> • Both diseases are easily spread in soil and mud adhering to boots, vehicles and machinery and the best way to slow spread is to try and minimize movement of soil. • Seek advice regarding the protocols for cleaning machinery. • Spread is most likely in soil from other cotton properties. • Hygiene will not guarantee that you will never get those diseases on your farm. <ul style="list-style-type: none"> • It is probably impossible to stop spread within your farm given the amount of machinery movement. • But it is possible to slow it down. If you have new block, prevent introducing large amounts of soil.
<p>Fruit-tree borers</p>  <p>Tree split longitudinally to show internal damage. Tunnel is only about 10 cm long. NSW Photo©Dept. of Industry & Investment.</p>	<p>The fruit-tree borer (<i>Maroga melanostigma</i>) is a pest of various species of fruit and ornamental trees. It can cause economic damage to prunes and other species.</p> <ul style="list-style-type: none"> • On smaller trees where infested areas are accessible, the loose bark and debris can be removed and any larvae found destroyed. • If any holes are present, they can be probed with a length of flexible wire to kill the larvae. The tunnels are short only 8-10cm deep. • Trees should be fertilized and watered appropriately. • Research into the biocontrol of this pest using nematodes or <i>Trichogramma</i> wasps has been inconclusive. • Neglected infested trees act as a source of moths which can then lay eggs on healthy trees.  <p>Larval damage to a trunk. Photo©NSW Dept. of Industry & Investment.</p>

On-farm Biosecurity



Exotic Plant Pest Hotline
1800 084 881
 Report an unusual pest, disease or weed

The 6 steps of On-farm Biosecurity to limit risk:

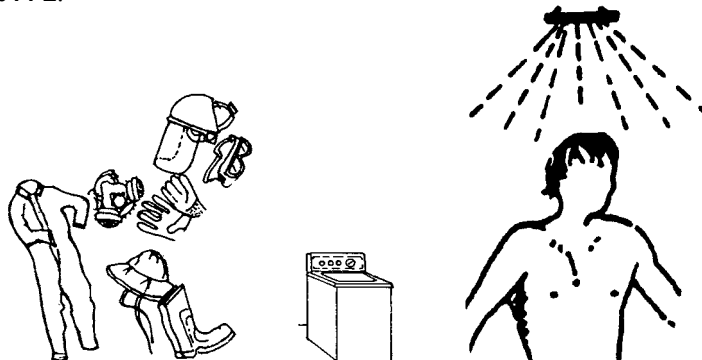
1. **Be aware of biosecurity threats on your property.** Make sure you and your workers and contractors are familiar with the most important grain pest threats. Conduct a biosecurity induction session on your farm to explain hygiene practices for people equipment and vehicles on your property.
2. **Ensure seed is pest-free and preferably certified.** Ensure all seed and other farm inputs are fully tested, pest-free and preferably certified. Keep records of farm inputs.
3. **Keep it clean.** Practice **good sanitation and hygiene** to help prevent the entry and movement of pests onto your property. Workers, visitor vehicles and equipment can spread pests, so ensure they are decontaminated before they enter and leave the farm. Have a designated visitor area; provide vehicle and personnel disinfecting facilities.
4. **Check your crop.** Monitor your crop frequently for early detection of any exotic plant pest threat, knowing the usual appearance of your crop will help you recognize anything new or unusual. Keep written and photographic records of unusual observations.
5. **Abide by the law.** Support and be aware of laws and regulations established to protect the grains industry, Australian agriculture and your region.
6. **Report anything unusual.** If you suspect a new pest or see anything unusual, report it immediately to the **EXOTIC PEST HOTLINE 1800 084 881.**



Biosecurity farm sign. Photo©Plant Health Australia.

Personnel Protective Equipment (PPE) and personnel

Commercial applicators must follow protocols for cleaning and maintaining PPE after each use, including having a shower. Home gardeners and volunteers often don't have appropriate PPE.



PROS, CONS & CHALLENGES

PROS

- **Sanitation** is a powerful control tool for some diseases, eg soilborne fungal infections.
- It is also important for farm, orchard or nursery biosecurity.
- Sanitation is an important **method of control** in **IPM** and **BMP** programs, eg in nursery accreditation schemes, but can be overlooked by growers.
- Sanitation can **reduce reliance on chemicals** in nurseries and storage areas.
- Some measures are prescribed by **legislation**.
- Usually **compatible** with other control methods.
- Usually **preventative**.
- **May be non-polluting**, eg burying rather than spraying.
- **May be practical**. If a crop is very valuable or the level of infection is low, in small gardens where labor is cheap or the cost of labor is not important.

CONS

- Know the **limitations** of hygiene procedures.
- Sanitation practices require **knowledge** of disease, pest and weed life cycles so that growers can understand how and when the cycle can be broken.
- Some sanitation practices are **labor intensive** and therefore expensive, especially with large plantings.
- **Rogueing is only worthwhile** if the crop has a high economic value, disease symptoms are conspicuous and the disease can only spread to a limited extent.
- Sanitation does not usually provide **100%** control, so:
 - May not satisfy customer or biosecurity requirements.
 - May need to be used in conjunction with other control methods, eg pesticides.
- Burning plant debris in the open causes **pollution**.
- Benefits are often **hidden** and mostly impossible to quantify or estimate the costs/benefits.
- Digging out perennial weeds with underground tuber or “nut” like *Cyperus esculentus* and *C. rotundus* can be unrewarding unless all underground tubers are removed. Even the very small ones will resprout and start the nightmare all over again. Do not compost. Even if herbicides are used several applications may be necessary.
- Check the warning notices on some products, eg composts.

CHALLENGES

- Convincing persons that sanitation is necessary and does work and is **worth doing**. Hygiene should be routine.
- Knowledge of plants is needed, eg you need to know what plants to pull out in revegetation projects, eg which species of willow need to be removed and which can be kept and why.
- Knowledge of a pest, disease or weed’s life cycle is needed so that sanitation measures can be carried out at the correct time.
- Hygiene is a cheap way to improve efficiency in a propagation unit but if it is to work, managers must be convinced that it is necessary and willing to ensure it is maintained.
- Open to people error like other control methods, people get slack, etc.
- How can you ensure that **hygiene practices** such as disinfecting boots when visiting and leaving commercial properties are actually carried out by visitors, other growers and consultants? A recent survey (2012) claimed that only 55 per cent ensured that footwear and equipment was disinfected and free from foreign matter. The visitors to the farm, other growers and consultants had a high level of knowledge of the threats faced by the grains industry but a low adherence to biosecurity practices that prevent the establishment and spread of any new pest or disease. Plant Health Australia has produced a Grains Farm Biosecurity Manual which explains the practices that farmers should carry out to reduce their biosecurity risks. Training in the fundamentals of hygiene practice has been offered by the WeedStop training group.
- Many motorists stopped at Fruit Fly Road Checks are found to be carrying fruit.
- A recent review of current knowledge of hygiene procedures for the control of plant pathogens showed that chemical fumigation and heat treatments are still the most reliable methods for the control of all plant pathogens. Chemical disinfectants only appear to be effective on a far narrower range of pathogens and more work on their use is required. New Best Practice protocols based on the review and featuring the use of double treatments have been developed.

REVIEW QUESTIONS & ACTIVITIES

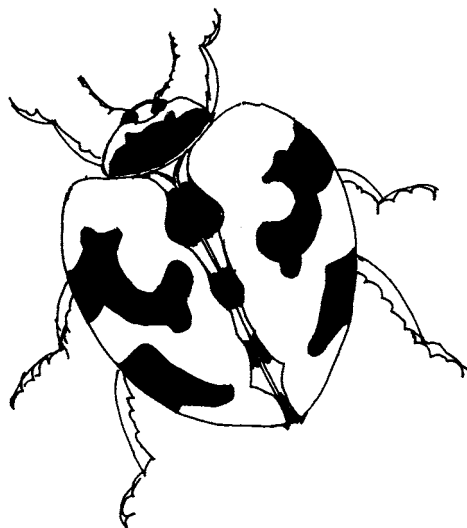
1. Explain the **meaning of sanitation**.
2. Describe in detail, **3 ways of disposing** of diseased / infested plant material.
3. Describe the local sanitation measures required by **legislation** to control fruit fly, codling moth or other local pests.
4. Describe 3 examples of diseases and / or pests partially controlled by **pruning**, and indicate when the pruning should be carried out.
5. Name 2 problems of trees and shrubs and 2 problems of indoor plants which may be so difficult to control that **removal and destruction of affected plants** may be recommended.
6. Name 1 disease that can be **transmitted by handling** and 1 that can be **transmitted on pruning tools**.
7. Describe **sanitation methods** that could be used in **Nursery Accreditation Schemes** and **Biosecurity**.
8. Explain the **advantages and disadvantages** of using sanitation methods for pest, disease or weed control.
9. Perform **practical exercises** in pest, disease or weed control using sanitation.
10. Describe 1 sanitation measure which contributes to controlling **4** of the following:

Tobacco mosaic	Weed seeds in a paddock
Chilean needle grass	Powdery mildew (apple)
Virus diseases (bulbs)	Wood rot
Grain storage pests	<i>Botrytis</i> (indoor plants)
Bacterial canker (stone fruit)	Borers (wattles)
Bacterial gall (oleander)	Citrus gall wasp
Crown gall (roses)	Codling moth
Brown rot (stone fruit)	Fruit fly
Damping off (seedlings)	Oriental fruit moth
<i>Phytophthora</i> root rot in containers	

SELECTED RESOURCES

- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- Australian Standards.
AS 3743 – 2003. *Potting mixes*.
AS 4454 – 2012. *Composts, soil conditioners and mulches*.
AS 4419 – 2003. *Soils for landscaping and garden use*.
- Baxter, N. 2010. *The Answer is “Blown” in the Wind*. Ground Cover May-June.
- Brown, J. F. and Ogle, H. J. (eds). 1997. *Plant Pathogens and Plant Diseases*. Rockvale Publications, Armidale, NSW.
- Cook, H. 2011. *Fungus-infected Trees to be Removed*. Canberra Times 16/7/2011.
- Creek, A. and Hardy, S. 2010. *Citrus Gall Wasp*. PrimeFacts. DPI, NSW.
- Gray, R. 2010. *Farmers of the Urban Footpaths: Design Guidelines for Street Verge Gardens*. Online.
- GRDC. 2010. *Recycled Organic Fertilizer*. Fact sheet May.
- Handreck, K. A. *Composting*. 1994. Discovering Soils Series, CSIRO, Melbourne.
- Handreck, K. A. and Black, N. D. 2010. *Growing Media for Ornamental Plants and Turf*. 4th Ed. NSW University Press, Sydney.
- Jarwal, S., Boland, A., Stevens, D. Faggian, R. 2006. *Using Recycled Water in Horticulture: A Growers Guide*. Vic. DPI.
- Leonard, E. 2011. *Harvest Weeds Kill Experience Shared*. Ground Cover. Nov-Dec.
- Lintz, H.E., Huso, M., Stanley, K.C., and Taylor, T. 2011. *Composting One Invasive Species to Control Another*. Restoration Ecology 19 (1) Jan.
- Moran, J. 2012. *Experts Drop Guard on Biosecurity Issues*. Weekly Times, Melbourne 20/3/2012. www.farmbiosecurity.com.au
- Nursery & Garden Industry Australia (NGIA). *Handbook of Major Pests and Diseases of Nursery plants* (2nd ed). Covers the major pests and diseases responsible for probably 90% of the losses in the nursery industry.
- NGIA. 2003. *Designing a Nursery Reed Bed*. The Nursery papers (NGIA). Issue No. 2003/07.
- NGIA. 2004. *Hygiene in Propagation*. NGIA Technical Papers 2004. Issue No 11.
- Nursery Industry Accreditation Scheme Australia (NIASA). *Best Management Practice Guidelines*. cur. ed. NIASA, Sydney.
- Smith, C., van Klinken, R. D., Seabrook, L. and McAlpine, C. 2012. *Estimating the Influence of Land Management Change on Weed Invasion Potential using Expert Knowledge*. Diversity and Distributions, 18: 818–831.
- Thompson, W. 2012. *Tracks Being Closed to Halt Kauri Disease*. 14 May 2012. NZ Herald, Auckland.
- Walsh, M. and Powles, S. 2012. *Harvest Weed Seed Control*. Australian Herbicide Resistance Initiative, UWA.
- State / Territory Departments of Agriculture / Primary Industry Fact Sheets and other leaflets** are available online
- Plant Health Australia** www.planthealthaustralia.com.au/
Industry Biosecurity Plans, eg *Nursery & Garden Industry: Threat Specific Contingency Plan - Aphid transmitted viruses*.
Industry Biosecurity Grower Manuals, eg *Almond, Apple & pear, Avocado, Banana, Bundaberg Horticultural Farms, Cherry, Citrus, Cotton, Honeybee industry, Mango, Northern Adelaide Plains Vegetable Growers, Nursery production, Summer fruit, Vegetable industry, Viticulture*

BIOLOGICAL CONTROL



INTRODUCTION	84
What is biological control (biocontrol)?	84
Techniques of biological control	86
Legislation	87
IT, communication and biotechnology	88
RABBITS AND OTHER VERTEBRATE PESTS	89
WEEDS	91
Classical biological control	91
Bioherbicides	91
Allelopathy and weeds	93
Contraceptive for weeds	93
Biological control of weeds (Table)	94
INSECTS AND ALLIED PESTS	98
By other insects and mites	98
Bioinsecticides	99
Vertebrates	100
Pheromones	101
Sterile insect technique (SIT)	103
Companion planting	104
Pest-suppressive crops and landscapes	106
Biological control of Insects and allied pests (Table)	108
PLANT DISEASES AND ABIOTIC FACTORS	112
Biofungicides	112
Predators and parasites (hyperparasites)	113
Competition for food and space	114
Direct toxic effects	115
Indirect toxic effects	115
Symbiotic organisms	116
Non-symbiotic organisms	118
Physical means	119
Inoculant standards	119
Disease-suppressive soils	120
Biological control of diseases (Table)	122
EFFECTIVE BIOLOGICAL CONTROL	125
Diagnostics	126
Microclimates and natural enemies - Triangles	127
Using chemicals with beneficials	130
MANAGING BIOCONTROL METHODS	131
PROS, CONS AND CHALLENGES	134
REVIEW QUESTIONS AND ACTIVITIES	135
SELECTED RESOURCES	135

INTRODUCTION

What is biological control (biocontrol)?

Since ancient times, Chinese citrus growers have placed nests of predacious ants in mandarin orange trees to feed on the insects which damaged the leaves. Interconnecting bamboo rods as bridges were installed to help the ants to travel from tree to tree.

Biological control is particularly important because of the advantages that '**clean and green**' produce confers upon our export and domestic markets. It offers the only long-term sustainable control method for some pests, diseases and weeds.

Natural control

Biocontrol is part of the overall phenomenon of natural control. For example, the numbers of eggs, caterpillars, pupae and adults of the cabbage white butterfly are controlled in nature by numerous natural enemies, including insect predators and parasites, birds and diseases. The weather, availability of host plants and other factors also influence pest numbers:

NATURAL ENEMIES include:

Insects and allied pests, eg

Parasites, eg wasps

Predators, eg bugs

Vertebrate pests, eg

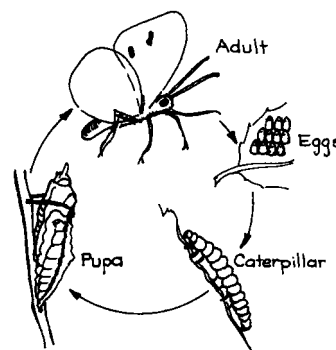
Birds

Diseases, eg

Virus diseases

Bacterial diseases

Fungal diseases



OTHER FACTORS, eg

Weather

Food supply

Space requirements

Natural enemies of the cabbage white butterfly (*Pieris rapae*).

Other examples of natural enemies include:

Mallow weed

Aphids

Twospotted mite

- Flea beetles, a rust disease.

- Predatory ladybirds, lacewings, hoverflies and earwigs.

- Parasitic wasps, fungal diseases.

- Predatory beetles and mites.

Remember, that each of the natural enemies has its own entourage of natural enemies and other controlling conditions which may affect the success of a biocontrol program.

Definition of biological control

Biological control, has over the years, been defined in many different ways depending on whether it has been referring to weeds, insects or diseases.

- **With the development of new techniques**, the process and definition of biological control is becoming ever more complicated. It is for this reason the order of study of biological control starts with the:
 - Simpler examples of vertebrate pests and weeds, followed by,
 - Insects and allied pests and finally,
 - Diseases which are more complicated.
- **Most of the species that we consider plant pests** have invaded a new habitat without being accompanied by the natural enemies that kept them in check in their original home land.
- **It is useful, though, to have a definition** which describes classical biological control.

CLASSICAL BIOLOGICAL CONTROL is the deliberate use of a pest, disease or weed's natural enemies to control that particular pest, disease or weed.

Pests, diseases and weeds

It depends on whether the problem is a:

- **A native pest, disease or weed** that already possesses its complement of natural enemies where there is some scope for their manipulation.
- **An introduced pest, disease or weed** that has usually gained a foothold in Australia without its natural enemies. An opportunity therefore exists for its control biologically by importing one or several of its natural enemies.

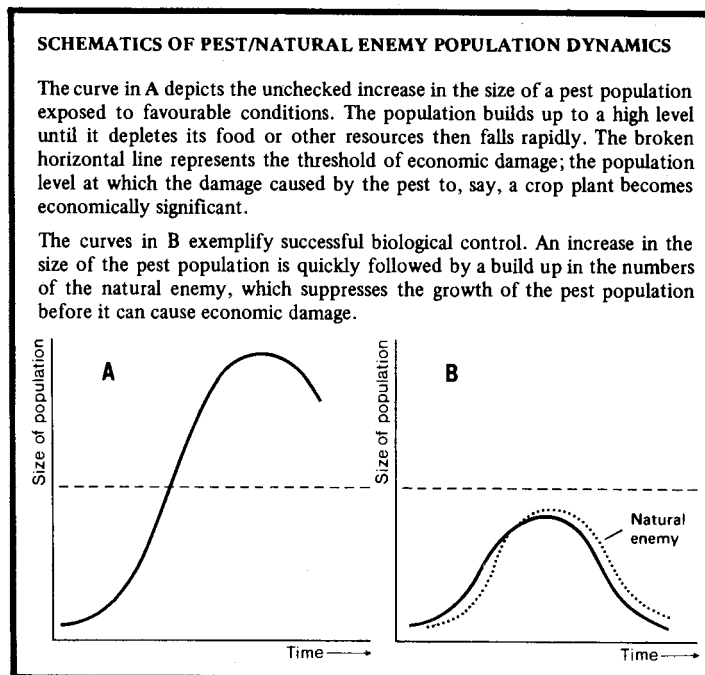


Rust (*Puccinia chondrillina*) was introduced to control skeleton weed which is native to Mediterranean Europe and the Middle East. Photo©CSIRO.

Target pest, disease or weed is not eliminated

Biological control does not usually eliminate the target pest, disease or weed.

- **If the natural enemy eliminates** the pest, disease or weed, it may in turn be eliminated.
- **If the pest, disease or weed should then return**, it could be very destructive because of the absence of natural enemies.
- **For these reasons, effective biological control tends towards stability at a low level of infestation**, or below the level of economic injury. It can reduce the spread and density of infestations to the level where the pest is no longer of concern.
- **If successful**, biocontrol reduces pests, diseases or weeds to an acceptable level where it can be controlled by other means or is not a key problem.



Pest and natural enemy population dynamics. Photo©CSIRO.

Techniques of biological control

Biological techniques traditionally use living natural enemies, either local, deliberately or fortuitously introduced, to minimize pest activity through disease, predation, or parasitism. Natural enemies may be conserved and manipulated, introduced as in classical biological control or applied like pesticides (Fig 11 below).

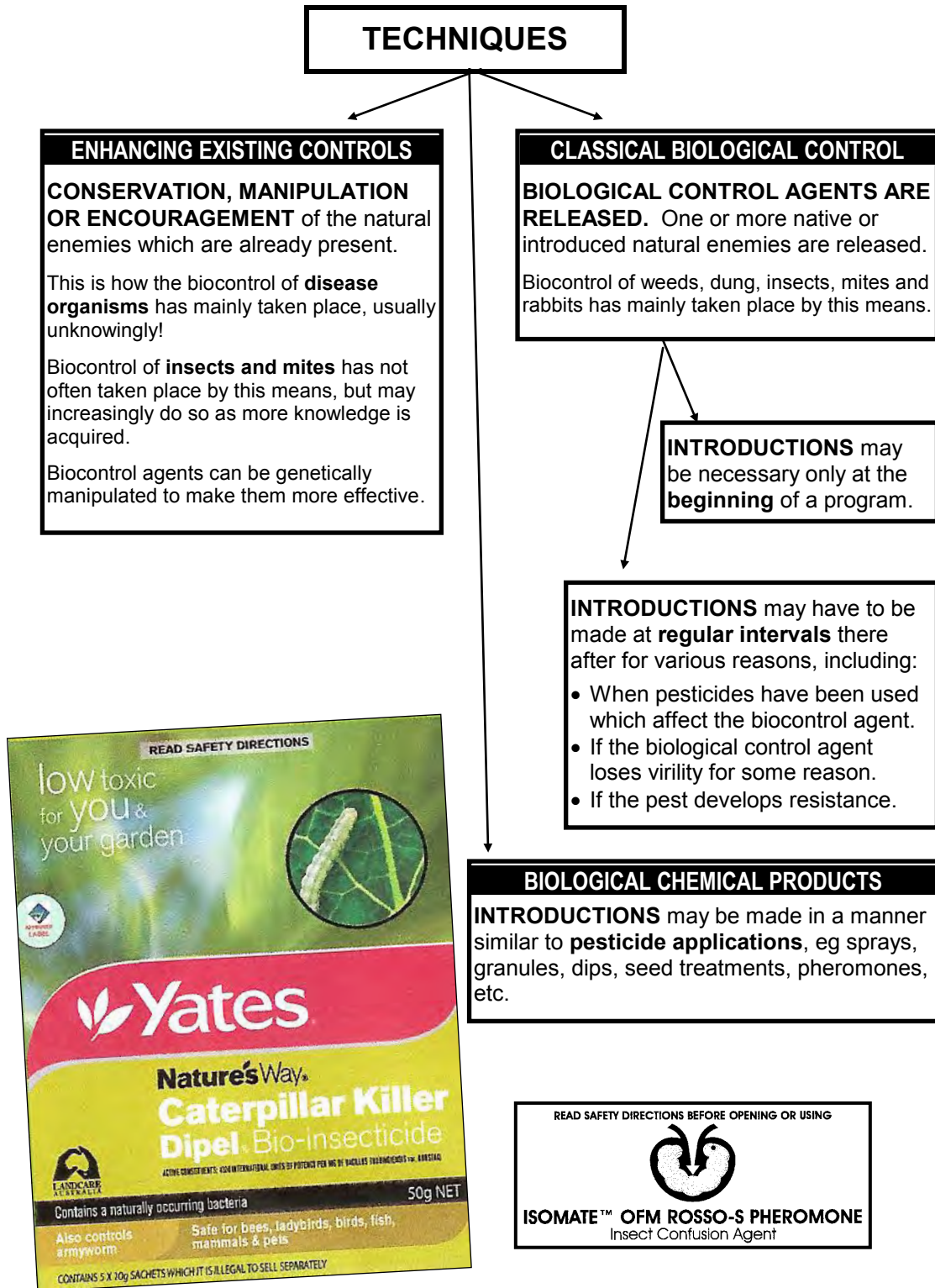


Fig.11. Techniques of biological control.

CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

Legislation

Legislation



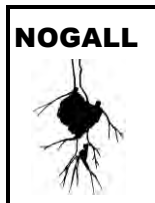
The **Biological Control Act 1984 (Cwlth) and its amendments** together with complementary State / Territory legislation, provides for:

- Control of **persons releasing agents**.
- Choice and declaration of **appropriate target organisms**, eg the specific weed.
- Choice and declaration of **biological control agents**, eg the specific insect.
- **Approval for release** of the biological control agent.

There is a range of other legislation including:

- **Under the Biosecurity Act 2012 (Cwlth)** each biological control agent is subject to an application for importation and release. Established protocols must be followed and a press release made.
- **Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)**. Environment Australia has a separate approval process for biological control agents.
- **The Wildlife and Protection (Regulation of Exports and Imports) Act 1982** and its Amendments, has control over importation and release of exotic species.
- **Agricultural and Veterinary Chemicals Code Amendment Bill 2010** is administered by the **APVMA** which registers biological chemical products which must go through the same approval process as synthetic chemicals (page 259).
- The **International Organization for Biological Control of Noxious Animals and Plants (IOBC)** promotes environmentally safe methods of pest control.

Biological
chemical
products



GreenGuard
SC Premium
Locusts, grasshoppers

“A **biological chemical product** is an agricultural chemical product where the active constituent comprises or is derived from a living organisms (plant, animal, microorganisms, etc), with or without modification. This includes many products that are commonly referred to as ‘botanicals’, ‘organics’ or ‘herbals’ (where the active constituent comprises an extract derived from an organism rather than the whole organism, it may be accompanied by unidentified components).”
There are currently 4 major groups of biological products:

- Group 1. Biological chemicals, eg pheromones, hormones, growth regulators, enzymes and vitamins.
- Group 2: Plant and other extracts, eg plant extracts, oils.
- Group 3. Microbial agents, eg bacteria, fungi, viruses, protozoa.
- Group 4: Other living organisms, eg microscopic insects, plants and animals plus some organisms that have been genetically modified.

Users must read, understand and follow label directions

Process of biological control


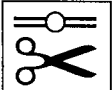

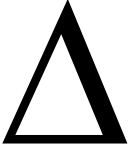

Guidelines are continually being amended and improved. Revised guidelines for the introduction of exotic biological control agents for the control of weeds and plant pests are available on the Australian Department of Agriculture website www.agriculture.gov.au/ (under construction, previously www.daff.gov.au/).

1. Approval of the target species as a candidate for biological control.
2. Off shore research on possible biocontrol agents in the target’s country of origin. Risk assessments are made.
3. Host-specificity test list.
4. Permission to undertake specimen testing in contained use in Australia.
5. Testing permit for the proposal.
6. Specificity testing.
7. Application to release the biocontrol agents.
8. Assessment of release package.
9. Release permit.
10. Amending the live import list for biocontrol agents that are animals.
11. Assess impact of biocontrol agents.

Remember

- The whole process may take as long as 10 years and is expensive.
- Avoid introducing alien species into the environment where possible.
- Biocontrol agents must not affect native species.
- Tests must include as wide a range of native species as possible.

IT, communication and biotechnology

<p>IT, expertise</p> 	<p>Many IT programs are now available to provide information on:</p> <ul style="list-style-type: none"> • The life cycle of diseases, pests and weeds and their parasites and predators. • Screening of selected biocontrol agents, eg ensuring that they are selective towards the weed in question and that they are unable to attack other plant species. • Climatic and ecological factors that determine or limit the distribution and effectiveness of possible biocontrol agents. • Possible effects of large scale environmental problems such as climate change on the life cycles of the pest and the biocontrol agent, eg overseasoning. • High levels of expertise are required to advance biological control methods.
<p>Generic engineering</p> 	<p>Biotechnology has many uses in biological control research, eg</p> <ul style="list-style-type: none"> • Making natural enemies or existing biocontrol agents more effective in attacking a disease, pest or weed. • Extending the host range and environmental tolerances of the biocontrol agent. • Producing tailor-made biocontrol agents. • Selecting for pesticide resistance in natural enemies and analyzing resistance in the predatory mite (<i>Typhlodromus pyri</i>) to synthetic pyrethroid insecticides. • The reduced need for insecticides on pest-resistant plants may allow predators and parasites to play a more significant role in pest control. • Aids in identification of pest and beneficial insects, eg parasitic wasps.
<p>Application of biological control agents</p>  <p>Commonwealth States / Territories</p>  <p>Industry Community</p> 	<p>Ground applications.</p> <ul style="list-style-type: none"> • Mechanized delivery of microbial pesticides and insect-parasitic nematodes by conventional pesticide delivery has been a reality for decades. Beneficial bacteria, fungi, viruses, nematodes are released into the field by spraying with conventional equipment using reliable spray technology which is familiar to operators. • Mechanized delivery of beneficial insects and mites which are readily available from numerous suppliers for control of many different pests, cannot generally be delivered by conventional equipment. Gardeners and workers in greenhouse crops can easily distribute them but it is not so easy over a 100 hectare field. Large augmentative (inundative) releases need to be mechanized to become routine, part of conventional agriculture and reduce application costs (Mahr 2000). <ul style="list-style-type: none"> • Adoption of biocontrol is often impeded by lack of quality control, storage problems, shipment and allocation, eg mechanical damage to eggs, difficulties with calibration, getting uniform distribution in the field and problems with cannibalism of lacewing eggs. Since then various mechanized pieces of equipment have been developed for lace wing eggs and predatory mites but there are still problems. • One of the most successful mechanical devices to date is the Bio-sprayer for the distribution of the eggs of beneficial insects onto pecan trees and grapevines – it uses air atomization to shear liquid into small droplets and propel them to target foliage – the nontoxic spray adhesive adheres eggs of <i>Trichogramma</i> wasps to the foliage. • Community participation can speed up the delivery of biocontrol agents for weeds. Community projects build on the success of the national bridal creeper and Paterson's curse biocontrol programs where farmers, communities, schools and government agencies joined forces to release biocontrol agents at thousands of sites across Australia. Weed targets include WONS and others invasive weeds that have a significant impact on key environmental assets in World Heritage Areas (Community Implementation of Biocontrol of weeds in south Eastern Australia. Weed News 30/8/2011). <p>Aerial applications are often more practical but challenges remain in developing mechanical methods to safely and effectively deliver biocontrol agents over large areas.</p> <ul style="list-style-type: none"> • Small-scale remote controlled aircraft, both fixed wing and helicopters. The Japanese are promoting several types of remote control aircraft which were used to spread chemicals for distributing beneficials, eg natural enemy dispensers spraying <i>Metarhizium</i> (page 99). • Recent developments for delivering lacewing eggs, Trichogramma in host eggs, predatory mites and other small arthropods may result in commercialization of both air and ground equipment for the delivery of both liquid and dry formulations of these natural enemies. Large scale releases are becoming a reality. <p>Bees battle Botrytis.</p> <ul style="list-style-type: none"> • Trays of Trichoderma harzarium granules are placed just outside the entrance to beehives. The bees get the spores on their legs when entering and leaving the beehives and pass the <i>Trichoderma</i> spores onto strawberry flowers which is where <i>Botrytis</i> infection usually starts. The bee delivery system is awaiting approval in Ohio State University (2001). • In Tasmania bees are to be used to spread a fungus normally present in apples to control core rot, reducing disease incidence and the need to spray during flowering.

RABBITS AND OTHER VERTEBRATE PESTS

Invasive Animals Cooperative Research Centre (IA CRC):
Australia's largest integrated invasive animal research program. www.invasiveanimals.com

Some methods currently in use to control vertebrate pests are inhumane and the community would generally welcome more acceptable methods, for example, some form of biological control. However, biocontrol of vertebrate pests is difficult for variety of reasons, including the fact that they are generally spread over a large area, are excellent scavengers, breed prolifically and are inherently wary of humans.

- The **Field Guide to Pest Animals of Australia App** provides the latest information about Australia's worst pest animals and can be accessed by phone users.
- **The IA CRC's FeralScan project** is now underway with **RabbitScan, CamelScan, FoxScan and MynaScan** which anybody can use to create a species Management Map for their property or local area. Any sighting data reported in FeralScan will help to provide a national overview of each species problem.
- **PestSmart** is a toolkit for information on **Best Practice Pest Animals Management** in Australia.

Virally vectored immune-contraception (VVIC)

The aim is to prevent specified vertebrate pests from breeding. VVIC involves vaccinating rabbits with a genetically engineered virus which carries a gene making rabbits infertile.

- **VVIC has been studied and promoted** as an alternative to lethal methods for vertebrate pest control in Australia and New Zealand.
- **VVIC offers a potentially humane** and species specific control method with potential for good benefit-cost outcomes.
- **Case studies for the house mouse, European rabbit, red fox and common brush tail possum** indicated that there were significant problems with delivery and efficacy. VVIC is not presently considered a viable alternative for the management of these vertebrate pests and it is unlikely that this will change in the near future.
- **An absence of benefit-cost data** also hinders decision-making, and until available it will not be clear if there are short- or long-term benefits resulting from the use of VVIC for broad-scale pest management (McLeod et al 2007).

Rabbits

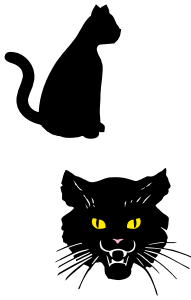



Myxomatosis and Rabbit Calicivirus Disease (RCD).

- **Myxomatosis**, caused by the myxoma virus of the South American forest rabbit is spread by mosquitoes and rabbit fleas. The myxoma virus was introduced into Australia in the early 1950s and was spectacularly successful in controlling rabbits. However, over many years the rabbit has developed resistance to the virus.
- **RCD was accidentally released in 1997.** More than 10 species of insects are vectors including blowflies, a carrion fly, mosquitoes and the European rabbit flea.
- **Myxomatosis** and **RCD** occur seasonally throughout southern Australia. However, genetic changes in the **RCD** virus are already apparent.
- **Managing rabbit populations** is a long-term strategy. **RCD** is not the be-all and end-all. Rabbits have been knocked in the short-term but have recovered from biocontrol and the chances are that they will do so again.
- **Research** is underway overseas to identify and evaluate overseas strains of **RCD** that could be more effective and are better able to control rabbits in temperate areas.
- **Biocontrol of wild rabbits in Australia over the last 60 years** has produced a benefit of A\$70 billion (2011) for agricultural industries, according to a new study published in Australian Economic History Review (Cooke et al 2013).

Integrated Pest management (IPM). Because the rabbit has developed resistance to various viruses, the **National Rabbit Control Training and Extension Package** has been prepared to promote effective and consistent long term rabbit control by the use of **IPM**, and includes the use of pesticides and warren and harbor destruction.



Fig. 12. Rabbits (about 200) around a waterhole. Photo©CSIRO.

<p>Feral cats</p> 	<p><u>The Australian Wildlife Conservancy (AWC)</u> suggests that dogs may be a major solution to Australia's feral cat problem which is devastating native mammal populations in the countries north. In recent times no other nation has seen as many of its mammals disappear (Barclay 2010).</p> <ul style="list-style-type: none"> • While feral cats are not the only cause of native mammals' decline they play a huge role. Other culprits include grazing by cattle and sheep and altered fire patterns. • There are currently no effective broad scale control methods for feral cats. • They don't take readily to bait or enter traps. • Possibly dogs could be used to locate cats, etc. • In the NT in the absence of baiting, dingo activity increased and cat activity decreased resulting in a marked increase in native reptiles but not mammals. • The manipulation of grazing and fire management and dingo density is being examined to at least soften the impact of feral cats. AWC is using several of its northern properties to implement different combinations of grazing and fire management and to monitor the response of native fauna. • A new curiosity bait attractive to feral cats which contains a toxin that halts the flow of oxygen in the blood is being trialed. It is considered a humane way to kill feral cats and less likely to be eaten by native animals; there would be restrictions on its use.
<p>Cane toads</p> 	<p><u>Herpetologist Rick Shine from the University of Sydney</u> has been recognized for his team's crucial work in developing a biocontrol agent to halt the relentless advance and growing impact of the cane toad across the country. The researchers are focusing on exploiting cane toad tadpoles' own chemical deterrent and pheromone systems as a potential way to disrupt the animal's life cycle.</p>
<p>Rats</p> 	<p><u>Using terrier dogs (Canine control) to detect and eradicate pest rats</u> from private properties has been successfully operated by the city authorities in Brisbane for more than 70 years. Dogs are ideally suited for detecting the Norwegian rat (<i>Rattus norvegicus</i>), a major pest species that lives in communal burrows below ground. The fox terrier squad helps to locate nests so baits can be laid.</p> <p><u>Owls in boxes in sugarcane fields</u> in Qld feed on rats (5 per night). The practicality of using owls instead of pesticide baits is an obvious problem.</p> <p><u>Attempts are to be made to reintroduce the native rat</u>, or Bogul rat (<i>Rattus fuscipes</i>), which has not been recorded the northern foreshore of Sydney harbour for years, to deal with the introduced European black rat or ship's rat (<i>Rattus rattus</i>), which is an invasive pest, fantastic climber, predator on nest eggs and kills a lot of the native birds. The native Bogul rat is able to defend its territory and so will fight for its habitat on the northern foreshore of Sydney harbor, so a rat war is about to be waged, and the winner will make the combat zone their home (Catalyst 12/8/2010).</p> <ul style="list-style-type: none"> • This project marks the beginning of the first management program to use a native mammal species, the Bogul, as a biocontrol agent against the introduced rodent in the Mosman and Sydney Harbour National Parkland region.
<p>Cattle dung and chicken manure</p> 	<p><u>Cattle dung.</u></p> <ul style="list-style-type: none"> • Australia has about 300 species of dung beetles which need dung for breeding and as a food supply (Landline 2007) • Because native dung beetles can only dispose of the pellet-like droppings of native herbivores, the introduction of cattle into Australia resulted in large areas of pasture being smothered by much larger dry dung pads which are undesirable for two main reasons: <ul style="list-style-type: none"> • Grass growing around the edges of the dung pad is unpalatable to stock. • Dung pads are a breeding ground for the bush fly and the buffalo fly. • Many species of dung beetles capable of disposing of large dung pads of cattle have been imported into Australia with varying degrees of success. It is likely that some species or strains were not suited to the climate in certain regions of Australia, however, 23 species have established to varying degrees. • Most dung beetles build their nests under dung pads and lay their eggs at depths up to 20cm. One species established in northern NSW makes the dung into balls, rolls it away and attaches it to the base of plants. The process of feeding and nest building breaks up the dung pad which releases the locked up nutrients. As many species bury the dung, the nutrients are returned to the soil. <p><u>Chicken manure.</u></p> <ul style="list-style-type: none"> • The lesser mealworm (<i>Alphitobius diaperinus</i>) beetles live in manure under chicken coops, it dries it out and turns it into a powder which can be used as fertilizer. • Drying out reduces fly breeding, gets rid of the smell and reduces the volume of manure to be removed, reducing labor costs. • The need for chemical sprays to kill flies and reduce odors, handling and disposing of wet unpleasant manure is reduced.

WEEDS

In horticulture and agriculture there are large financial gains to be made in the control of weeds. They also reduce biodiversity. **There are 2 main types of weed biocontrol** – by classical biological control (releasing natural enemies) and by bioherbicides. Biocontrol offers long term hope for weeds that have got beyond control by other techniques. It cannot eradicate a weed but can reduce the spread and density of infestations to the extent that the weed is no longer of concern and no other control is necessary. More commonly, other methods are still required. Incorporating biocontrol agents into **Integrated Weed Management (IWM)** systems gives the greatest chance of success. Weeds and their biocontrol have been well studied in Australia (Julien et al 2012). There is also information on State / Territory and Commonwealth websites, eg

Weeds Australia www.weeds.org.au/ Weed Information www.weedinform.com.au/
Weeds In Australia www.environment.gov.au/biodiversity/invasive/weeds

Classical biological control

By releasing natural enemies



Cactoblastis caterpillars.
Photo©CSIRO.

Classical biological control is the most common way to biocontrol weeds and is achieved by the release of insects, mites, rusts and other organisms into a region to permanently suppress targeted weeds. The aim is to establish a natural balance between the weed and its control agent – similar to the balance found in the native range of the weed. If the agent successfully establishes itself, control becomes self-perpetuating and self-regulating as the control agent becomes a perennial part of the region's ecology. However, successful programs including development and establishment phases, may take more than 10 years to be effective and results may vary from area to area.

- **In their country of origin most weeds are kept in check by more than one agent** and it is likely more than one biocontrol agent will be required in Australia.
- **After due protocols, biocontrol agents that are well adapted and specific to the weed** are introduced to Australia. They can eventually reduce the density of the weed to a manageable level by decreasing plant vigor and competitiveness and / or minimizing seed production, thus diminishing any long term seed-bank.
- **Releases have been made by Division of Entomology, CSIRO, Canberra** and various task forces, eg *NSW Lantana Biological Taskforce*, State Departments, etc.
- **Biocontrol is not usually suitable** when fast control or eradication is required.
- **In a worldwide review of the biocontrol of weeds** it was calculated that 63% of agents released became established but only 24% of releases were considered effective in controlling their weed host.

Bioherbicides

Bioherbicides are fungi, bacteria and other microorganisms already present in Australia that cause plant diseases that often result in death or reduced weed vigor, this avoids biosecurity issues. Not many bioherbicides are on the market. Initially they may be used in the organic market but over time, they could move into the conventional market where they could be mixed and matched similar to regular chemical tank mixes, they could make chemical herbicides better (Marrone Bio Innovations).

Fungal bioherbicides

Fungal bioherbicides are not self-sustaining and have a short active period.

- **Mostly it is grass weeds** important in crops which would repay such an approach but only a few of these have a range of fungi already infecting them in Australia.
- **Multiple pathogen bioherbicides (cocktails)** of a number of pathogens and directed at one or more related weeds are being researched, and may be more successful.
- **There is an International Bioherbicide Group (IBG)** which publishes the IBG News and BioHerbicides Australia Pty Ltd (BHA),

Application:

- **Fungal spores are sprayed onto weeds** or applied as a cut stump treatment in the same way as chemical herbicides. Repeat treatments may be necessary.
- **They must undergo a registration process** in the same way that pesticides do. High doses are applied to target weeds, eg annual grass weeds rely on **seed production and germination** for their survival. A naturally occurring seedborne disease (*Pyrenophora* sp.) **infects weed seeds**, depletes seed numbers and prevents germination. It is being researched as a biocontrol agent for annual ryegrass and other annual grass weeds.
- **Fungi used should be:**
 - Easily mass produced, highly infective and host specific.
 - Indigenous or naturalized, and occur naturally on weeds in the area.
 - Formulated to reduce evaporation from applied spores and increase water retention at the weed surface. Most fungi need moisture to germinate and penetrate the host.
 - Applied in high doses when the weeds are most susceptible to infection.
 - **Wounds** caused by mowing or grazing may enhance infection.

HAVE A CHECKLIST, eg
Steps involved?
Which formulation?
How to apply?
• Spray-ons
• Wound then inoculate
How are the spores to be distributed?
• Wind
• Spread by insects from hot spots
Etc?

Constraints and advantages

Lowering costs is a priority

Main constraints to developing mycoherbicides include:

- **The period of time that fungi require in a high moisture** or free water environment to germinate and penetrate the plant surface (the dew period). New formulations are required to overcome dew requirements.
- **Some have wide host ranges** and host variability.
- **Soil applications are in a protected environment** but these fungi often are very virulent with wide host ranges.
- **Difficulty in mass production** which is necessary for a commercial use.
- **Commercial limitations**, eg size and stability of the market, patents, cost of research, and competition from chemical herbicides, regulations, etc.
- **Mycoherbicides may just need reductions in growth** and competitiveness of weeds to reduce yield losses. Chemical herbicides used at low rates might increase the efficacy of the biocontrol agents. This would need regulatory approval.
- **Feasibility of improving bioherbicide candidates** through genetic manipulation.
- **In the short term new bioherbicides will most easily find a place in the tropics** or in other situations where the environment can be manipulated such as gardens or turf.

Advantages of mycoherbicides are:

- Specificity and high safety factor for applicators and for wildlife.
- Mycoherbicides may have their best potential for situations either where for some reason a chemical is unacceptable, eg water catchments, or when specificity is high enough allow application over mixed stands of vegetation without the need to avoid desirable species.

Bioherbicides marketed overseas

Londoners and Ontarians are banned from using chemical pesticides under a law that took effect in 1999

Opportune®
Streptomyces acidiscabies

Bioherbicides marketed overseas include:

- **Collego®** (*Colletotrichum gloeosporioides* f.sp. *aeschynomene*) controls northern joint vetch (*Aeschynomene virginica*) in rice and soybean fields in the USA.
- **DeVine®** (*Phytophthora palmivora* MWV disease) is effective against milkweed vine (*Morrenia odorata*) in citrus orchards in Florida (90% control within 1-2 years).
- **Camperico®** (*Xanthomonas campestris* pv. *poae*) is sprayed on freshly cut turf to control winter grass (*Poa annua*) in golf courses in Japan.
- **A fungus** (*Phoma macrostoma*) that attacks dandelions and other broadleaved weeds (not grasses) is being developed in Canada. Plants turn white, can't photosynthesize, use up their root storage and die. The fungus is applied to the soil in a granule form before or after weeds emerge. **Phoma** also attacks thistles, clover, chickweed and ragweed. The fungus produces a toxin in the soil that attacks the roots of the weeds and tends to increase in the soil for up to 2 months and then starts to decline, a year later it can't be detected in the soil (AgroNews, 2011. *Scientists find weed-killing fungus*).
- **Potential use of ascospores of Sclerotinia sclerotiorum** (wide host range) as a mycoherbicide for *Ranunculus* spp. in NZ dairy pastures (Pottinger et al 2008).
- **In China, a fungus** (*Colletotrichum gloeosporioides*) was developed to control the parasitic weed dodder (*Cuscuta* spp.).
- **Opportune** (*Streptomyces acidiscabies*) is a microbial compound rather than the entire microbe – there is no infection process of the weed; it is strictly based on the microbe producing a compound which controls broadleaved weeds in grasses. **Opportune** controls glyphosate-resistant weeds and could be used with chemicals, such as glyphosate, to make them more effective (Marrone Bio Innovations www.marronebioinnovations.com).

Bioherbicides in Australia

Di-Bak Parkinsonia

There is potential for mycoherbicides to control:

- Alligator weed
- Noogoora burr
- Bitou bush (Ensby 2011)

Many biocontrol agents have already been released in Australia

Several fungi have been investigated in Australia including:

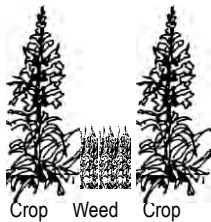
- **A native fungus** (*Rhynchosporium alismatis*) as a biocontrol agent on a range of weeds **in rice crops**.
- **Drechslera avenacea** as a biological control agent for **wild oats** (*Avena* spp.).
- **Hyaloperonospora parasitica** is a damaging and widespread fungal pathogen of **wild radish** (*Raphanus raphanistrum*). Isolates from wild radish are genetically distinct from the isolates found on other *Brassica* spp. opening up the possibility of using the fungus as a conservation or augmentative approach to the biocontrol of wild radish (Maxwell and Scott 2008).
- **A widespread native fungus** ("**Di-Bak Parkinsonia**") which promises to be a sustainable and long-term solution for **Parkinsonia** and other **invasive woody weeds such as prickly acacia, mimosa and Athel pine** is being developed by The University of Queensland.
 - **The first bioherbicide to be developed** will be for **Parkinsonia**, which has spread across Qld, the NT and northern WA and costs \$60 million per annum in chemicals to control. The fungus used in the bioherbicide was isolated from naturally infected Parkinsonia plants that were dying back in the NT.
 - **A hole is drilled in the tree trunk**, a capsule containing millet and the colonizing fungus inserted, the hole sealed with silicone; a mechanized delivery system will make the injection will be much faster. . The tree dies within six months to two years.
 - **Parkinsonia creates a very large seed bank**, which makes its control with chemical herbicides or manual removal ineffective, new plants pop-up for years afterwards. Once the fungus is established in the trees it may remain in the soil and kill germinating seeds that come up after the adult tree is gone. As it is thought to spread laterally to adjacent untreated trees via the plants' roots, it may only be necessary to inoculate one in five trees in thick clumps of Parkinsonia. The technology has been licensed to BioHerbicides Australia Pty Ltd (BHA) and registration and production of **Di-Bak Parkinsonia** are expected in 2014.

Allelopathy and weeds

Allelopathy

Allelopathic-chemicals have potential as bioherbicides

Note: Allelochemicals released into the soil may retard crop growth



Seedbed allelopathy is being explored

Allelopathy refers to the beneficial or harmful effects of one plant on another plant, both crop and weed species, by the release of chemicals from plant parts, by leaching, root exudation, volatilization, residue decomposition and other processes. It occurs in both natural and agricultural systems and provides a means for developing new herbicides (Ferguson and Rathinasabapathi 2009). See also page 59.

- **Allelopathy offers great potential** to:
 - **Increase agriculture production**, eg food grains, vegetables, fruits, forestry.
 - **Decrease harmful effects** of modern agricultural practices, eg multiple cropping, leaching losses from N fertilizers, indiscriminate use of pesticides and development of pest and weed resistance.
 - **Maintain soil productivity** and pollution free environment for future generations (Narwal 2012).
- **Crop breeding for genetic manipulation and allelopathic potential against weeds.**
 - **Incorporation of allelopathic traits from wild or cultivated plants into crop plants** by traditional breeding or biotechnology could enhance release of allelochemicals.
 - **Phytotoxins** are poisonous substances derived from plants or substances produced by some disease organisms that are toxic to plants (phytotoxic).
 - **Natural phytotoxins leaching from plant residues** can be used to inhibit the germination of seeds and growth of many weeds in crops. There are many crop species known for their allelopathic potential. These future herbicides could be used to supplement cover crops in reduced tillage practices. Some may be more biodegradable than traditional herbicides but may also have undesirable effects on non-target species, eg *Leucaena leucocephala* reduces yield of wheat but increases the yield of rice.
 - **Phytotoxins may be produced by some fungi** and have possible uses as herbicides, eg Nigerazine by *Aspergillus niger*
Citreoviridin by *Penicillium charlesii*
- **Crop and weed mulch of the proper type and amount** could be used for weed management. Residue management, crop rotation, timing of operations and proper agronomic practices need to be identified for specific areas of production to make use of allelopathic production. Modifying these natural products could provide more active, selective and persistent herbicides.
 - **Promising results** occurred when allelopathic crops have been included in a **rotation**.
 - **Allelopathic chemicals** have potential as bioherbicides.
 - **Allelopathy can be exploited** to benefit production systems utilizing natural phytotoxins leaching from plant residues to inhibit germination of seeds and growth of many weeds.
- **Successfully planted legume cover crops** can suppress weed growth by competition for nutrients, light and water but also possibly through release of allelochemicals.
- **Much allelopathic research is ongoing worldwide**, eg
 - **Sunflower (*Helianthus annuus*)** has potential as a natural herbicide. White mustard is ineffective in weed control. Researchers are exploring native Australian plants for natural herbicides.
 - **Dried mango leaf powder** completely inhibited sprouting of purple nutsedge tubers but may also have undesirable effects on non-target species.
 - **Leptospermon** is the allelochemical produced by the roots of bottlebrush (*Callistemon citrinus*). Callisto (mesotrione) was a further development of this and is a new herbicide developed for control of broadleaved weeds in maize crops. Often different formulations are used for both pre and post emergent control of broadleaved weeds in maize.
 - **Composting one invasive species to control another** can be effective and merits trials. The process is uncertain but may be related to weed seed burial or the allelopathic potential of the mulch (Lintz et al 2011).

Contraceptive for weeds

Is this biological control?

Scientists aim to trick weeds into shutting down their reproductive system by fooling them into thinking they are having sex with themselves. The project hopes to mimic in the laboratory the chemistry that most plants use to spot and reject their own pollen to avoid inbreeding. When sprayed on weeds it would act as a contraceptive, confusing them into thinking they are being self-fertilized (Macey 2005).

- **A lot of weeds produce flowers that have both male and female organs** and can reproduce by themselves but they don't (self incompatibility). Nature has given these weeds a protein to detect their own pollen when activated it triggers chemical mechanism which prevents self-fertilization.

Biological control of weeds

Table 2. Examples of the biological control of weeds in Australia.

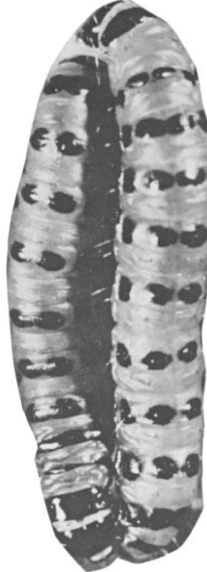


WEEDS	BIOLOGICAL CONTROL AGENTS include:
<p>Prickly pear <i>Opuntia stricta</i> var. <i>stricta</i></p>  <p style="font-size: small;">Cactoblastis caterpillars. Photo©CSIRO.</p>	<p>Cactoblastis moth (<i>Cactoblastis cactorum</i>). Prickly pear cochineal (<i>Dactylopius opuntiae</i>). Other <i>Opuntia</i> spp. by cochineal mealybugs (<i>Dactylopius</i> spp.).</p> <p>During the 1920's, caterpillars of the cactoblastis moth were imported from Argentina and ate their way through some 25 million hectares of prickly pear-infested country in Qld. The Cactoblastis Memorial Hall near Chinchilla in central Qld on the Warrego Highway, commemorates the little grubs' feat. The moth caterpillars tunnel into the cactus pads causing mechanical injury. They carry with them cosmopolitan soft rot bacteria which rot the pads.</p> <div style="display: flex; justify-content: space-around;">   </div> <p style="font-size: small; display: flex; justify-content: space-around;"> Prickly pear-infested country. Photo©CSIRO. After release of cactoblastis. Photo©CSIRO. </p>
<p>Alligator weed <i>Alternanthera philoxeroides</i></p>	<p>Alligator weed flea beetle (<i>Agasicles hygrophila</i>) controls the aquatic form of alligator weed in the warmer climates of Australia, but has been unsuccessful in controlling the terrestrial form and does not control the weed in cooler temperate climates. Alligatorweed moth (<i>Arcola malloi</i>), a stem borer. Flea beetle (<i>Phenrica</i> spp.). Stem-galling fly (<i>Ophiomyia marelli</i>) and other stem / leaf mining flies. A rust fungus.</p>
<p>Bathurst burr <i>Xanthium spinosum</i></p>	<p>Anthrachnose (<i>Colletotrichum orbiculare</i>) is being developed as a mycoherbicide. The development of the bioherbicide took over 10 years. One major stumbling block was the close relationship between the weed and an important crop species, sunflower. Spores of specific races of the fungus are suspended in vegetable oil, sprayed on young seedlings and considerable damage develops with 2 weeks. Other biocontrol agents, such as the Bathurst burr seed-fly (<i>Euaresta bullans</i>) and the rust (<i>Puccinia xanthii</i>) have limited effectiveness.</p>
<p>Bitou bush and Boneseed <i>Chrysanthemoides monilifera</i></p>	<p>Bitou bush seed fly (<i>Mesoclanis polana</i>) reduces seed production by 40% in some areas. The larvae feed on developing seed, reducing seed production. It is well established. Bitou bush tip moth (<i>Comosotolopsis germana</i>) feeds in stem tips destroying developing leaves, buds and flowers, reducing seed production. It is also now widely established in the field but does suffer heavy predation and parasitism at some sites. Rust (<i>Endophyllum osteospermi</i>) affects boneseed (and bitou bush). Boneseed buckle mite (<i>Aceria</i> sp.), various leaf beetles (<i>Chrysolina</i> spp.), the lacy-winged seed fly (<i>Mesoclanis magnipalpis</i>) and the boneseed leaf roller moth (<i>Tortrix</i> sp.); none has yet successfully established in Australia partly due to predation by native insects and mites.</p>
<p>Blackberry <i>Rubus fruticosus</i></p>	<p>Blackberry leaf rust (<i>Phragmidium violaceum</i>) has not been effective at controlling all biotypes and taxa of blackberry.</p>
<p>Bridal creeper <i>Asparagus asparagoides</i></p>	<p>Bridal creeper leafhopper (BCLH) (<i>Zygina</i> sp.) is established in WA, NSW, SA and Vic. Bridal creeper beetle (<i>Crioceris</i> sp.) from South Africa consumes expanding leaves and shoots; it might be more effective in drier areas than the leaf fungus and the rust fungus. Rust (<i>Puccinia myrsiphylli</i>) which attack leaves and stems has been released in SA. Since the first agent was released, a concerted effort by the CSIRO and the Cooperative Research Centre for Australian Weed Management, in collaboration with community groups, schools and landholders, has led to one of the most successful biological control programs in Australia.</p>

Table 2. Examples of the biological control of weeds in Australia (contd).

WEEDS	BIOLOGICAL CONTROL AGENTS include:
Cassinia spp. (native species)	Native scale insects cause massive damage in some areas to <i>Cassinia</i> spp. In others areas the inability of the native scale to control <i>Cassinia</i> , may be due to other predators and parasitoids such as small wasps which use the scales as hosts for their offspring (Campbell et al 1994).
Blue heliotrope <i>Heliotropium amplexicaule</i>	Blue heliotrope leaf beetle (<i>Deuterocampta quadrijuga</i>). Blue heliotrope flea beetle (<i>Longitarsus</i> sp.), adults feed on leaves and larvae feed on roots.
Crofton weed <i>Ageratina adenophora</i>	Crofton weed crownborer (<i>Dihammus argentatus</i>). Gall fly (<i>Procecidochares utilis</i>). Galled stems usually die, but the level of galling is usually too low for any substantial effect; parasitised by a native insect, its effect is consequently patchy. Fungal leaf spot (<i>Phaeoramularia eupatorii-odorati</i>) was accidentally introduced. Mexican rust fungus (<i>Baeodromus eupatorii</i>) is being researched for possible introduction to Lord Howe Island. High levels of control have never been obtained by the biocontrol of Crofton weed so it should never be solely relied upon.
Gorse, furze <i>Ulex europaeus</i>	Gorse is considered an important weed in some situations, yet of value in others. Gorse seed weevil (<i>Exapion ulicis</i>). Gorse spider mite (<i>Tetranychus lintearius</i>). Gorse soft shoot moth (<i>Agonopterix ulicetella</i>). Gorse thrips (<i>Sericothrips staphylinus</i>). Gorse pod moth (<i>Cydia succedana</i>). Gorse lace bug (<i>Dictyonota strichnocera</i>).
Groundsel bush <i>Baccharis halimifolia</i>	Groundselbush leaf beetle (<i>Trirhabda baccharidis</i>). Groundselbush leafwebbing caterpillar (<i>Aristotelia ivae</i>) Stemboring moth (<i>Hellensia balanotes</i>). Groundselbush gall fly (<i>Rhopalomyia californica</i>). Groundselbush stemborer (<i>Megacyllene mellyi</i>) and stemborer <i>Oidaematophorus balanotes</i> Combining bioherbicides, eg bacteria and fungi (<i>Botrytis</i> and the rust, <i>Puccinia evadens</i>). Results indicate that groundsel bush biocontrol agents may be patchy in their effectiveness due to factors such as rainfall and plant size. However, simulation models demonstrated that they have potential to reduce individual plant and population growth when damage is high.
Horehound <i>Marrubium vulgare</i>	Horehound plume moth (<i>Pterophorus spilodactylus</i>) has now established at over 100 localities throughout south eastern Australia. Horehound clearwing moth (<i>Chemaesphesia mysiniiformis</i>). The native brightly colored orange and black horehound bug (<i>Agonoscelis rutile</i>) is often seen on horehound in great numbers but does not provide any worthwhile control.
Lantana <i>Lantana camara</i>	This woody perennial shrub is a serious weed in Qld and NSW. 25 biocontrol agents have been trialed and released for its control of lantana. Some have been partly successful with the majority having little impact. Examples include: Lantana flower caterpillar (<i>Epinotia lantana</i>). Lantana lace bugs (<i>Leptobyrsa decora</i> , <i>Teleonemia scrupulosa</i>). Lantana leafmining beetles (<i>Octotoma scabripennis</i> , <i>Uroplata girardi</i> , <i>U. fulvopustulata</i>). Leaf-feeding chrysomelid beetle (<i>Alagoasca parana</i>). Lantana leafmining fly (<i>Calcomyza lantanae</i>). Lantana seed fly (<i>Ophiomyia lantanae</i>). Membracid bug (<i>Aconophora compressa</i>). Moth (<i>Ectaga garcia</i>) from Brazil (by the NSW Lantana Biological Taskforce). Leaf-sucking bug (<i>Falconia intermedia</i>) has been recently approved for release in Australia. Leaf-feeding moth (<i>Hypena laceratalis</i>) causes seasonal damage to lantana in Australia. Leaf-feeding moth (<i>Neogalea sunia</i>) is common and widespread in Qld and northern NSW. Leaf-mining beetle (<i>Octotoma championi</i>) has only a limited distribution. Mealy bug (<i>Phenacoccus parvus</i>) was introduced accidentally as a contaminant on imported plants. As it feeds on many different plants, it is not recommended as a biocontrol agent. Leaf-feeding moth (<i>Salbia haemorrhoidalis</i>) is most abundant in tropical areas. Flower-feeding moth (<i>Lantanophaga pusillidactyla</i>) is widespread and common, but has limited effect. Rust (<i>Prospodium tuberculatum</i>) only attacks the pink flowering lantana varieties, heavy infestations of the fungus lead to premature loss of leaf.

Table 2. Examples of the biological control of weeds in Australia (contd).

<p>Mimosa <i>Mimosa pigra</i></p>	<p>This weed is the most important biological threat to Kakadu National Park in the NT.</p> <p>Twelve insect species and two fungal pathogens have been released in Australia over the last 22 years and are now having a noticeable impact on this recalcitrant weed. At least 7 of these insects are well established and abundant, including:</p> <p>Mimosa flowerbud weevil (<i>Coelocephalapion aculeatum</i>). Mimosa flower weevil (<i>C. pigrae</i>). Mimosa leaf beetle (<i>Chlamisus mimosae</i>). Seed weevils (<i>Acanthoscelides</i> spp.). Stem boring moths (<i>Neurostrotta gunniella</i>, <i>Carmenta mimosa</i>). Mimosa flea beetle (<i>Nesaecrepida infuscata</i>) attacks roots and leaves. The giant sensitive psyllid (<i>Heteropsylla spinulosa</i>). Leaf feeding beetle (<i>Malacorhinus irregularis</i>). Seed eating weevil (<i>Chalcodermus serripes</i>). Mimosa looper (<i>Leuciris fimbriaria</i>). Looper moth (<i>Macaria pallidata</i>).</p> <p>A fungus (<i>Phloespora mimosae-pigrae</i>) attacks leaves. Indigenous stem-spot fungus (<i>Corynespora cassicola</i>). A rust fungus (<i>Diabole cubensis</i>).</p> <p>Several new agents are being investigated that damage the roots and leaf buds, the parts of the plant that still lack effective agents.</p>
<p>Noogoora burr <i>Xanthium strumarium</i></p>	<p>Noogoora burr longicorn (<i>Nupserha vexator</i>). Stem boring beetle (<i>Mecas sarurnine</i>) had no significant impact. Noogoora burr seed fly (<i>Euaresta aequalis</i>), no significant impact. Gall-forming-moth (<i>Epiblema strenuana</i>) causes some damage. Rust (<i>Puccinia xanthii</i>) was accidentally or illegally introduced into Australia in 1975 and has largely brought infestations along eastern Queensland under control, but has not been efficient at controlling infestations in the far north of the Northern Territory and Western Australia. Leafspot fungus (<i>Alternaria zinniae</i>) has potential as a mycoherbicide for <i>Xanthium</i> spp.</p>
<p>Paterson's curse, Salvation Jane <i>Echium plantagineum</i></p>	<p>Root weevil (<i>Mogulones geographicus</i>) is expected to contribute to biocontrol. Crown weevil (<i>Mogulones larvatus</i>) may kill 95% plants. Larvae feed on the crown, petioles and upper parts of rosettes, adults feed on leaves. Echium flea beetle, root hair weevil (<i>Longitarsus aeneus</i>). Larvae tunnel into the tap root and secondary roots where they are protected from grazing animals. Tap root flea beetle (<i>Longitarsus echii</i>). Flower beetle, pollen beetle (<i>Meligethes planiusculus</i>). Leafmining moth (<i>Dialectica scalariella</i>). Larvae mine inside the leaves causing them to blister; it is now widespread on Paterson's curse and Viper's bugloss causing minor damage to plants. Longhorn beetle, stem beetle (<i>Phytoecia coerulescens</i>).</p> <p>Wooragee Landcare Group aims to assist with the control of Paterson's curse on areas that are not easily accessible for the use of conventional control methods. The group is organising collection days for flea and pollen beetles and root and crown weevils.</p>
<p>Prickly acacia <i>Acacia nilotica</i></p>	<p>Six insects have been introduced into Australia as biological control agents against prickly acacia with two of these establishing and providing some benefit. A beetle (<i>Bruchidius sahlbergi</i>) established successfully and is now widespread. Seed predation is generally low but may reach up to 80% where mature pods are available. Geometrid moth (<i>Chiasma inconspicua</i>). The leaf-feeding caterpillar (<i>Chiasmia assimilis</i>) has not established in western Queensland but is exerting pressure on prickly acacia in coastal locations. Recent surveys in India have identified a further three insects and two rust fungi as potential biocontrol agents. These will be subject to host-testing studies prior to release. Prickly acacia is attacked by native insects associated with Australian native acacias and other native plants causing dieback. Generally, leaf-feeding, sap-sucking, root, pod and seed feeding insects attack actively growing prickly acacia. Bark and wood-feeding insects (including borers and twig girdlers) prefer stressed and dying plants. Native insects can weaken prickly acacia and can contribute to the death of plants when other stresses are involved. Since the 1970s, dieback of large areas of prickly acacia has occurred throughout western Queensland infestations. The causal factors remain unclear but may involve water stress during dry seasons and drought, high salt concentrations in soils, root predation by cicada nymphs, and attack by insects and diseases on stressed plants.</p>
<p>Ragwort <i>Senecio jacobaeae</i></p>	<p>Ragwort flea beetles (<i>Longitarsus flavicornis</i>, <i>L. jacobaeae</i>) are having a major controlling influence on ragwort at many sites in Victoria and Tasmania. Ragwort stem and crown moth (<i>Cochylis atricapitana</i>) are well established at many sites. Ragwort rust fungus (<i>Puccinia expansa</i>). Ragwort plume moth, ragwort crown-boring plume moth (<i>Platyptilia isodactyla</i>). Cinnabar moth (<i>Tyria jacobaeae</i>) but has had no impact.</p> <p>Tasmania's ragwort biocontrol program is one of the ultimates in IWM, using traditional natural enemies to destroy the weed. Ragwort was a huge problem in the beef, dairy and wool industries. The program deployed a range of living enemy agents, especially the ragwort flea beetle to achieve effective control. Estimated to save the industry \$2-3 million which otherwise would have been production losses. The team at Tasmanian Institute of Agriculture Research (TIAR) is currently working in finding and deploying biocontrol agents for ragwort, bone seed, horehound, the brooms, thistles and Paterson's curse (Tasmania ABC Rural 6/4/2011).</p>

Table 2. Examples of the biological control of weeds in Australia (contd).

<p>Salvinia <i>Salvinia molesta</i></p>	<p>Salvinia weevil (<i>Cyrtobagous salviniae</i>) successfully controls salvinia weed in northern Australia, the weevil larvae feed inside the stems and the adults feed on the buds. Salvinia moth (<i>Samia multiplicalis</i>).</p>
<p>Serrated tussock <i>Nassella trichotoma</i></p> <p>Chilean needle grass <i>Nassella neesiana</i></p>	<p>Serrated tussock (<i>Nassella trichotoma</i>) and Chilean needle grass (<i>Nassella neesiana</i>) are two related species of South American grass that are highly invasive in south-eastern Australia (McLaren and Anderson 2011). Serrated tussock (<i>Nassella trichotoma</i>): Surveys have identified a rust fungus in Argentina which attacks the leaves and a smut fungus that prevents seeding of serrated tussock. Rust (<i>Puccinia nassellae</i>). Smut (<i>Tranzscheliella</i> spp.) prevents viable seed forming. <i>Corticium</i> sp. is not much studied. Chilean needle grass (<i>Nassella neesiana</i>): Several pathogens have been identified; two rusts (<i>Uromyces pencanus</i> and <i>Puccinia graminella</i>) were chosen as the best candidates. Detailed host specificity testing is currently being done for the <i>N. neesiana</i> rust fungus (<i>U. pencanus</i>). It is expected that if this continues to show that the agent is highly specific, an application to import and release this agent into Australia and New Zealand will be made in the near future.</p>
<p>Scotch broom English broom <i>Cytisus scoparius</i></p>	<p>Scotch broom is a threat to the environment, forestry and grazing land. English broom psyllid (<i>Arytainilla spartiophila</i>) attacks spring buds, reduces the weed's vigor and indirectly, its ability to produce flowers and seed. Broom twig-mining moth (<i>Leucoptera spartifoliella</i>). Broom gall mite (<i>Aceria genistae</i>). Broom seed beetle (<i>Bruchidius villosus</i>), larvae feed on seeds. Broom leaf beetle (<i>Gonioctena olivacea</i>) and the broom leaf-feeding moth (<i>Agonoapterix assimilla</i>) are undergoing testing.</p>
<p>Skeleton weed <i>Chondrilla juncea</i></p>	<p>Many insects and mites have been released, including: Chondrilla gall midge (<i>Cystiphora schmidtii</i>). Chondrilla gall mite (<i>Eriophyes chondrillae</i>). Skeleton weed rust fungus (<i>Puccinia chondrillina</i>) (photo page 85).</p>
<p>Solanaceous weeds</p>	<p>Solanaceous weeds in SE Australia could possibly be managed by a mycoherbicide (<i>Alternaria zinniae</i>) either alone or when in combination with chemical herbicides applied at lower than usual rates. This would need regulatory approval.</p>
<p>Spiny emex, double gee, etc <i>Emex australis</i></p>	<p>Weevil (<i>Perapion antiquum</i>) did not establish. Weevil (<i>Lixus cribricollis</i>). This species also appears to have not established. Red apion (<i>Apion miniatum</i>) has not established. Dock aphid (<i>Brachycaudus rumexicolens</i>) reduced amount of dormant seed produced by <i>E. australis</i>. Fungus (<i>Phomopsis emicis</i>) reduced the amount of dormant seed produced by <i>E. australis</i>.</p>
<p>St John's wort <i>Hypericum perforatum</i></p>	<p>Currently, only six of the twelve agents released as biocontrol agents for St John's wort have become established in Australia. These agents can reduce the spread and density of St John's wort infestations, and in some cases control is achieved to the level where the weed is no longer of concern and no other control is necessary. More commonly, other methods are still required to achieve the desired level of control; however, these need not be used so frequently or intensively. St John's wort leaf beetles (<i>Chrysolina hyperici</i>, <i>C. quadrigemina</i>). St John's wort gall midge (<i>Zeuxidiplosis giardi</i>). St John's wort stunt mite (<i>Aculus hyperici</i>), an eriophyid mite. St John's wort rootborer (<i>Agrilus hyperici</i>), a beetle. Aphid (<i>Aphis chloris</i>). A fungus (<i>Colletotrichum gloeosporioides</i>) has been considered a potential biocontrol agent.</p>
<p>Nodding thistle <i>Carduus nutans</i></p>	<p>The following agents have been released. Together they reduce plant vigor and seed production. However, there are large numbers of seeds present in the soil, so that nodding thistle will not be reduced dramatically until this seed bank has been depleted. Seed weevil (<i>Rhinocyllus concius</i>) - thistle-head weevil. Seed fly (<i>Urophora solstitialis</i>). Crown weevil (<i>Trichosirocalus horridus</i>). The rosette weevil (<i>Trichosirocalus mortadelo</i>) was released in 1993 and it attacks the crown region of the rosette.</p>
<p>Water hyacinth <i>Eichhornia crassipes</i></p>	<p>Water hyacinth is regarded as the world's most serious floating aquatic weed. It is one of the fastest growing most aggressive plants on earth. Waterhyacinth weevil (<i>Neochetina eichhorniae</i>) and <i>N. bruchi</i>. Waterhyacinth moth (<i>Niphograpta albiguttalis</i>). A moth (<i>Xubida infusellus</i>) with limited establishment and minimal impact. In Australia, waterhyacinth weevil and an indigenous fungus (<i>Acremonium zonatum</i>) together provide greater control than either the weevil or fungus alone.</p>
<p>Water lettuce <i>Pistia stratiotes</i></p>	<p>Weevil (<i>Neohydronous affinis</i>) in Queensland has reduced the weed to insignificant levels at release sites. The weevil has spread and effectively controlled water lettuce throughout most of its range in eastern Australia.</p>

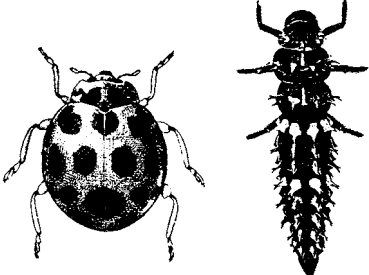
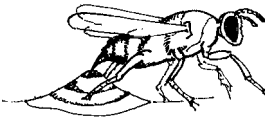
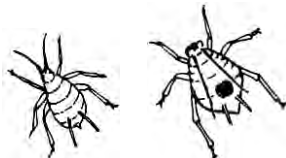
INSECT AND ALLIED PESTS

Traditionally, biological control of insects and mites has been brought about by other insects and mites and by disease organisms. Because biological control is part of the phenomenon of natural control, the number of aphids on roses at any one time can be controlled naturally by at least 10 insects, several diseases, the weather, availability of food, and other factors. Most natural enemies increase proportionately to their host numbers. **Closely related methods** include pheromones (page 101) and sterile insect release techniques (**SIT**) (page 103).

The biocontrol program against a particular pest not only varies between crops but increasingly between varieties. In leafminer control in tomatoes, variety can be the major factor influencing buildup of the pest and must be reflected in the introduction rate and pattern of parasitoids.

By other insects and mites

The mass release of beneficial insects is now a "mainstream" component of many cropping systems, most notably - citrus, strawberries, nursery, cut flower and glasshouse vegetable crops, sweet corn, macadamia nuts. Insects are introduced into the crop then disperse on their own. They may be predatory or parasitic.

<p>Predation</p> <p>PREY</p>	<p>Predatory insects, mites and spiders attack and eat other insects or mites — PREY.</p> <ul style="list-style-type: none"> • Predatory ladybirds, other beetles and lacewings feed on their prey by chewing. Predatory bugs and mites suck juices from their hosts. • Either adults or larvae or both may be predatory. • Some predators supplement their diet with pollen, nectar and fungi. • Predators are usually more robust than parasites. • Ladybird beetles devour more aphids when aphids are abundant than when aphids are scarce. 	 <p>Common spotted ladybird (<i>Harmonia conformis</i>) and its larvae feed on aphids. NSW Dept. of Industry & Investment.</p>
<p>Parasitism</p> <p>HOST</p> <div style="border: 1px solid black; padding: 2px;"> <p>A parasitoid is an organism that lives on or in a host organism and ultimately kills the host.</p> </div> <div style="border: 1px solid black; padding: 2px;"> <p>Kairomones are a type of pheromone that can attract parasites and predators</p> </div>	<p>Parasitoids lay eggs on or in other insects — HOST. The eggs hatch and the developing larvae feed on the host.</p> <ul style="list-style-type: none"> • The most common parasitoid insects are wasps and flies. • Each species of parasitoid attacks a certain stage of its host's life cycle. • Female wasps lay their eggs in the host insect. Each wasp egg hatches into a larva which consumes the host eventually killing it. The wasp larva pupates and later an adult wasp emerges through an exit hole. • Parasitoids are commonly used in biocontrol programs to parasitize adult insects, larvae and eggs. <div style="border: 1px solid black; padding: 5px;"> <p>Trichogramma wasps are insect egg parasitoids commonly used throughout the world. Some species have a wide host range others are more specific. Adult female wasps use chemical and visual clues to locate moth eggs on foliage (Crawford, 2006b).</p> <ul style="list-style-type: none"> • Kairomones on the mother scale are left by her near the eggs during egg laying. • The visual clues are the egg shape and color. The female wasp drills a hole in the egg and deposits 2-3 eggs. • Trichogramma wasp eggs hatch inside and the emerging wasp larvae feed on the contents of the moth egg, parasitized eggs turn a dark color. The wasp larvae pupate inside the moth egg and finally the adult wasp emerges chew a circular hole in the moth egg to emerge. </div>	 <p>A tiny parasitic wasp lays its eggs in a scale insect.</p>  <p>Parasitized aphids swell, change color (brownish). A few days later an adult parasitic wasp chews its way out of the mummy leaving a neat round hole.</p>

Bioinsecticides

Diseases of insects and mites are caused by viruses, bacteria, fungi and nematodes. When applied, they are often called bioinsecticides, microbial or biological pesticides, as they are usually applied in the same way as pesticides. Some biocontrol agents must be registered before they can be sold commercially in Australia.

Virus bioinsecticides

GEMSTAR
nuclear
polyhedrosis virus

Virus diseases are researched in Australia. Viruses only reproduce in living cells, are **UV** sensitive, slow to kill, sensitive to host age, but are host specific and relatively safe. They can be genetically engineered to increase the speed at which they kill infected insects.

- **Entomopoxviruses (EPVs)** only attack insects, eg beetles, grasshoppers, caterpillars.
- **Gemstar® (nuclear polyhedrosis virus (NPV))** is registered for the biocontrol of corn earworm (*Helicoverpa armigera*) and native budworm (*H. punctigera*) in cotton, sorghum and chickpeas.
 - Although not as fast acting as conventional insecticides, it has minimal impact on beneficial insects and a favorable environmental impact. Gemstar® is an insect virus produced from *Helicoverpa* larvae infected with **NPV**.
 - During the manufacture *Helicoverpa* are reared from eggs and then infected with the virus, which is then allowed to replicate within the insect. At a specified time the insects are harvested, milled and the product formulated.
- **Other insect viruses** include cabbage white butterfly virus, codling moth virus, lightbrown apple moth virus and potato moth virus.

Bacterial bioinsecticides

CHECK CURRENT
REGISTRATION
STATUS OF
PESTICIDES
PRIOR TO USE

Bt (Bacillus thuringiensis) is a soil bacterium that produces a protein with insecticidal qualities. Traditionally a fermentation process has been used to produce an insecticidal spray from these bacteria. In this form the **Bt** toxin must be eaten by the insect. There are several **Bt** toxins available commercially, each one is specific to certain target insects, eg

- **Bt var. kurstaki** (Dipel®), many more) controls certain **caterpillars**.
- **Bt var. aizawai** (XenTari®, Widestrike®) controls **caterpillars**, eg **corn earworm** or cotton bollworm (*Helicoverpa armigera*), **diamondback moth** (*Plutella xylostella*).
- **Bt var. israelensis** (Vectobac®), many more) controls **mosquitoes**.
- **Bt var. tenebrionis** is toxic for chrysomelid and tenebrionid **beetles**. In Australia, it is used for treating chrysomelid pests of plantation eucalypts.

DIPEL

XenTari

Crop plants have been genetically modified (GM) to contain and produce the pest-killing proteins from **Bt**. When a susceptible insect ingests the **GM** crop expressing the **Bt** protein; it stops feeding and soon dies as a result of the **Bt** toxin binding to its gut wall (page 412).

- **Compared with typical insecticide sprays**, the **Bt** toxins produced by **GM crops** are much safer for people and the environment. Resistance strategies must be put in place to avoid or reduce the chance of the *Helicoverpa* developing resistance.
- **Bt corn and cotton** is now commercially available in a number of countries to control *Helicoverpa* spp. which is otherwise controlled by spraying.

Serenade® Max
Bacillus subtilis

Bacillus firmus is a new insect pathogen of some caterpillars. *B. firmus* is also a naturally occurring soil bacterium which possesses nematicide activities when applied as directed to the soil or as seed treatments.

Bacillus popilliae is supplied commercially to help control the Japanese beetle by infecting it with “milky disease” overseas.

Fungal bioinsecticides

Entomopathogenic
fungi. Fungi need high
humidity

GreenGuard
SC Premium
Locusts,
grasshoppers

Fungal spores are sprayed on aerial plants parts or applied as a soil drench. Spores attach themselves to a suitable host, germinate and penetrate the insect’s cuticle, killing it either by asphyxiation or by emitting toxins. **Fungi** are considered by some to show more promise than nematodes or bacteria against **greenhouse insects** because they can target several pests at once over a range of crops and environmental conditions. They are effective against both aerial and soil-dwelling insect life stages. However, they are not as virulent, need higher doses but are easy to mass produce.

- **Green Guard® (Metarhizium spp.)** is registered for use by the Australian Plague Locust Commission (APLC) and others, to control **locusts and grasshoppers**. It has been approved for use on organically certified properties and in environmentally sensitive areas. It is specific to locust and grasshoppers and cannot be a source of residues; there is no withholding limit and the only other insect known to be at risk are foraging bees. If worker bees are foraging in the spray area when *Metarhizium* is applied, some kill can be expected but the fungus does not affect the overall health of the hive. Hard-bodied beneficial insects including ladybirds and lacewings will not be harmed.
- **ChaferGuard® (Metarhizium sp.)** for **redheaded pasture cockchafer** (*Adoryphorus couloni*).
- **BioCane® (Metarhizium sp.)** for **greyback canegrub** (*Dermolepida albohirtum*).



Fungal bioinsecticides
(contd)

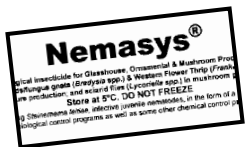
- **Other fungi which kill a range of insects** include:
 - *Verticillium lecanii*.
 - *Entomophthora* sp. and *Paecilomyces* spp. may attack aphids.
 - *Beauveria bassiana* has been commercialized overseas for use against a wide variety of pests, including **whiteflies, beetles, grasshoppers and psyllids**. It is a facultative parasite but it can grow as a plant endophyte and form interactions with plant roots. *B. bassiana* can be genetically manipulated to improve virulence and other traits (Wu et al 2008).
 - *B. bassiana* is also effective against Lepidoptera pests, eg **armyworm, beet armyworm, black cutworm, corn borer** which are destructive pests of corn and cabbage and other vegetables.
 - *Mycotrol* and *BotaniGard* are registered for use in the **US and Mexico** for biocontrol of grasshoppers, whiteflies, aphids, thrips and diamondback moth on crops such as cabbage, broccoli, cucumbers and greenhouse ornamentals.
 - **Native Australian fungus (name withheld) for soft-bodied pests** such as mirids, aphids, mites and early stage *Heliothis* larvae on cotton (Becker Underwood and Cotton CRC 2008). Specially reared spores are mixed with oil and then added to a water solution which is sprayed on crops in the same way as synthetic chemical treatments. When the sucking pest comes in contact with the fungus, the spores germinate and invade the insect body tissue and the pest dies in 3-7 days. The next step is field trials then submitting an application for the commercial registration of the bio-control fungus with the **APVMA**.
 - **Biopesticides containing beneficial fungi are often grown on grains or other solids** but it appears that a liquid diet can work better (liquid culture fermentation), is much cheaper and increased yields of insect-killing fungi including *Metarhizium* and can produce different types of fungal cells (conidia, blastospores and microsclerotia) for application to insects.

Nematode bioinsecticides
Entomopathogenic nematodes (ENs)



NEMATODES
(50 million infective juveniles)

Ecogrow
www.ecogrow.com.au/



Some nematodes are symbiotically associated with bacteria which they carry within their intestinal tract, often within a specialized vesicle. The **nematodes seek out natural openings on insects** and move into the bloodstream where they release the bacteria which multiply and causes septicemia. Certain insects are susceptible and given enough nematodes they will die. The bacteria then convert the insect into a suitable food for the nematodes which breed in large numbers which in turn feed on surrounding insects (Grewal et al 2005).

<i>Beddingia siricidola</i>	- Sirex wasp (<i>Sirex noctilio</i>) in <i>Pinus radiata</i>
<i>Heterorhabditis bacteriophora</i>	- Black vine weevil (<i>Otiorhynchus sulcatus</i>)
<i>Heterorhabditis zealandica</i>	- Argentine stem weevil (<i>Listronotus bonariensis</i>), certain scarab grubs, bill bug
<i>Rhabditidae necromena</i>	- Portuguese millipede
<i>Steinernema carpocapsae</i>	- Cutworms, armyworms, house termites, cat fleas; research with banana borer weevil and pecan weevil
<i>Steinernema feltiae</i>	- Currant borer moth caterpillars (<i>Synanthedon tipuliformis</i>) in Tasmania, kills 99.8% of caterpillars in cuttings
<i>Steinernema feltiae</i>	- Fungus gnats, mushroom fly

Becker Underwood is the world's largest producer of beneficial nematodes, which work well in management programs to control insects such as thrips, weevils and codling moth. Also a range of beneficial nematodes that control slugs. www.beckerunderwood.com/

- **Nemasys®Pro** is the dedicated website for **Nemasys®** and **Nemaslug®** brands of beneficial nematodes produced for the commercial market by **Becker Underwood** and distributed in Europe. For the home and garden market visit their website www.nemasysinfo.com

Vertebrates

Chooks, frogs, birds



Vertebrates, especially birds have long been known to prey on insects.

- **Controlling vineyard pests** is now only a phone call away! Vine weevils damage leaves, shoots and grapes reducing vigor and yield; severe infestations may lead to death. Foraging chickens eat weevils in the leaf litter and topsoil on the vine yard floor. The intent is to use a mobile system which allows chickens to be moved between properties targeting areas where weevil infestations are high. To protect against raiding foxes there is a convenient remote-controlled door.
- **Frogs** play a major role in minimizing damage to rice crops by eating a large range of pests. The study highlighted the potential risks of reducing frog numbers on farms either deliberately or inadvertently which could potentially result in the rise in rice pests and associated crop damage (Doody et al 2010).

Pheromones

What are pheromones?

A **pheromone is a chemical that is secreted** by one insect which influences the behavior or development of another insect of the **same species**.

- **Pheromones are widespread** in the animal kingdom.
- **Some pheromones have been synthesized.**
- **In pest control, sex attractants have been given the most attention**, because they are often effective in incredibly small concentrations; one caged virgin female of a pine sawfly has been shown to attract over 11,000 males!
 - Sex attractant pheromones are chemicals which directly facilitate mating. Typically the pheromone is produced by one sex only and affects the other, but this varies.
 - Sex pheromones occur in many groups of insects, but moths have received the greatest attention, mainly because of their economic importance and observations of collectors.

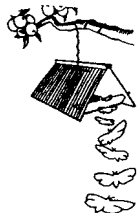
A **kairomone** is a chemical messenger emitted by organisms of one species that benefits or affects organisms of **another species**, eg may indicate a food source or the **presence of a predator** for the receiver. They may also attract parasites and predators.

Pheromones in pest control

Pheromones may be used for:

- Monitoring, eg detection and counting.
- Direct insect control, eg mating disruption.
- Manipulating insect behavior of both pests and beneficial insects.
- Lure and kill technology.

Monitoring Identification and counting



Female codling moth (*Cydia pomonella*) lure which attracts male moths (a Delta trap).

Monitoring is the identification and counting of an organism.

- **Pheromone traps attract a specific insect pest** depending on the pheromone used.
- **Insect pests are lured to a place** where they can be held long enough to be identified and counted, ie monitored.
- **Regular inspections of insects** captured in pheromone-baited traps scattered throughout a crop indicates the presence, distribution and abundance of a pest.
- **Monitoring buildup of early season populations** provides early warnings of pest infestation. Control measures can be undertaken before serious damage occurs.
- **Monitoring before and after** a control treatment measures the success of spray and other control programs.
- **Detecting hot spots of pest activity**, perhaps areas of inadequate insecticide application or areas of pest resistance.
- **Detecting insects that are small and green and hard to spot in an orchard**, eg fruit spotting bugs. Early detection can tell a grower when to implement control.
- **Thresholds or action levels** can be difficult to determine.
- **Specialized pheromone traps for different situations**, eg
 - Vertical sticky traps for red scale, whiteflies, aphids, thrips.
 - Funnel traps for corn earworm, black cutworm, sweet potato weevil.
 - Delta traps for codling moth, lightbrown apple moth, oriental fruit moth, potato moth, diamond back moth, Queensland and Mediterranean fruit flies.

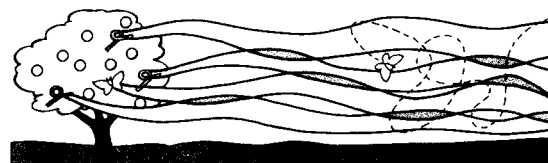
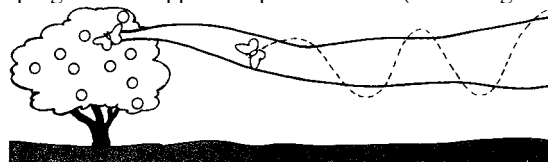
Direct insect pest control Mating disruption



Simple long life dispensers containing the **pheromone** are twisted around the new wood in spring (4 per tree).

A **confusion and mating disruption agent** is formulated as a **slow release generator**. The air around a crop is flooded with female pheromone by placing pheromone dispensers at prescribed places within the crop. Male insects become so confused that little or no mating takes place, eg

- **Mass trappings of pests.** Many traps emitting the pheromone are placed in the crop to lure and capture pests, reducing the pest population and the amount of damage caused. Except for a few pests this method of control is limited and ineffective.
- **Luring insect pests from one place to another** where they cause little damage.
- Used in **IPM** programs for apple and pear orchards (Hetherington 2009).



Upper: In nature the **female** oriental fruit moth (*Grapholita molesta*) releases a powerful sex attractant which allows the male moth to home in and mate.

Lower: Dispensers flood surrounding air with female pheromones. **Male** moths become so confused that finding a mate is impossible. **Isomate®OFM Rosso** pheromone dispensers controls oriental fruit moth (*Grapholita molesta*) in commercial stone fruit orchards.



Lure and insecticide system to indicate the presence of Qld fruit fly.

Lure and Kill formulations

Attract and kill

Most effective when used over large areas or entire cropping regions

Lure and kill formulations redirect pest insects away from the natural pheromone sources they normally target and lure them into traps

New "attract & kill" formulations have no chemical residues on fruit, etc.

- **Magnet Insect Attractant Technology** is a blend of volatile attractants formulated with insecticides effective against *Helicoverpa* moths. Magnet attracts moths to treated strips in the crop. Can be used for monitoring or a knockdown product.
- **Magnet MED** is a 'lure and kill' type of formulation for Mediterranean fruit fly (*Ceratitis capitata*) in WA. It contains a fruit fly attractant and an insecticide (deltamethrin) which kills them within seconds. The card-like device is hung on the branches of trees. No chemical residue is left on fruit.
- **Eco-Naturalure, Entrust** contain a yeast protein bait that lures fruit fly to feed on it and ingest a natural insecticide, spinosad, which kills them before they can mate and lay eggs. Rotting fruit (a source of protein) must be cleaned up. Must be applied as recommended.
- **Male Annihilation Technique (MAT)** is designed to reduce male populations. Celotex wafers impregnated with the **powerful male-specific parapheromone attractant** methyl eugenol and the insecticide dibrom spinosad, is aerially distributed.
- **Attract and kill formulations** can be developed following the successful identification of a sex pheromone attractant in an insect, eg the green mirid (*Creontiades dilutus*).
- **However, the inclusion of certain types of insecticides** or sterilants in some lure and kill formulations presents a major obstacle to public acceptance.

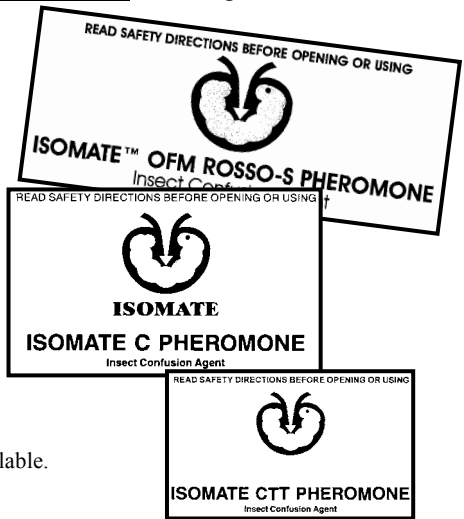
Some pheromones for insect pests

In Australia pheromone traps are available for many insect pests including:

- **Moths** (Lepidoptera), eg
 - Citrus leafminer (*Phyllocnistis citrella*)
 - Cluster caterpillar (*Spodoptera litura*)
 - Codling moth (*Cydia pomonella*)
 - Corn earworm (*Helicoverpa armigera*)
 - Lightbrown apple moth (*Epiphyas postvittana*)
 - Native budworm (*H. punctigera*)
 - Oriental fruit moth (*Grapholita molesta*)
 - Potato moth (*Phthorimaea operculella*)
- **Flies** (Diptera), eg
 - Mediterranean fruit fly (*Ceratitis capitata*)
 - Queensland fruit fly (*Bactrocera tryoni*)
- **Cockroaches** (Blattodea), eg
 - German cockroach (*Blattella germanica*)
 - Oriental cockroach (*Blatta orientalis*)
- **Beetles** (Coleoptera), eg
 - Sweetpotato weevil (*Cylas formicarius*)
 - Dried fruit beetle (*Carpophilus* spp.)
- **Bugs** (Hemiptera), eg
 - Citrus mealybug (*Planococcus citri*)
 - Fruitspotting bugs (*Amblypelta* spp.) not yet available.
 - Red scale (*Aonidiella auranti*)
- **Many stored product beetle and moth pests.**

DISRUPT-CM
MATING DISRUPTING AGENT

DISRUPT-OFM
MATING DISRUPTING AGENT



Pros and cons of pheromones

Where insecticides are still used, pheromone monitoring helps timing and precision of spray application and allows less frequent use of insecticides and lowers costs.

- **Reduced use of insecticides** results in less operator hazard, less residues in soil, water and food, less impact on the environment and less potential for resistance to develop.
- **No harmful effects on beneficial insects**, other animals or harmful residues.
- **Pheromone monitoring** is the mainstay of Integrated Pest Management (IPM) programs for major and minor pests.
- **It is possible to trap different species** in the same trap using different lures.

Considerations include:

- **Mating disruption controls only target species**; therefore it may not be practical where there is a complex of pest species.
- **Some insects, eg aphids** are not directly controlled by pheromones because:
 - Aphids are not as attracted to scents as moths are.
 - Aphids reproduce asexually for most of the year.
 - Climatic conditions, eg wind controls aphid flight paths.

Manipulation of predators and parasitoids, etc

Predator pheromones can be used to:

- Identify, detect and monitor predator and parasitoid populations.
- Draw parasites and predators away from areas to be sprayed with a toxic pesticide.
- Attract parasites and predators to crops, orchards and gardens where the pests are.
 - **Envirofeast**® is a yeast-based product for the attraction and sustenance of beneficial insects in cotton. Envirofeast® increases the numbers of beneficial insects, eg lady beetles and lacewings, which prey on *Helicoverpa* spp. and twospotted mites. Optimum timing and placement of Envirofeast® in cotton systems is essential.
 - **Predalure** attracts beneficial insects, eg lacewings, hover flies, etc.
 - **Honey bee magnet** is a blend of selected pheromones which attract worker bees to potential food sources (flowers) as a pollination aid.
 - **Traps plants** attract predators and other beneficial insects (page 104).

Envirofeast

Predalure

Honey bee magnet

Detecting presence of pheromones

Sensors can be used **to detect pheromones at extremely low levels**, giving advance warning of the presence of pests at levels that would not normally be detected, allowing early management actions such as the introduction of beneficial organisms or spraying. The technology can also be used to disrupt mating (SARDI 2008).

CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

Sterile insect technique (SIT)

How does SIT work?	<p>SIT involves the production and release of large numbers of sterile flies over infested areas. By mating with wild flies, these 'sterile flies' introduce sterility and other genetic defects into field populations.</p> <ul style="list-style-type: none"> • SIT has been successful in controlling only a few insect pests, usually flies. • Flies are reared in vast numbers on artificial media and sterilized by exposure to gamma radiation. • The dose is carefully calculated so as to achieve sterility without diminishing the vigour and competitiveness of the males. • Sterilisation of male insects chemically or by irradiation is only successful with species where the females only mate once and are unable to differentiate between sterile and non-sterile males. • Very large numbers (millions) of sterile male flies must be released over infested areas to ensure that a substantial percentage of wild females mate with sterile males. • Successive releases are made and the percentage of successful wild male / female matings is progressively reduced. <ul style="list-style-type: none"> • If a sterilised male is involved, only a proportion of the resulting eggs will hatch. • Male offspring inherit this infertility. • Female offspring receive several mutations that, in following generations, result in the production of mutant, blind female flies.
Genetic engineering can improve SIT	<p>A group of British entomologists have engineered vinegar flies (<i>Drosophila</i> spp.) so that only males are produced and when they mate with normal females, the females give birth only to males (thus ending the population).</p> <ul style="list-style-type: none"> • In 2010, when the vector of dengue fever, the mosquito (<i>Aedes aegypti</i>), was genetically modified and released in a similar system, the resident mosquito population in part of Grand Cayman in the Caribbean was reduced by 80%.
Screw-worm flies overseas	<p>SIT has been used effectively against:</p> <ul style="list-style-type: none"> • The old world screw-worm fly (<i>Chrysomya bezziana</i>) is the most important insect threat facing Australia's livestock industry. It is a serious pest of livestock in Papua New Guinea and SE Asia. Females lay their eggs in sores or other open wounds on animals. After hatching the larvae eat into the tissues of the host. • The new world screw-worm fly (<i>Cochliomyia hominivorax</i>) which is a pest of livestock in the USA and Mexico.
Flies in Australia	<p>Australian sheep blowfly (<i>Lucilia cuprina</i>).</p> <ul style="list-style-type: none"> • In attempts to control this pest, chromosomally altered flies have been mass produced on artificial media and released in very large numbers. • The offspring of genetically altered males and wild females are defective, eg they may be sterile or blind and incapable of surviving or reproducing. <p>Queensland fruit fly (<i>Bactocera tryoni</i>).</p> <ul style="list-style-type: none"> • Millions of Queensland fruit flies (<i>Bactocera tryoni</i>) are reared at the Elizabeth Macarthur Agricultural Institute (EMAI), Camden, and then irradiated at the Australian Nuclear Science and Technology Organization (ANSTO) to render them sterile. They are then released into the environment to "overflow" wild fruit fly population, to minimize the chance of a wild fertile male and female mating to make viable eggs. SIT is used with parasitic wasps to provide augmentative control of Queensland fruit fly (page 125).

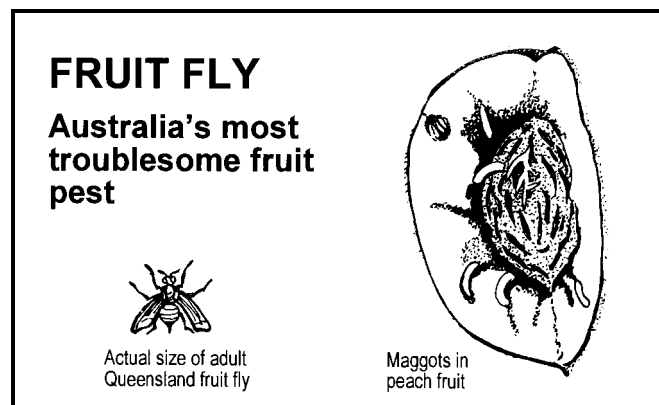



Fig. 13. Queensland fruit fly (*Bactocera tryoni*).

Companion planting

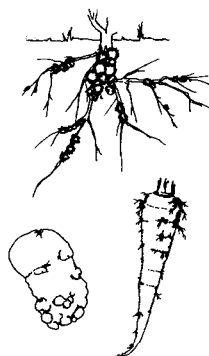
We expect too much from companion planting (Cedric Bryant 2011)

<p>Companion plants</p> <p>Companion planting has evolved into sophisticated IPM, etc. Farm habitats can be ecologically engineered making them less favorable for pests and more attractive to beneficial insects.</p>	<p>True companion planting means mixing species which are said to grow better in each other's company than alone and avoiding mixing those which do not.</p> <ul style="list-style-type: none"> • Onions and related plants react badly on most other vegetables, especially beans and peas, but they grow well with carrots. • Carrots grow well with lettuce, broad beans, peas, radishes and the onion family. • Cabbages grow well with potatoes and cucumber. • Potatoes do not react well with tomatoes, but prefer beans, peas, celery and cabbage. • Tomatoes grow well with asparagus, parsley and basil. • Peas grow well with turnips, carrots, cucumbers, potatoes and sweet corn. • Lettuce grows well with radishes and carrots. • Celery grows well with cauliflower, leeks and tomatoes.
<p>Semiochemicals</p>	<p>Semiochemicals are "signaling" compounds that are produced by some plants that either attract or repel potential insect pests. They are non-toxic chemicals such as sex pheromones which modify insect behavior patterns, eg mating.</p> <ul style="list-style-type: none"> • Some can attract or retain parasitoids within the crop. • The butterfly pea (<i>Crotalaria ternatea</i>) has behaviour modifying compounds that can potentially deter insect egg laying, feeding and cause direct mortality of insects. The compounds are semiochemical products and their use will enhance conservational biocontrol, support IPM and reduce pest control costs on cotton while reducing overall pesticide use in the industry (Mensah 2011).
<p>Attracting beneficials</p>	<p>Providing predators and parasites of pests with food sources such as nectar and pollen, shelter and alternative hosts or prey may help them more effectively reduce pests.</p> <ul style="list-style-type: none"> • Herbs in flower attract beneficials because they have a 2-fold diet of pollen / nectar. Predator insects generally need plants with open flowers which have readily accessible pollen and nectar. Beneficial insect attractors include angelica borage, caray, coriander, dill, and fennel. • Tansy (<i>Phacelia tanacetifolia</i>) in NZ attracts hoverflies which use the flowers as a pollen source. • Commercial attractants include Envirofeast and Predalure (page102).
<p>Attracting pests</p> <p>Trap plants</p> <p>Trap plants often do not give sufficient degree of control to offset the expense and risk involved in their use.</p> <p>Trap crops</p>  <p>Corn earworms (<i>Helicoverpa</i> spp.) (up to 40 mm long). Photo©NSW Dept. of Industry & Investment.</p>	<p>Trap plants are sometimes called decoy plants, bait plants and other names depending on how they are used for disease or pest control (Agrios 2005).</p> <ul style="list-style-type: none"> • Trap plants are highly susceptible plants that can be set either around plants or between rows of plants grown in areas known to be infected with diseases or infested with insect pests. They lure pests away from valued crops. • Lists of trap crops are included in most books on organic plant protection. However, you can think of a suitable plant or crop which is very susceptible to the pest you wish to control. Ideally a trap crop should be of economic value and included in normal crop rotation, but this can be difficult. • The pest must be controlled on trap plants; otherwise they become breeding grounds for the pest. <p>Trap plants may be used to:</p> <ul style="list-style-type: none"> • Monitor pests. • Provide some control, eg pests on trap plants must then be handpicked or sprayed. <p>Examples of trap crops.</p> <ul style="list-style-type: none"> • Corn earworm, native bollworm (<i>Helicoverpa</i> spp.) prefers to dine on chickpeas, sorghum and pigeon peas rather than cotton and other susceptible crops. These trap crops can be grown in patches in cotton growing areas to entice <i>Helicoverpa</i> moths to lay their eggs on them. When there are sufficient caterpillars feeding on the trap crops they are slashed before many of the larger caterpillars can pupate in the soil and the soil cultivated thoroughly to destroy pupating caterpillars. Early-season trapping can yield immediate benefits to growers by significantly lowering <i>Helicoverpa</i> pressure, reducing the use of pesticides. • Spring trap crops, eg chickpeas, field peas, are designed to attract <i>H. armigera</i> as they emerge from overwintering pupae in spring. A trap crop is timed to flower in spring to concentrate locally emerging <i>H. armigera</i> moth into a crop where they can be destroyed. Can help reduce the early season buildup of <i>Helicoverpa</i> in a district in some seasons. • Summer trap cropping aims to draw <i>Helicoverpa</i> away from a susceptible crop such as cotton or mung beans and concentrate them in another crop such as sorghum, pigeon pea. Once concentrated in the crops, <i>Helicoverpa</i> larvae can be rigorously controlled or the crop destroyed. Also some summer crops may produce large numbers of beneficial insects that can move into nearby crops, eg parasitic wasps (<i>Trichogramma</i> and <i>Microplitis</i>) are often produced in large numbers in sorghum and maize. In central Qld cotton growers are using summer trap crops of pigeon pea as part of their resistance management strategy for Bollgard® cotton. Check your cotton pest management guide.

Attracting pests

Crop plants (contd)

Cotton growers must plan the flowering of trap crops to coincide with the life cycle of *Helicoverpa* moths and ensure that trap crops do not just breed more *Helicoverpa*



Root knot (*Meloidogyne* spp.) damage to vegetables.

- **An area-wide management** strategy **combines spring trap cropping**, timely *Helicoverpa* control in crops and **pupae busting in autumn**. In combination these activities aim to reduce the size of the local *Helicoverpa* populations, reducing *Helicoverpa* pressure on susceptible crops in the participating region. The trap crop must be managed appropriately (Spring Crop Management Guidelines (Daff, Qld 2000).
- **Eucalyptus leaf beetles** (*Chrysophtharta bimaculata*) are serious pests of eucalypt plantations (*Eucalyptus nitens*) in Tasmania (Baker et al 2003). Insect defoliation projected over 20 years is estimated to reduce wood volume by up to 50%.
 - **Interplanting of tree species preferred by the leaf beetles** in *E. nitens* plantations may act as trap trees or act as early warning for monitoring large populations of leaf beetles.
 - **Studies indicate that inundative release of predatory ladybirds** into *E. nitens* plantations to biologically control the leaf beetles was feasible but not always an economic option.
- **Root knot nematodes** (*Meloidogyne* spp.) can be controlled by cultivars belonging to the French marigold group (*Tagetes patula*) which produce root exudates that stimulate hatching of nematode eggs. Larvae which develop from these eggs enter the roots of the plants, die shortly afterwards without completing their life cycle.
 - **Plant marigolds in 15 cm wide rows** about 15 cm apart and grow them for a whole growing season (90-120 days). **The marigold crop must be kept free of weeds** during this period. A winter crop of grass, eg annual rye or fescues, will continue control for many months. The combined effects of marigolds and grass will starve out the nematodes.
 - **By using trap plants in a crop rotation**, root knot nematode populations can be reduced sufficiently to allow annuals to be grown without further treatment the next season.
 - **Other trap plants may suppress other nematodes** (Agrios 2005). The eggs of the potato cyst nematode (*Globodera pallida*) can be forced to hatch in the absence of a host by:
 - Amending the soil with purified forms of **egg-hatching factors**.
 - Planting sticky nightshade as a "trap crop" whose roots exude the chemicals, but don't support the nematode's reproduction.
- **Vectors of virus diseases**. Corn, rye or other tall plants can be planted around a field of beans to trap **incoming aphids carrying viruses** which affect beans and pepper. The aphids feed on the peripheral taller rows of corn and rye and as most of these aphid-borne viruses are non-persistent in the aphid, the virus reaching the crop is diminished.

Repelling pests

Pest repellent plants

Purchase one of the many books available on repellent plants, some contain spray recipes

Structure. Prickly plants such as gorse, some grevilleas and hakeas will repel dogs and cats. However, it should be noted that such plants can cause serious eye injuries.

Aroma. Many organic gardeners maintain that repellent plants bestow some protection on nearby crops up to a distance of 1 meter.

- **Many herbs contain substances that protect them from pest attack** but these substances do not protect surrounding plants. They can be extracted and used as a spray to kill or repel garden pests.
- **Some reputedly repel a variety of insects**, while others are apparently only effective against a particular pest.
- **More research is needed on which pest species are repelled by which plant species.**
 - **Chives and garlic** are reputed to repel aphids, but bulbs of these plants are often infested with black bulb aphid (*Rhopalosiphoninus latysiphon*). Chives and garlic possibly only repel some species of aphid, eg green peach aphid (*Myzus persicae*).
 - **Some insecticides contain garlic** and other herbs to repel insect pests in addition to an insecticide to kill them.
- **Companion planting is not usually practical for farmers** who need something much simpler, less space consuming and more effective.

Table 3. Plants which reputedly repel certain pests.

REPELLENT PLANTS	PESTS REPUTED TO BE REPELLED
Chives, garlic onion (<i>Allium</i> spp.) make a great border	Some species of aphids, other insects, spider mites.
Citronella, lemon grasses (<i>Cymbogon</i> spp.)	Ants, possibly cats, mosquitoes, general insect repellent.
Lavender (<i>Lavendula</i> spp.)	Aphids, whitefly, clothes moths, silverfish, attracts bees.
Mint, pennyroyal (<i>Mentha</i> spp.)	Aphids, cabbage white butterfly, fleas, flies, mosquitoes, attracts pollinators.
'Mozzie Blocker' (<i>Leptospermum liversidgei</i>) in pots	Mosquitoes.
'Mozzie Buster' pelargonium (<i>Pelargonium citrosum</i> 'Van Leenii')	Mosquitoes, other insects.
Pyrethrum (<i>Chrysanthemum cinerariifolium</i>)	Aphids, thrips, whitefly.
Rosemary (prostrate) (<i>Rosmarinus officinalis</i>)	Aphids, cabbage white butterfly, other caterpillars, and whitefly, and clothes moths, leafhoppers.
Tansy (<i>Tanacetum vulgare</i>)	Ants, aphids, fleas, flies, fruit flies, moths.
Wormwood (<i>Artemisia absinthium</i>)	Aphids, whiteflies, bugs, cats, dogs, snails, slugs.
Marigold (<i>Tagetes</i> spp.) French or African marigolds	Reduce nematode infestations.
Nasturtium (<i>Tropaeolum majus</i>)	Whiteflies and fleas.

Pest-suppressive crops and landscapes

There is mounting evidence that the restoration of plant biodiversity within and around crop fields can improve habitat for domestic and wild bees as well as for other insects (Nicholls and Altieri 2013). Habitat manipulation is also in tune with the public's desire for clean food and concern for the environment.

Pest-suppression	<p><u>Environments that favor the movement of beneficial insects into crops</u> could help in the fight against insect pests. Crops near remnant vegetation contain more beneficial insects than those remote from native vegetation. Projects have been established to understand features that may create landscapes that are less prone to pests.</p> <ul style="list-style-type: none"> • <u>In sites in Qld, NSW and WA</u>, native plants are rarely found to harbor insect pests of crops but are sources of beneficial insects, eg spiders, lace wings. • <u>Weeds often harbor pests</u>. Some landscapes seem to be less prone to insect pest infestation. The field work consists of 3 major components: <ul style="list-style-type: none"> • Identifying habitats where pests and natural enemies breed. • Assessing their movement between crops and native vegetation. • Determining their relative time of arrival to the crop. This is important as the best pest control happens when natural enemies arrive at about the same time as the pests. • <u>Native vegetation</u> is an important habitat for beneficial insects particularly when few crops are planted and weeds and volunteer crop plants are harboring pests. • <u>Results highlight</u> the importance of maintaining and managing native vegetation remnants on farms to provide pest control services while contributing to biodiversity conservation and landscape amenity and stewardship. • <u>The challenges</u> of mixed plantings are described on page 59.
Guidelines for growers <div style="border: 1px solid black; padding: 2px;"> <p>Guidelines for property management to capture pest control services in IPM practices and management of their natural resources are available.</p> <p>This may lead to keeping pest populations lower for longer, and so:</p> <ul style="list-style-type: none"> • Delays insecticide use • Decreases amount of insecticides needed • Reduces production waste </div>	<p><u>Perennial habitat</u> is important for encouraging pest control services. Research will show how much perennial habitat is needed and the best place to put it. For some growers perennial crops may work best for their business. However, revegetating with native bush species has benefits beyond ecosystem services of pest control including biodiversity, habitat for pollinators and carbon capture (Bowman 2012).</p> <ul style="list-style-type: none"> • <u>Several species of aphid predators</u> important for crop pest control were found breeding on native bush eating prey not found in crops. A single ladybird eats up to 60 aphids per day. Many of the predators providing pest control in crops use the native vegetation when no crops are in the ground. The native bush provides important breeding habitats allowing predators of crop pests a place to live and breed, ready to move onto crops. • <u>However, weeds in the native bush must be managed</u> as they can often harbor pests and diseases of crops. • <u>Remnant native vegetation</u> in grain landscapes has fewer pests and higher numbers of predators than cropping areas. Native vegetation is rich and abundant with spiders which are the first predators to colonize newly emerging crops. • <u>Once native habitat on farms drops below 10%</u> there is a rapid increase in pest damage. Other perennial habitat other than native vegetation can capture better pest control services. Research in the Lockyer valley showed that pest populations were kept lower for longer in agricultural landscapes with lucerne excessing 10% of the cropping area.
Habitat manipulation Ecological engineering Revegetation by Design <div style="border: 1px solid black; padding: 2px;"> <p>Gurr et al (2004) reviews progress in the fields of ecological engineering and habitat manipulation.</p> <p>Chapters cover a broad sweep of research in agriculture and agroforestry to molecular approaches. These are academic articles but anyone with an interest in sustainable pest management would find it useful and stimulating.</p> <p>See also page 370.</p> </div>	<p><u>Habitat management</u> is a form of conservation biological control. It is about modifying the environment, eg manipulating farm habitats to make them less favorable for pests and more attractive for beneficial insects. It involves providing the predators and parasites of pests with food sources such as nectar and pollen, shelter and alternative hosts or prey so they can more effectively reduce pest densities. Most Australian research has focused on broadacre crops, viticulture and commercial horticulture, but there is potential for habitat manipulation to contribute to ornamental horticulture, landscape management, bush areas and gardens (Gurr et al 2004, Landis et al 2000, Moody 2004).</p> <ul style="list-style-type: none"> • <u>Crop diversification</u> can be provided by paddock margin planting, within-crop strips or cover crops that provide resources to natural enemies. • <u>Knowledge of which plant species are most useful is far from complete</u>. Flowers structure, flowering time and flower color need to be considered. <ul style="list-style-type: none"> • <u>The size and shape of a flower limits the kinds of insects</u> that can access its pollen and nectar, often permitting tiny parasitic wasps access to both pollen and nectar while preventing access to larger pest species. Brassicaceae (mustard family) including alyssum and rocket, and members of the Umbelliferae (carrot family), such as coriander, dill, fennel and Queen Anne's lace are widely regarded as having suitable flower structures. Many flower crops in the Fabaceae (legume family, eg faba beans, lucerne, and vetch) provide habitat and alternate prey for a wide variety of natural enemies. • <u>Flowering time is important since many adults of many beneficial species</u> live only a few days if unable to feed. Pollen and nectar must be available early in the growing season to nip pest outbreaks in the bud. Sequential plantings of short-lived flowers or promotional fresh flowering may be needed to enable flowering at the appropriate stage of the insect life cycles which give season long control (Moody 2004). • <u>Food plants for natural enemies must enhance them and decrease pests</u> so plant species must be carefully selected and tested, to avoid introducing weedy species. There is potential for adverse consequences of introducing inadequately tested plants into the landscape. The crop itself must be made more hospitable to natural enemies.

Habitat manipulation

(contd)

An important feature of habitat manipulation is:

It isn't diversity that counts –

It is the right type of diversity

- **An advantage of ecological engineering for pest management** is that the introduced plants may provide other benefits, an effect known as “**multi-function agricultural diversity**”. This includes wildlife conservation, carbon sequestration, aiding water purity or catchment management, landscape considerations, aesthetic appeal for farm tourism, secondary income stream, eg timber, herbal crops and nitrogen fixation by leguminous ground cover (Gurr et al 2004).
- **The crop itself can be made more hospitable to natural enemies**, eg
 - **Potato moth** (*Phthorimaea operculella*) is a worldwide pest of potato crops. In NSW, the parasitoid wasp (*Copidosoma koehleri*) is widely distributed but not very successful in preventing pest damage. However, marginal plantings of borage (*Borago officinalis*) were fed on by wasps but not the moths. Further research is needed to provide precise recommendations such as width of planting and frequency of spacing.
 - **Lightbrown apple moth larvae (LBAM)** (*Epiphyas postvittana*) cause considerable damage to grapevines. A native parasitic wasp (*Trichogramma carveriae*) promoted as a biocontrol agent has a short life span unless it can feed on nectar which is in short supply in grapevines due to weed control. Sward planting of **white flowered sweet alyssum** (*Lobularia maritima*) provided nectar for the wasps but not for the **LBAM**. Pink and purple flowered alyssum failed to attract the parasitic wasp.
 - **Strip cutting of Lucerne**. An abundance of both pests and beneficial insects inhabit perennial lucerne fields. Conventional harvesting of whole paddocks at 25-30 day intervals in spring and summers results in a high mortality of predators species. In a 60-hectare lucerne field predatory insects in uncut lucerne strips were significantly higher than in cut control areas. *Heliothis* caterpillars were suppressed by the enhanced population of predators.
- **The surrounding vegetation can be made more hospitable to natural enemies**, eg
 - **Revegetation by Design** both reduces pest habitat and promotes populations of beneficial mites and insects. The research is based in the **high-density vegetable production area** on the Northern Adelaide Plains, where major vegetable crop losses are caused by **western flower thrips (WFT)** (*Frankliniella occidentalis*), which transmits the **tomato spotted wilt virus**. The project aims to **replace exotic weed species**, which are an ideal haven for pests such as **WFT**, with **native plant species** which are less suited to the pests and provide food and protection for beneficial species. Research has shown that:
 - Pest thrips are abundant on many weeds but not on some native plant species.
 - Parasitoids and other beneficial insects were the most abundant and diverse invertebrates on the plants native to the area.
 - Crops adjoining the strips of native vegetation should benefit from reduced pest pressure and increased populations of beneficial insects, and if so, reduce the need for toxic sprays to maintain market-quality produce.
 - Revegetation by Design www.sardi.sa.gov.au/

Banker plants, beetle banks, money banks, predator homes, refuge crops



- The aim of banker plants** is to sustain a reproducing population of natural enemies within a crop that will provide long-term pest suppression. They help reduce control costs, increase the chances of establishing natural enemies in production areas. Banker plant methods have been recently reviewed (Huang et al 2011).
- **Non-pest insects or mites on a compatible banker plant** can provide a food source that sustains natural enemies when their target pests are low in the commercial crop. Banker plants are discarded and renewed periodically with fresh ones infested with the non-pest aphids (or whiteflies or other insects or mites). The banker plant insects are usually relatively specific to its banker plants and will not survive or damage the economic crop. A banker system is designed for a specific troublesome pest in a greenhouse and may not work if other pests are introduced or environmental conditions are unfavorable.
 - **Banker plants in greenhouses**. In British Columbia, Canada, a gerbera company used banker plants (wheat plants infested with a harmless strain of aphids) to keep their biocontrols happy when they had eaten all the pests. The aphids only attack monocotyledons (grasses), not dicotyledons (gerbera) so the company has managed to keep their production 100% biological by having 6 wheat plants over each 30,000 sq. ft. section of their greenhouse.
 - **Money banks, predator homes, beetle banks**. Placing the beetle banks in the centers of fields is good for wingless predators such as ground beetles, which are then closer to the highest concentrations of prey.
 - **Refuge crops**. When insecticide use is reduced both adult and larval ladybirds are important predators in cotton. **GM** cotton has reduced the industry's reliance on chemical pesticides but the potential for the main cotton insect pests *Helicoverpa* to develop resistance to **GM** varieties is of concern for growers (Lawrence et al 2007).
 - **As part of a strategy to manage *Helicoverpa*** resistance to **Bt** cotton growers are required to plant refuge crops. The role of these crops is to produce susceptible moths to mate with potentially resistant moths from **Bt** cotton.
 - **A key strategy to prevent resistance developing** involves planting refuge crops near cotton which support significant populations of secondary pests and beneficial species important to cotton production. There is new interest in managing and encouraging beneficial insect and mite parasites and predators, as part of control management strategies for *Helicoverpa* and secondary pests such as mirids.

Biological control of insects and allied pests

Table 4. Examples of the biological control of insects in Australia.





INSECTS	BIOLOGICAL CONTROL AGENTS include:
<p>Aphids Hemiptera</p>	<p><u>Various aphid species</u> (Aphididae) by: Parasitoid wasps (<i>Aphelinus</i>, <i>Aphidius</i>, <i>Aphytis</i>, <i>Praon</i>, <i>Trioxys</i>), eg Rose aphid (<i>Macrosiphum rosae</i>) by <i>Aphidius rosae</i>. Woolly aphid (<i>Eriosoma lanigerum</i>) by woolly aphid parasite (<i>Aphelinus mali</i>). Natural enemies world-wide include 5 species of wasp parasitoids, 2 species of ectoparasite mites, 73 species of predatory insects and a fungus <i>Verticillium lecanii</i>. Cabbage aphid by the cabbage aphid parasite (<i>Diaeretiella rapae</i>). More than 40 species of aphids including including 2 of the most serious pests, green peach aphid (<i>Myzus persicae</i>) and the melon or cotton aphid (<i>Aphis gossypii</i>) by the parasitoid wasp (<i>Aphidius colemani</i>). It can maintain very low levels of aphids if released regularly but does not respond fast enough to 'treat' an aphid outbreak. Sorghum aphids by <i>Lysiphlebus testaceipes</i>. Predatory ladybirds and lace wing larvae placed near an aphid colony attack immediately, eg Common spotted ladybird (<i>Harmonia conformis</i>). Transverse ladybird (<i>Coccinella repanda</i>). Spotted amber ladybird (<i>Hippodamia variegata</i>). Fungal diseases, eg <i>Entomophthora</i> spp., <i>E. neoaphidis</i>. <i>Verticillium lecanii</i> which can suppress green peach aphid (<i>Myzus persicae</i>).</p>
<p>Beetles Coleoptera</p> 	<p>Argentine stem weevil (<i>Listronotus bonariensis</i>) by: Nematode (<i>Heterorhabditis zealandica</i>). Banana weevil borer (<i>Cosmopolites sordidus</i>) by: Nematode (<i>Steinernema carpocapsae</i>). Fungus (<i>Beauveria bassiana</i>). Black vine weevil (<i>Otiorhynchus sulcatus</i>) by: Nematode (<i>Heterorhabditis</i> sp.). Chrysomelid beetles on plantation eucalypts by: <i>Bacillus thuringiensis</i> var. <i>tenebrionis</i>. Elm leaf beetle (<i>Pyrrhalta luteola</i>) by: <i>Bacillus thuringiensis</i> subspecies <i>tenebrionis</i> (Btt) - Novodor®. Egg parasitoid (<i>Oomyzus gallerucae</i>) – a wasp failed to reappear after the first winter. Larval parasitoid (<i>Erynniopsis antennata</i>) - small fly. Pupal parasitoid (<i>Tetrastichus brevistigma</i>) in USA. Scarab grubs (Scarabaeidae) by: BioCane® (<i>Metarhizium</i> sp.) for greyback canegrub (<i>Dermodipida albobirtum</i>). Chafer Guard® (<i>Metarhizium</i> sp.) for redheaded pasture cockchafer (<i>Adoryphorus couloni</i>). Nematode (<i>Heterorhabditis zealandica</i>) for African black beetle (<i>Heteronychus arator</i>) turf.</p>
<p>Caterpillars Butterflies and moths Lepidoptera</p>    <p style="font-size: small; border: 1px solid black; padding: 2px; margin-top: 5px;">If the remains of a virus-killed <i>Helicoverpa</i> caterpillar are eaten by a healthy caterpillar of the same species, the healthy caterpillar will soon sicken and die. This is how disease can spread rapidly when many caterpillars are present.</p>	<p>Caterpillars (Lepidoptera) by: Dipel® (<i>Bacillus thuringiensis</i> (Bt) var. <i>kustaki</i>). Nematodes (<i>Steinernema</i>) to control armyworms and cutworms in turf. Wasp parasitoid (<i>Trichogramma</i> spp.) – moth and caterpillar control. Codling moth (<i>Cydia pomonella</i>) by: Codling moth virus - poor control. Pheromone lures attract male moths for monitoring for spray thresholds. Isomate®C, Isomate®C-S, Isomate®CTT, Isomate®C/OFM TT – mating disrupting pheromones. Parasitoid wasp (<i>Mastrus ridens</i>); female wasps attack codling moth cocoons and lay eggs on moth larvae. Will contribute to pest management of codling moth. Corn earworm, cotton bollworm (<i>Helicoverpa armigera</i>) by: Dipel® (Bt var. <i>kustaki</i>), XenTari® (Bt var. <i>aizawai</i>). Gemstar®, Vivus® Gold (nuclear polyhedrosis virus of <i>Helicoverpa</i> spp.). Native parasitoid wasps and flies. Correct habitats are critical for their survival. In NZ the parasitic fungus, <i>Isaria farinose</i> (formerly known as <i>Paecilomyces farinosus</i>). Currant borer moth (<i>Synanthedon tipuliformis</i>) in Tasmania by: Nematodes (<i>Steinernema</i> spp.) applied to currant cuttings. Diamondback moth (DBM) (<i>Plutella xylostella</i>) in brassicas by: Dipel® (Bt var. <i>kurstaki</i>), XenTari® (Bt var. <i>aizawai</i>) applied to young caterpillars. Parasitoid wasps (<i>Trichogramma</i> spp.) can be purchased. Predators and wasp parasitoids of this pest are present in crops in low numbers and can provide some level of control. A fungus (<i>Zoopthora radicans</i>). In a novel approach, the insects themselves will be used to spread the fungal spores to other DBM earlier in the season than the natural outbreaks would occur. Male moths, attracted to inoculation stations by pheromones (sex attractants), can pick up the fungal spores and then spread them through the DBM population. This 'auto-dissemination', has obvious advantages over chemical insecticides, eg environmental, economic and avoidance of resistance problems. Oriental fruit moth (<i>Grapholita molesta</i>) by mating disruption pheromones: Isomate® OFM Rosso-S, Isomate® OFM Rosso, Isomate®C/OFM TT. Fruitpiercing moths (<i>Eudocima</i> spp.) by: Egg parasites (<i>Ooencyrtus</i> spp., <i>Telenonus</i> sp.). Lightbrown apple moth (<i>Epiphyas postvittana</i>) by: Isomate® LBAM Plus (mating-disrupting pheromone).</p>





Table 4. Examples of the biological control of insects in Australia (contd).

INSECTS	BIOLOGICAL CONTROL AGENTS include:
<p>Bugs Hemiptera</p> <div style="border: 1px solid black; padding: 2px;"> <p>Fruitspotting bugs are considered by some entomologists to be the most damaging pest in the horticultural sector after fruit fly</p> </div>	<p>Green vegetable bug (<i>Nezara viridula</i>) has been substantially reduced in importance throughout Australia by the introduction of the wasp below and other parasitic wasps, but on some crops, eg soybean and pecans, it can still cause economic damage. Green vegetable bug egg wasp parasite (<i>Trissolcus basalis</i>). A fly parasite (<i>Trichopoda giacomellii</i>) parasitizes nymphs and adults. Other natural predators of this pest include ants, spiders, and predatory bugs.</p> <p>Fruitspotting bugs (<i>Amblypelta</i> spp.) by: Egg parasitoids (<i>Anastatus</i>); also <i>Ooencyrtus caurus</i>, <i>Centrodora darwini</i> and <i>Gryon</i> sp. to be evaluated in the field. Green tree ant (<i>Oecophylla smaragdina</i>) was the most important factor regulating bug populations in the NT. Tachinid fly (<i>Trichopoda giacomellii</i>). Pheromone monitoring and trapping.</p> <p>Spined citrus bug (<i>Biprorulus bibax</i>) by: Parasitoid wasps (<i>Acroclisoides</i>, <i>Trissolcus</i>, <i>Eupelmus</i>). Assassin bug (<i>Pristhisanicus papuensis</i>) preys on adults and nymphs. Predator pheromones could be used to monitor populations where spined citrus bug is a problem or to draw assassin bugs away from orchards if farmers intend applying a pesticide harmful to the predators.</p>
<p>Flies Diptera</p> <div style="border: 1px solid black; padding: 2px; text-align: center;"> <p>VECTOBAC</p> </div>	<p>Fruit flies Parasitic wasps (<i>Diachasmimorpha tryoni</i>) is under investigation. Sterile Insect Technique (SIT), page 103.</p> <p>Fungus gnats (sciarid flies) by: Nematode (<i>Steinernema feltiae</i>). Hypoaspis (<i>Stratiolaelaps miles</i>), a soil dwelling mite. VectoBac® WG Biological Larvicide (<i>Bacillus thuringiensis</i> subsp. <i>israelensis</i>) serotype H14. Rove beetles (<i>Dalotia (Atheta) coriaria</i>) are generalist predators that will feed on fungus gnats, shore flies and thrips. They are used in an IPM program in conjunction with Hypoaspis.</p> <p>House fly (<i>Musca domestica</i>) and stable fly (<i>Stomoxys calcitrans</i>) by: A tiny wasp (<i>Spalangia endius</i>) that is naturalized to Australia. The adult female wasp lays her eggs into immature fly pupae.</p> <p>Mosquitoes (Culicidae) by: Entomopathogenic fungus (<i>Beauveria bassiana</i>) in the laboratory. Bt var. <i>israelensis</i> (Cybate®, Vectobac®). <i>Wolbachia</i>, an endosymbiotic bacteria that lives in mosquitoes is being researched.</p>
<p>Locusts Orthoptera</p>	<p>Locusts and grasshoppers by various formulations of: GreenGuard (<i>Metarhizium anisopliae</i> var. <i>Acridium</i>) spores. <div style="border: 1px solid black; padding: 2px; text-align: center;"> <p>GreenGuard</p> </div></p>
<p>Mealybugs Hemiptera</p>	<p>Longtailed mealybug (<i>Pseudococcus</i> spp.) by: Mealybug ladybird (<i>Cryptolaemus montrouzieri</i>). Citrus mealybug (<i>Planococcus citri</i>) by: Wasp (<i>Leptomastix dactylopii</i>). Cotton Solenopsis mealybug (<i>Phenacoccus solenopsis</i>) in cotton in 2009 by maximizing the use of local beneficial insects, eg ladybirds, lace wings, earwigs and cockroaches, etc.</p>
<p>Scales Hemiptera</p> <div style="border: 1px solid black; padding: 2px;"> <p>The aim is to have effective parasites for 6 citrus scales</p> </div> <div style="border: 1px solid black; padding: 2px; margin-top: 10px;"> <p>CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE</p> </div>	<p>Various scales by ladybirds and their larvae including: Parasitic wasp (<i>Pseudophycus flavidulus</i>). Black ladybird (<i>Rhizobius ventralis</i>). Common spotted ladybird (<i>Harmonia conformis</i>). Transverse ladybird (<i>Coccinella repanda</i>).</p> <p>Cottony cushion scale (<i>Icerya purchasi</i>) by: Vedalia ladybird (<i>Rodalia cardinalis</i>).</p> <p>Red scale, California red scale (<i>Aonidiella aurantii</i>) by: Red scale wasp parasites (<i>Aphytis chrysomphali</i>, <i>A. lingnanensis</i> (egg parasite), <i>A. melinus</i>, <i>Comperiella bifasciata</i>, <i>Encarsia perniciosi</i>).</p> <p>San Jose scale (<i>Quadraspidiotus perniciosus</i>) in some orchards by: Native ladybird (<i>Rhizobius lindi</i>).</p> <p>White wax scale (<i>Gascardia destructor</i>) by: Parasitic wasps (<i>Anicetus communis</i>, <i>Paraceraptrocerus nyasicus</i>, <i>Scutellista cyanea</i>, <i>Tetrastichus ceroplastae</i>). These parasitic wasps control white wax scale on citrus in some areas of Australia. Red chilocorus beetle (<i>Chilocorus circumdatus</i>).</p> <p>Soft brown scale (<i>Coccus hesperidum</i>) by parasitic wasp (<i>Metaphycus luteolus</i>) - egg parasite. Hemispherical scale (<i>Saissetia coffeae</i>) on citrus, passionfruit, coffee, ornamental plants by the parasite (<i>Encyrtus unifelix</i>).</p> <p>Black scale (<i>Saissetia oleae</i>) and soft brown scale (<i>Coccus hesperidum</i>) in citrus olives and ornamentals by parasitic wasps (<i>Metaphycus helvolus</i>, <i>M. lounsburyi</i>).</p> <p>Armoured scales, eg white louse scale / citrus snow scale (<i>Unaspis citri</i>), red scale (<i>Aonidiella aurantii</i>), oriental scale (<i>Aonidiella orientalis</i>), oleander scale (<i>Aspidiotus nerii</i>) by red chilocorus beetle (<i>Chilocorus circumdatus</i>) - predator. Oriental scale (<i>Aonidiella orientalis</i>) by the blue chilocorus beetle (<i>Chilocorus baileyi</i>).</p>

Table 4. Examples of the biological control of insects in Australia (contd).

INSECTS	BIOLOGICAL CONTROL AGENTS include:
Soilborne insects	<i>Mesostigmata</i> mites are abundant in soil and feed on a broad range of invertebrates including plant-feeding pests that spend part or most of their lives on or in the soil or root systems . Many species are habitat specific and may be sensitive to agricultural practices and other land management systems. They have potential for biocontrol of pests and as indicators of soil quality and sustainable agricultural practices (Beaulieu and Weeks 2005).
Termites Isoptera	Termites by: Green muscardine fungus (<i>Metarhizium</i> sp.). Other fungi include <i>Beauveria bassiana</i> and <i>Paecilomyces fumosoroseus</i> . Nematode (<i>Steinernema carpocapsae</i>).
Thrips Thysanoptera	Various thrips by: <i>Hypoaspis</i> (= <i>Geolaelaps</i>) <i>aculeifer</i> – a soil dwelling predator under development. <i>Amblyseius swirskii</i> targets larvae of various thrips. Montdorensis (<i>Typhlodromips montdorensis</i>), a predatory mite that feeds on thrips, eg melon thrips (<i>Thrips palmi</i>), onion thrips (<i>T. tabaci</i>), plague thrips (<i>T. imagine</i>), tomato thrips (<i>Frankliniella schultzei</i>) and Western flower thrips (<i>F. occidentalis</i>). Western flower thrips (WFT) (<i>Frankliniella occidentalis</i>). A WFT control program is likely to involve a combination of complementary predators. Predators and parasites being considered as biological control agents overseas and / or in Australia include: Predatory bugs (<i>Anthocoris nemorum</i> , <i>Orius</i> sp.). The tomato spotted wilt virus which is carried by the WFT and other thrips has been destroying vegetable crops on the Adelaide Plains for the past decade. A native bug has been discovered which has the potential to eradicate one of the world's viruses affecting the Australian vegetable industry. Predatory mites (<i>Amblyseius cucumeris</i>), Montdorensis (<i>Typhlodromips montdorensis</i>). Predatory mites (<i>Neoseilus cucumeris</i> , <i>N. barkeri</i>). <i>N. cucumeris</i> is effective in combatting thrips in flowers such as roses, chrysanthemums and gerberas, and vegetables such as capsicums, cucumbers and egg plants. <i>N. cucumeris</i> feeds on immature thrips and some mites and persists at extremely low pest levels allowing it to be used preventatively; it plays a key role in reducing pesticide use. Hypoaspis (<i>Stratiolaelap miles</i>), a soil dwelling mite. A UK company has launched a biological product, Hyposure cucumber mix for thrips in cucumbers. The product contains the predator <i>Hypoaspis miles</i> together with sufficient food mites to enable the predators to establish in a crop in the absence of the pest. Parasitoid wasp, possibly (<i>Ceranisus</i> sp.). Predatory thrips , eg sixspotted thrips (<i>Scolothrips sexmaculatus</i>) are generalist predators of small prey such as other thrips, mites and small eggs. Do not confuse with pest thrips.
Wasps Hymenoptera	Citrus gall wasp (<i>Bruchophagus fellis</i>) by: Citrus gall wasp egg parasites (<i>Megastigmus trisulcus</i> , <i>M. brevivalvus</i>). European wasp (<i>Vespula germanica</i>) by: Sequences corresponding to <i>Lactococcus</i> , <i>Lactobacillus</i> , a novel <i>Leuconostoc</i> and two <i>Rickettsiella grylli</i> strains. Parasitic wasp (<i>Sphacephaga vesparum</i>) has been released, effectiveness is unknown. Baits (meat-based + insecticide) are being researched in Australia and NZ. Sirex wasp (<i>Sirex noctilio</i>). At least 15 biological agents have been released including: Nematode (<i>Deladenus</i> (<i>Beddingia</i>) <i>siricidicola</i>). Sirex parasites (<i>Ibalia leucospoides</i> , <i>Megarhyssa nortoni</i> , <i>Rhyssa persuasoria</i> , <i>Schlettererius cinctipes</i>). Biological control, management of forest thinning and other practices keep trees vigorous.
Whiteflies Hemiptera	Greenhouse whitefly (<i>Trialeurodes vaporariorum</i>), silverleaf whitefly (<i>Bemisia argentifolii</i>) by: Greenhouse whitefly parasite (<i>Encarsia formosa</i>) parasitizes nymphal stages of the whitefly. Parasitized nymphs turn black within a few days and can be distinguished from the normal white 4th nymphal stage. After the wasp emerges a round hole may be seen on the upper surface of the nymph. Predatory Montdorensis mite (<i>Typhlodromips montdorensis</i>) in protected crops. Predatory ladybird (<i>Delphastus pusillus</i>) is a small black ladybird beetle from Australia that will consume about 150 whitefly eggs per day. They are recommended for moderate to heavy infestations (10-15 whitefly larvae per leaf). This small beetle is used to provide control of greenhouse, sweet potato and silverleaf whiteflies. They work well in areas with great diversity by hunting and eating immature whiteflies and especially the eggs. This predatory beetle will sometimes consume spider mites. Both the adults and larvae are predacious with tremendous appetites. Silverleaf whitefly (<i>Bemisia tabaci</i> biotype B) by parasitoid wasp (<i>Eretmocerus hayati</i>). In all areas, levels of parasitism are well in excess of those previously recorded from parasitoids already present. In many areas growers have now modified their insecticide management practices to encourage the parasitoid. Predatory Montdorensis mite (<i>Typhlodromips montdorensis</i>) in protected crops. Tobacco whitefly (<i>Bemisia tabaci</i>), a virus vector, has become the most serious and economically damaging insect pest in warmer agriculture areas worldwide where it is spreading a range of viruses through crops including tomato yellow leaf curl virus. A range of <i>Bemisia</i> parasites have been identified with varying effectiveness against the different species and subspecies of this pest, eg <i>Eretmocerus eremicus</i> Ladybird predator (<i>Delphastus</i> spp.). Predatory mite (<i>Amblyseius swirskii</i>) overseas, feeds on eggs and larvae of whitefly.

Table 5. Examples of the biological control of pest mites and snails in Australia.

PEST MITES	BIOLOGICAL CONTROL AGENTS INCLUDE:
<p>Twospotted mite (TSM) <i>Tetranychus urticae</i></p> <p>Twospotted mite is resistant to more than 70 different compounds in the southern US (Beaulieu and Weeks 2005).</p> <p>Chilean predatory mite uses odors (kairomones) to locate their prey – if plants have contact with each other, predators can move freely about.</p> <p>Horticultural oils may be used on hot spots (where 2-spotted mites have built up to damaging numbers) ahead of <i>Phytoseiulus persimilis</i> build-up. Oils are not selective and may harm predatory mites (oil suffocates pest and predator alike, but there are no residues and their effect is short-lived). Oils may damage some plants but this can be managed by using low concentrate sprays (about 0.5%) and avoiding spraying in the heat of the day.</p>	<p>Insecticide-resistant predatory mites are used in monoculture systems in both greenhouses and in the field where the use of pesticides can be carefully controlled. They are not resistant to some of the commonly used insecticides but some miticides are not toxic to the predators used in fruit, vegetables and ornamental crops.</p> <p>Chilean predatory mite (<i>Phytoseiulus persimilis</i>) moves into trees later in the season in response to high populations of twospotted mites, quickly reducing populations then disappearing. Used on ornamental crops such as roses and orchids and berry fruits. Will also feed on some other spider mites.</p> <p>Predatory mite (<i>Galendromus occidentalis</i>), formerly <i>Typhlodromus occidentalis</i>. In horticultural crops, it will also control other spider mites.</p> <p>Californicus (<i>Neoseiulus californicus</i>) is an aggressive and robust predator of spider mites. It is tolerant of a wide range of temperature and humidity conditions and is used widely overseas as a powerful biocontrol agent. Californicus is able to survive well even at low prey densities due to their ability to use alternate prey and pollen as a food source. Will also feed on broad mite (<i>Polyphagotarsonemus latus</i>) and cyclamen mite (<i>Steneotarsonemus pallidus</i>).</p> <p>Predatory gall midge (<i>Feltiella acarisuga</i>) larvae feed on many species of spider mites overseas and are better able to withstand low humidities than <i>Phytoseiulus</i>.</p> <p>Native species of predatory mites are generalist feeders and can use alternative food in the absence of mite pests. Therefore they can persist more effectively in the environment and contribute to the control of several pests. The reduced and selective use of pesticides, accompanied by scouting services, has allowed some control of plant-feeding mites by native species in several Australian tree crops, especially grapevine and citrus. Stethorus ladybirds (<i>Stethorus</i> spp.) and steelblue ladybird (<i>Halma chalybeus</i>) are natural predators.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>0.55 mm long Twospotted mite (<i>Tetranychus urticae</i>).</p> </div> <div style="text-align: center;">  <p>0.5 mm long Chilean predatory mite (<i>Phytoseiulus persimilis</i>).</p> </div> </div>
<p>European red mite (ERM) <i>Panonychus ulmi</i></p>	<p>Insecticide-resistant predatory mite (<i>Typhlodromus pyri</i>). <i>T. pyri</i> is not resistant to all pesticides. Used to control ERM in IPM programs in pome fruit orchards in Tasmania and Victoria. It is also a pollen feeder and will feed on TSM and other mites, so it can sustain itself even if ERM and TSM are present in low numbers or absent. Various predators, which feed on ERM have been recorded in WA deciduous fruit orchards.</p>
<p>Redlegged earth mite (RLEM) <i>Halotydeus destructor</i></p>	<p>A predatory mite (<i>Anystis wallacei</i>) introduced from France preys on RLEM as well as the blue oat mite and lucerne flea. Landscape management could enhance existing natural enemies.</p>
<p>Broad mite <i>Polyphagotarsonemus latus</i></p>	<p>Predatory mites (<i>Neoseiulus cucumeris</i>, <i>N. barkeri</i>) control broad mite and cyclamen mite. Broad mites are also preyed upon by lacewing larvae, and other general predators. Overseas a bacterial preparation is successfully used.</p>
<p>Other mite pests</p>	<p>Victorian predator mite (<i>Euseius victoriensis</i>, formerly <i>Amblyseius victoriensis</i>) used to control several eriophyid and other mites where humidity is low and temperatures are high including: Broad mite (<i>Polyphagotarsonemus latus</i>). Tomato russet mite (<i>Aculops lycopersici</i>). Rust mites (various species) on citrus. Rust mites (various species) and blister mite (<i>Colomerus vitis</i>) on grapevine.</p>
<p>Snails and slugs</p>	<p>Snails feed on emerging crops, clog up machinery and contaminate harvested grain. Conservation tillage gives snails a convenient cover. Practices such as stubble management, burning and baiting can be expensive, time consuming and may not fit with other farming practices.</p> <p>A fly (<i>Sarcophaga penicillata</i>) may spell disaster for snails. There has been an experimental release.</p> <p>Birds and ducks. Provide water to attract birds which feed on snails and slugs, Khaki Campbell ducks are also good at cleaning up snails but duck dropping are very messy.</p> <p>Pheromones and hormones are under investigation for controlling snails in grains and grain stores. Species-specific snail genes for pheromones can be identified and biochemical blockers developed to confuse snails or used in traps to lure them away from crops.</p> <p>A snail contraceptive would be useful too, so they are looking at ways of achieving infertility by targeting the proteins essential for snail attraction and reproduction.</p> <p>Commercialization of nematodes is underway for use in selected crops in southern Australia. Selected native nematodes can attack and kill 4 species of exotic species of round and conical snails resulting in 90-100% mortality. They enter the host snail through natural openings, and then release symbiotic bacteria that live in their guts. The bacteria multiply turning the host's inner body into food for the nematodes. Nematodes actively hunt snails as they move across the ground to get to crops and to lay their eggs in the soil. They are being trialed in different management approaches, eg excluding snails from the paddocks being cropped by applying a barrier of nematodes around the perimeter of paddocks using protein-based foam formulations that will protect the nematodes.</p>

PLANT DISEASES AND ABIOTIC FACTORS

The biological control of plant diseases and abiotic factors (non-living) is in its infancy compared with the biological control of weeds and insects. Many antagonists are naturally present in crop soils and exert some degree of control over one or many plant pathogens regardless of human activities. They bring about control by several methods and are affected by environmental factors such as moisture and temperature. Biological control of plant diseases is part of natural control (Fig. 16) and may become cost competitive with fungicides. There is a particular need to develop effective means of controlling postharvest diseases of fruit and vegetables.

NATURAL ENEMIES include:

Insects and allied pests, eg

Fly larvae

Vertebrates, eg

Humans

Rodents

Snails and slugs, eg

Diseases, eg

Virus and virus-like diseases

Bacterial diseases

Fungal diseases

Nematode diseases



ABIOTIC FACTORS include:

Weather

Nutrients

Space arrangements

Time

Fig. 14. Natural enemies of edible mushrooms (these mushrooms grow on organic matter in the soil, not on plants, but have been used as an example).

Biofungicides

Biofungicides

Biological chemical products

Biological control organisms (BCOs)

Biofungicides are commercial products that are composed of beneficial organisms such as fungi, bacteria, or actinomycetes that suppress plant diseases. These biocontrol agents are formulated as powders for seed treatments, in granular form for soil incorporation and as suspensions for root drenches and foliar sprays.

- **These specialized** fungi and bacteria microorganisms normally inhabit most soils. They are tested in laboratories for their ability to control plant pathogens.
- **Biofungicides may give good control under low levels of inoculum.**
- **These products may never become the quick fix like** with chemical fungicides.
- **However, they do offer some unique advantages** over chemical fungicides such as:
 - Shorter-re-entry intervals.
 - Decreased residue worries and less consumer concern.
 - Less chance of resistance developing in the pathogen population since they may use many different mechanisms to suppress disease compared to single mode of action fungicides.
 - Products that utilize several mechanisms may have increased activity and / or may inhibit a wider range of plant pathogens.
 - Beneficial fungi and bacteria could be genetically altered to seek out a plant pathogen and kill it before it has a chance to attack the host.
 - Table 6 (page 122) includes examples of these organisms and the diseases they control.

Mechanisms of suppression/antagonism

Most biocontrol agents apply only one of these 4 mechanisms but some use more than one.

1. Direct competition with target organisms for nutrients & space
2. Induced resistance to the host
3. Antibiosis
4. Trigger the plant to turn on its own host defense mechanisms

Mechanisms by which antagonistic microorganism affect pathogen populations are not always clear but are generally attributed to one of several effects. Many have several modes of action, eg *Trichoderma*.

- **By parasites (hyperparasitism)** of the pathogen and **predation** by springtails, etc.
- **Competition** with pathogens and other organisms for food and space.
- **Direct toxic effects** by antibiotics substances released by the antagonists.
- **Indirect toxic affect** by volatile substances such as ethylene, released by the metabolic activities of the antagonist.
- By **symbiotic organisms**.
- By **non-symbiotic organisms**.
- By **physical means**.

Many biocontrol agents improve growth and suppress disease by increasing nutrient availability. This could explain why treated plants are larger than untreated plants even when a pathogen is absent. By altering the pH or by exporting enzymes that dissolve insoluble elements, these biocontrol agents increase the availability of certain fertilizers. This mode of action may be important in nutrient deficient soil mixes (see Biostimulants, page 53).

Predators and parasites (hyperparasites)

Predators

Predators are generally non-specific natural enemies which eat many prey.

- **Mites, springtails, protozoans, free-living nematodes and earthworms** in soil feed on disease organisms and may contribute to their biological suppression.
- **Some amoebae** ingest yeasts and small spores or bore holes in fungal hyphae.
- **Common bacterial and fungal-feeding nematodes** consume large number of bacteria.
- **The beneficial fungus-eating ladybird (*Illeis galbula*)** may eat powdery mildew fungi on leaves without damaging them.

Parasitism, hyperparasitism

Hyperparasite
A parasite parasitic on another parasite



Trichodex
Biofungicide



Antagonistic fungi may parasitize fungal disease organisms by directly penetrating the host hyphae and killing them. Examples include:

- **“Tricho” compounds** (*Trichoderma* spp.) are used in intensive horticultural crops and professional turf. *Trichoderma* has several modes of action, eg mycoparasitic activity, antagonism via production of antibiotic which inhibit growth of many other fungi, denaturing of fungal proteins via production of chitinase, immune response protection by plants, it also competes for space on bare surfaces and suppresses root pathogens such as *Pythium*, *Rhizoctonia*, *Phytophthora*, *Sclerotinia* and *Verticillium*.
- **Selected or multiple strains of *Trichoderma* are formulated** as granules, sprays, etc are used to treat growing media, soil, foliage and fruit, etc, eg
 - **Soilborne fungal diseases** such as *Pythium*, *Rhizoctonia*, *Fusarium*, *Phytophthora*, *Sclerotium*, *Cylindrocladium*.
 - **Grey mould (*Botrytis*)** in grapes and other fruit, also brown rot in stone fruit (Dodd et al 2004).
 - **Bark and peat based growing media** (a powdery formulation of *Trichoderma* sp.).
 - ***Eutypa dieback of grapevines*** by VineVax® (*T. harzianum*).
- *Trichoderma* is sometimes **formulated with mycorrhizal fungi** (page 116).
- *Trichoderma* can be **genetically manipulated** for pesticide-tolerance and efficacy.
- Of interest, *Trichoderma* can cause disease in mushrooms (green mould).

Trichoderma can be spread by resident insects, eg thrips or by wind currents on the leaves and flowers of kiwifruit vines over an entire growing season (Dodd et al 2004).

- **Other fungal parasites** (most are not currently available commercially), eg
 - ***Cladosporium herbarum* or *Penicillium*** suppresses subsequent *Botrytis cinerea* infections of developing fruits, must be applied prior to infection.
 - ***Ampelomyces quisqualis*** (hyperparasite) controls **powdery mildew** (*Sphaerotheca fuliginea*) of cucumber in greenhouses. Repeat applications are necessary. It is marketed as **AQ10 Biofungicide** (*Ampelomyces quisqualis* isolate M-10).
 - ***Actinovate* (*Streptomyces lydicus* strain WYEC 108)** is marketed overseas for disease control in greenhouse crops. It is a microbial inoculant and available as a soil drench to suppress **damping-off and foliar fungal pathogens**.
 - ***Verticillium lecanii***, other fungi and some *Bacillus* sp. can parasitize **rust fungi**.
 - ***Coniothyrium minitans*, *Sporidesmium sclerotivorum* and *Gliocladium* spp.** can parasitize a range of **soilborne fungi**.
 - **Non-parasitic *Pythium* spp.** may parasitize parasitic ***Pythium* and *Phytophthora***.
 - ***Mycostop* (*Streptomyces griseoviridis* strain K61)** targets *Fusarium* spp., *Alternaria brassicola*, *Phomopsis* spp., *Botrytis* spp., *Pythium* spp. and *Phytophthora* spp. that cause seed, root and stem rots, and wilt diseases.

Bacteriophages

A bacteriophage is a virus that can infect a bacterial cell and cause the host cell to break down. In Florida bacterial spot of tomato (*Xanthomonas campestris* pv. *vesicatoria*) has developed **resistance** to copper and streptomycin.

- **The application of a bacteriophage specific to bacterial spot** provided better disease control than copper-mancozeb or untreated controls.
- **Bacteriophages offer an alternative to conventional disease control strategies** and especially when combined with acibenzolar-S-methyl (ASM) in **Integrated Disease Management (IDM)** programs (see also page 158).

Biosurfactant-producing bacteria occur commonly in nature

Surfactants are compounds that lower the surface tension of a liquid, the interfacial tension between two liquids, or that between a liquid and a solid.

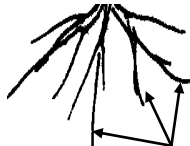
- **Biosurfactant-induced rupture** of the plasma membrane of zoospores is an antagonistic mechanism for the biocontrol of zoospore-forming plant pathogens, eg downy mildews, *Pythium*, *Phytophthora*, *Aphanomyces*, *Olpidium*, etc.
- **Zoosporic plant pathogens**, especially downy mildew zoospores which need free water for their liberation, would be the optimum environment for the solubilisation and dispersal of bio-surfactant-producing bacteria, eg *Pseudomonas aeruginosa*.
- **The use of chemical fungicides** could be substantially reduced.
- **Soil** should be good for biocontrol because of the moist environment.
- **Zoosporic plant pathogens** could be controlled by managing the environment to enhance activities of introduced or naturally occurring biosurfactant-producing bacteria.

CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

Competition for food and space

Competition occurs when two or more organisms require the same resource for growth and survival (Brown and Ogle 1997). Competition with pathogens can be an effective means by which biocontrol agents reduce disease; the biocontrol agent out-competes the target organisms for nutrients and space. The biocontrol agents are usually fungi or bacteria that grow quickly, overwhelming the target organisms which are suppressed by lack of food and space. Although the target organisms may not die out completely the population becomes so low that it is no longer a problem. Biocontrol agents that use competition to suppress disease generally need to be applied in high densities before the pathogen is present (they are preventative, not curative) and at frequent intervals.

Soilborne diseases



The rhizosphere is the narrow region of soil around **living roots**.

Before root infection can occur, pathogens must gain access to the root. They must also gain access to the space closely associated with the root known as the **rhizosphere**. Both beneficial and harmful microbes can compete initially for occupation of the rhizosphere since it is a nutrient rich area where roots exudates are continuously being released (see page 43 for more detail). Many biocontrol agents suppress disease by occupying the available sites along the plant roots and preventing the pathogens from making contact with the root tissue.

Competition for food

Natural enemies with the same nutrient requirements as the disease organism are the disease organism's most effective competitors, eg

- **Bacteria in the root zone** compete for the same **carbon source** as damping off fungi (*Pythium ultimum*) resulting in successful biological control in some crops.
- **Other bacteria** such as *Pseudomonas* spp.:
 - **Compete for ethylene** as a source of carbon. Treating seeds with *Pseudomonas putida* which utilises ethanol as its sole carbon source increases seedling emergence in *Pythium*-infested soil.
 - **Compete for iron**, eg fluorescent *Pseudomonas* spp. and soilborne fungal pathogens such as *Fusarium oxysporum*.

Competition for space

There are hundreds of microorganisms which compete for space, but only a few have been registered and are commercially available for use.

- **All have one feature in common**; they take advantage of the virtually sterile bare surface on new leaf scars, freshly cut stumps or new pruning wounds.
- **They are aggressive colonists of the plant's surface** and become established in advance of the disease organism to inhibit its development.
- **In the case of soilborne diseases**, the antagonistic microorganisms also inhibit the disease organisms.

Fungi which compete for space include:

- **Trichoderma** spp. controls several **soilborne diseases**.
- **Giogard[®]** (*Gliocladium virens*, syn. *Trichoderma virens*) controls **seedling diseases** of ornamental and bedding plants overseas; it is also a hyperparasite.
- **Fusarium lateritum** rapidly colonizes pruning wounds and outcompetes **eutypa dieback** (*Eutypa armeniacae*) which attacks apricot trees and grapes (**dying arm**). Specially designed cutters apply a suspension of saprophytic *Fusarium lateritum* spores to the pruning wound as it is cut. *Fusarium* in culture also produces an antibiotic which inhibits spore germination and growth of *Eutypa*.

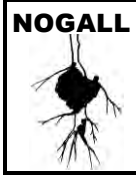

Bacteria which compete for space include:

- **Competition between organisms** which are closely related taxonomically, eg
 - **Saprophytic bacteria** (*Erwinia herbicola*) compete for space with fireblight (*E. amylovora*) on pome fruits.
- **Bacillus subtilis**.
 - **Clarity** (*Bacillus subtilis*) has been trialled in New Zealand since 2008 and has been shown to give equivalent performance to other *B. subtilis*-based products in the field against *Botrytis* in wine grapes.
 - **Kodiak[®]** (*B. subtilis*) is used in a limited way overseas as a seed treatment and results in better growth and protection against **root diseases**.
 - **B. subtilis** also prevents the establishment of **canker** (*Nectria galligena*) on apple trees. The bacteria persist in leaf scar wounds and reduce the number of shoots that become infected with canker in spring.
- **Pseudomonas sp.** applied to seeds, seed pieces and roots of plants, reduces damping off and rot roots (*Pythium*, *Phytophthora*) and increases growth and yield in several crops overseas, eg **Dagger[®] G** (*P. fluorescence*) controls **damping off** (*Rhizoctonia*, *Pythium*) of cotton.
- **Streptomyces sp.** applied overseas to seeds of cereals, sweetcorn and carrots has protected plants against **root diseases** resulting in improved growth and yield.

Clarity
Bacillus subtilis

Direct toxic effects

Many microbial biocontrol agents produce chemical compounds such as antibiotics or toxins that kill or has a detrimental effect on the target organisms. Some of the more common antibiotics that humans use to ward off infection came originally from fungi and bacteria. **Biological Control Organisms (BCOs)** that use antagonism may not necessarily have to be present in high numbers but need to exert their antibiotic effects **before infection occurs**. Once the pathogen has gained entry into the root the antibiotic may have no effect.

<p>Antibiotic substances</p> 	<p><u>Only a few have been commercialized.</u></p> <ul style="list-style-type: none"> • Some release antibiotics which suppress disease organisms, eg <ul style="list-style-type: none"> • Nogall[®] (<i>Agrobacterium</i> strain K 1026) is used commercially in Australia to control crown gall (<i>Agrobacterium</i> spp.) on some horticulture plants. <i>Agrobacterium</i> strain K 1026 produces an antibiotic or bactericin called agrocin 84 which inhibits growth of pathogenic <i>Agrobacterium</i> spp. Nogall[®] is applied to plant wounds when striking cuttings, during pruning, repotting and field planting. • A strain of <i>Pseudomonas fluorescens</i> produces a phenazine antibiotic which suppresses take-all (<i>Gaeumannomyces graminis</i> var. <i>tritici</i>). • Some release volatile substances such as ethylene. • Biosurfactants produced by naturally-occurring bacteria, kill zoospores produced by downy mildews, <i>Pythium</i> and <i>Phytophthora</i> (Stanghellini and Miller 1997).
<p>Bacillus subtilis</p> 	<p><u>It is getting harder to find new chemical molecules</u> to advance the effectiveness of new and existing products and combat resistance. Research is taking longer and becoming more expensive.</p> <ul style="list-style-type: none"> • Serenade Max[®] (<i>Bacillus subtilis</i> strain QST 713) is used as a preventative spray in humid climate conditions to protect some vegetable, fruit and vine crops against diseases such as <i>Botrytis</i>, powdery mildew and <i>Sclerotinia</i>. • Some formulations of B. subtilis can be used for organic production.
<p>Yeast</p>	<p>Bayer CropSciences (2011) has reached an agreement Koppert Biological Systems, in the Netherlands to grant exclusive worldwide right on the marketing registration and production of the new yeast-based biocontrol agent, Shemer[®] (<i>Metschnikowia fructicola</i>).</p> <ul style="list-style-type: none"> • Shemer[®] is an antagonist that protects fruit and vegetables against fungal diseases, it also supplements and complements pre-harvest and / or post-harvest applications and is ideal for part of resistance management and IPM programs.
<p>Antagonists in the soil and on fruit and vegetables</p>	<p><u>Many antagonists are naturally present in crop soils.</u> Humans attempt to increase the effectiveness of antagonists by either:</p> <ul style="list-style-type: none"> • Adding soil amendments that provide nutrients to stimulate growth of the antagonists present in the soil and so increase their inhibitory effects on the pathogen. However, added organisms cannot maintain themselves for very long and soil amendments are not selective enough to support and buildup the introduced or existing antagonists. • Introducing new and larger populations of antagonists, eg <i>Trichoderma</i>. <p><u>Many beneficial microflora already exist naturally on fruit and vegetable surfaces.</u></p> <ul style="list-style-type: none"> • These could be managed to suppress postharvest diseases, or • Antagonists could be introduced to suppress postharvest pathogens.
<p>Suppressive soils</p>	<p><u>In suppressive soils, antagonistic microorganisms</u> suppress soilborne diseases (page 120 for more detail). Suppressiveness may be:</p> <ul style="list-style-type: none"> • General, eg many antagonistic microorganisms affect growth of pathogens or • Specific, when only one to two antagonistic microorganisms control a particular disease organism. • Do not confuse with replant disease (Sick Soil Syndrome) which occurs when susceptible plants such as apples, pears, plums, cherries and roses are planted into soil previously occupied by a related species. Soilborne disease organisms survive in the soil and decaying roots from the tree that died or was removed, then attack the new plant causing it to establish poorly.

Indirect toxic effects

<p>Ethylene</p>	<p>Indirect toxic effects on the pathogen by volatile substances such as ethylene, released by the metabolic activities of the antagonist.</p>
------------------------	--

CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

Symbiotic organisms

Endophytes

Defense mechanisms against:

- Drought
- Pests and diseases
- Also improve growth
- May meet demands for reduced pesticide use and for lower inputs in turf maintenance



Endophytic fungal mycelium within a plant. Diagrammatic.

Advanced Nitrogen alternative required. All roads lead to TwinN Nitrogen fixing microbes. Irrigation Summer 2009.

An endophyte is a fungus or a bacterium which grows **systemically** in many **grasses**, (Family Poaceae) causing few or no symptoms, but protects them from attack by pests and diseases, and improves **growth and drought tolerance**. The fungi are located in leaves, leaf bases, rhizomes and seeds (see also page 150).

- **General endophytes live for at least part of their life cycle symbiotically within plants** preventing **colonization by other organisms that may cause disease**. Endophytes may also inhibit the growth of competitor plants and help increase tolerance to both biotic and abiotic stresses. A single plant leaf might harbor several different endophytes.
 - **Vertical transmission**. Endophytes are transmitted directly from the host plant to the next generation **in the seed / grain**. However, endophytes tend to die faster than the seed, particularly at high temperatures and humidity. Epichloae (*Epichloe/Neotyphodium* spp.) are fungal endophytes that colonize grasses.
 - **Horizontal transmission**. Endophytes are transmitted from one plant to another plant, eg when they reproduce sexually and produce **spores spread by wind or insects**.
- **They have both deleterious and beneficial effects on their** hosts, providing a range of benefits that aid host survival and persistence (provide cereals with additional defense mechanisms against pests, diseases and **abiotic factors such as drought** (Caradus and Hume 2011).

TwinN-nitrogen fixing bacteria for non-legumes.

- **TwinN-nitrogen fixing bacteria is a new system of Non-host Specific** microbial inoculum that allow non-legumes, eg grass crops, to behave like pseudo legumes and convert **atmospheric N** into **plant available N** in the quantities required by the plant. They fill a similar role to that of *Rhizobia* bacteria in legumes. However, TwinN is not specific to just legumes and does not form root nodules.
- **TwinN microbes are a mix of endophytes**, which live inside the plant's vascular system and strains that occupy the root zone – 2 sites for N fixation to take place mean greater N fixation efficiency. **TwinN** does not leach, does not form nitrous oxide emission and does not destroy soil organic carbon. Only in its **3rd year of commercial release**. Application is via a boom spray to wet foliage of a young crop or alternatively via irrigation equipment such as drip or overhead.

Biological suppression of plant parasitic nematodes.

- **Mutualistic bacterial and fungal endophytes** can biocontrol root knot nematode (*Meloidogyne incognita*) and the potato cyst nematode (*Globodera pallida*) on tomato or potato. These bacterial and fungal endophytes can colonize the endorhiza at some point in their life cycle, can grow saprophytically in the soil, not in the rhizosphere and have plant health promoting activity and antagonistic activity towards sedentary plant parasitic nematodes (Sikora et al 2007).

Mycorrhizas



Mycorrhiza on an *Alnus* root

Invigormate™

Mycorrhizas are symbiotic associations between fungi and roots of most plants. They are initiated when a plant root becomes infected with an appropriate fungus.

- **Mycorrhizas obtain some nutrients from plants** in return they promote plant growth.
- **Some mycorrhizas are available commercially.**
- **If mycorrhizas are present** damage to seedlings of forest trees caused by common root pathogens, eg by *Phytophthora cinnamomi*, *Rhizoctonia solani*, *Fusarium oxysporum* and *Pythium* spp., is reduced.
- **Mycorrhizas improve plant hardiness** in phosphorus-deficient and dry soils by supplying phosphorus and water to plants. Mycorrhizal plants can improve drought resistance and can tolerate higher temperatures than uninfected plants (Geary 2011).
- **Invigormate™** is a combination of **safe, beneficial mycorrhizal and Trichoderma fungi strains** that promote vigor, growth and yield.
- **The mycorrhizal network in the soil** can connect plants below the ground (page 150).

Truffle strains used in Australia have been examined to identify possible causes of some low truffle yields. Genetics forms the basis of most interactions known between plants and their symbionts / pathogens. Truffle genetic diversity and mating type is continually assessed.

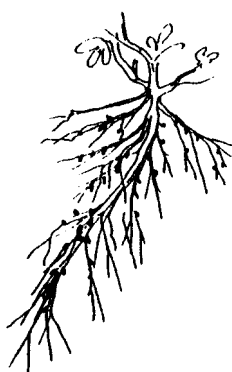
Mutualistic viruses boost plant ability to tolerate drought, cold and heat

Collaboration between some viruses and plants can confer **drought and cold tolerance** in different crop plants (page 150).

- **Collaboration between viruses, fungi and a tropical panic grass**, found in Yellowstone National Park can confer **heat tolerance**, ie grow together in temperatures > 51°C.

Nitrogen-fixing bacteria in legumes

DIAZOTROPHS
Organisms that can fix atmospheric nitrogen gas into a more usable form such as ammonia.



Nitrogen-fixing nodules on roots.

Trade-off between?

- N fixation,
- Root biomass and
- Drought tolerance

Almost all plants rely on nitrogen from the soil to grow, but only a few, eg legumes, are able to use it directly from the air. Nitrogen-fixing bacteria are mostly associated with the roots of legumes.

Microbial inoculants have an important role in Australian agriculture. Currently the inoculant industry is almost exclusively based around the manufacture of rhizobia for legume inoculation. The N inputs and disease break afforded by a legume rotation is fundamental to the environmental and economic sustainability of many farming systems (Wakelin and Rider 2004). Projects in progress include:

- **To examine any links between biological N fixation** and acidification in ecosystems.
- **To indicate any benefits of biological N fixation** by comparison with the use of fertilizer N, particularly ammonium based fertilizers.
- **Establish and maintain an accessible collection of Rhizobia strains** and other diazotrophs, genetic tools and information centre in support of biological N fixation.
- **Plants that form nitrogen-fixing associations are also normally mycorrhizal**. The two symbiotic associations react synergistically. If nitrogen and phosphorus are limited, mycorrhizas may improve phosphorus uptake, leading to increased nitrogen fixation which, in turn, promotes further mycorrhizal development.

Nitrogen-fixing bacteria (Rhizobia spp.) grow in nodules in LEGUMES, eg clover, peas, beans and wattles, and fix nitrogen from the air, making it available to the plant in the form of ammonia, enhancing plant growth.

- **Rhizobia** bacteria deliver a small molecule to the plant that the plant perceives in a very specific way. This triggers new cell division and changes development within the plant that results in a new organ being formed (a nodule) which is colonized by the bacterium. Together in the soil they convert N gas into ammonia in that organ.
- **Plants unable to fix nitrogen** can get it from nodulating plants growing nearby. Grass tends to grow more vigorously close to wattle trees due to receiving nitrogen from the secretion of amino acids from the roots and nodules of live trees and from the decay of dead roots and nodules.
- **Some domesticated legumes are considered to be not very good at selecting the most efficient bacterial partners** for symbiosis and N fixation from naturally occurring choices in the soil. If true, it has implications for plant breeding and agronomic practices.
 - **Farmers often add improved strains of rhizobia to the soil**, but they add them in such large quantities that they swamp out any *Rhizobia* diversity that pre-exists. So those legumes don't have to be able to select the good bacteria, because they are being provided with the best strain. However, if they are planted without added rhizobia they are unable to select *Rhizobia* strains very efficiently and this can reduce yields and plant fitness.
 - **Growers urged to test rhizobia level**. Researchers say growers are relying too much on residual populations of bacteria in the soil without actually testing this assumption.
- The **SunFix Sydney University Nitrogen Fixation Centre** aims to maximize the economic application of *Rhizobium* inoculates to pasture and crop legumes and provide agriculture with choices of **leguminous and other nitrogen-fixing crops**.

Drought tolerance (Norwood 2012).

- **Nitrogen availability** is a huge issue for agriculture everywhere. There is some evidence that domestication has eroded the capacity for symbiosis.
- **Are there links between legume root nodulation**, reduced root development and drought sensitivity? Casual observations indicate that nodulated roots are smaller than those on uninoculated plants. If verified, there are implications for crop improvement programs.
- **It appears that when chickpeas and other legumes** encounter the bacterium symbiotic rhizobia, **it not only results in the production of a new organ but is also changes root development**. The root systems of plants undergoing symbiosis are smaller than those of plants that are not. In domesticated chickpeas the roots systems are substantially smaller than those of their wild relatives. Possibly there could be a tradeoff between N fixation, root biomass and drought tolerance which generally require larger root systems.

Nitrogen fixation in rice

Anabaena-Azolla symbiosis

Blue green algae belonging to a general Cyanobacteria genus, fix atmospheric nitrogen and are used as inoculations for paddy crops.

- **Rice plantations utilize healthy populations of nitrogen-fixing cyanobacteria** (*Anabaena*, as symbiotes of the aquatic fern *Azolla*) for use as rice paddy fertilizer.
- **Anabaena in association with water fern Azolla** contributes nitrogen up to 60 kg / ha / season and also enriches soils with organic matter.
- **Some species form special nitrogen fixing cells** (heterocysts) which are specialized for nitrogen fixation and are able to fix nitrogen gas into ammonia, nitrites or nitrates which can be absorbed by plants and converted to protein and nucleic acids.

Non-symbiotic organisms

Biofertilizers are expected to reduce the use of chemical fertilizers and pesticides
You may never need to put fertilizer on your plants again!

<p>Biofertilizers Bioinoculants</p> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> <p>Plant Growth-Promoting Rhizobacteria (PGPRs) live freely in the rhizosphere (soil around living roots) and are antagonistic to soilborne plant pathogens</p> </div> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> <p>Bio-fertilizers such as <i>Rhizobium</i>, <i>Azotobacter</i>, <i>Azospirillum</i> and blue green algae have been in use a long time</p> </div>	<p>A biofertilizer is a substance which contains living microorganisms which, when applied to seed, plant surfaces or soil, colonizes the rhizosphere (soil around living roots) or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the plant (see also page 53).</p> <ul style="list-style-type: none"> • They do not enter into symbiosis. • Since they play several roles, a preferred scientific term for such beneficial bacteria is plant-growth promoting rhizobacteria (PGPR). • Biofertilizers fix atmospheric nitrogen, solubilize and mobilize phosphorus and translocate minor elements like zinc and copper to the plants. They help to produce plant growth promoting hormones, vitamins and amino acids and assist in controlling plant pathogenic fungi, thereby improving soil health and crop production. • Are present in both the absence and presence of disease-causing organisms. • Bio-fertilizers are eco-friendly and more cost-effective than chemical fertilizers. • The microorganisms in bio-fertilizers restore the soil's natural nutrient cycle and build soil organic matter. • Non-legumes rely upon manure or synthetic fertilizer. Nitrogen applications are a major expense in growing wheat, rice and maize crops and is ecologically damaging. Strains of nitrogen-fixing bacteria (<i>Azorhizobium</i>, <i>Rhizobium</i>) associate with these non-leguminous crops.
<p>Phosphate-solubilizing bacteria</p> <div style="border: 1px solid black; padding: 2px; margin: 5px 0; text-align: center;"> <p>Jumpstart®</p> </div> <p style="text-align: center;"><i>More phosphorus and nitrogen</i></p>	<p>A reduction in phosphate sources and environmental pollution from both production and applications of chemical phosphorus fertilizers demand a new generation of phosphate fertilizers, globally known as phosphate-solubilizing bacteria or phosphate biofertilizers.</p> <ul style="list-style-type: none"> • Phosphate-solubilizing bacteria, such as <i>Pantoea agglomerans</i> strain P5 or <i>Pseudomonas putida</i> strain P13 are able to solubilize the insoluble phosphate from organic and inorganic phosphate sources. • JumpStart (<i>Penicillium bilaii</i>) is a phosphate-solubilising inoculant that makes better use of soil and fertiliser phosphate for use on crops like wheat and sorghum in addition to pulse crops. • Some formulations for legumes contain phosphate-solubilizing bacteria and nitrogen fixing Rhizobium bacteria (TagTeam <i>MultiAction</i>®) providing better access to phosphate and more fixed nitrogen (Novozymes Biologicals Australia).
<p>Sorghum, millet, maize</p> <p>Diazotroph An organism that is able to grow without external sources of fixed nitrogen.</p>	<p>Azospirillum represents the best characterized genus of plant growth-promoting rhizobacteria and are recommended mainly for sorghum, millets, maize.</p> <ul style="list-style-type: none"> • Other free-living diazotrophs are repeatedly detected in association with plant roots, eg <i>Acetobacter diazotrophicus</i>, <i>Herbaspirillum seropedicae</i>, <i>Azoarcus</i> spp. and <i>Azotobacter</i>. Aspects of the plant root interaction include plant root interaction, nitrogen fixation and biosynthesis of plant growth hormones.
<p>Vegetables, cotton wheat, maize</p>	<p>Azotobacter can be used with crops like wheat, maize, mustard, cotton, potato and other vegetable crops. They are aerobic, free-living soil microbes which play an important role in the nitrogen cycle in nature, binding atmospheric nitrogen, which is inaccessible to plants, and releasing it in the form of ammonium ions into the soil.</p>
<p>Research is ongoing</p>	<p>Burrowing bacteria may end need to fertilize plants. By adding these bacteria that can burrow into the cells of plant roots, there is a reduced need for artificial fertilizer. Biologists at the University of Nottingham claim to have discovered a form of bacteria found in sugar cane juice that traps this nitrogen by itself.</p> <div style="border: 2px solid black; padding: 10px; margin-top: 10px;"> <p style="text-align: center;">SunFix Sydney University Nitrogen Fixation Centre:</p> <ul style="list-style-type: none"> • Fosters research and teaching on N fixation and Biological N Fixation (BNF). • Researches biological nitrogen fixation in cereals and other crops which currently require fertilizers as a source of nitrogen. • Develops new technologies for improving the survival of N-fixing inoculants and in the application of diazotrophs for plant growth promotion, yields and environmental sustainability for rice and wheat crops. • Aims to apply the benefits of biological nitrogen fixation to provide sustainable systems for agriculture and forestry. </div>

Bio-priming seed treatments Bioactive	<p>Long-term activity of bio-priming seed treatments for biocontrol of faba bean (<i>Vicia faba</i>) root rot pathogens, eg <i>Rhizoctonia solani</i>, <i>Fusarium solani</i>, <i>Sclerotium rolfsi</i>. Seed treated with <i>Trichoderma viride</i>, <i>T. harzianum</i>, <i>Bacillus subtilis</i> and <i>Pseudomonas fluorescens</i>, show a reduction in root rot incidence at both pre-emergence and post-emergent stages of plant growth (El-Mougy and Abdel-Kader 2008).</p>
<p>Reduce root rots Reduce chemical use Reduce fertilizer use</p>	<ul style="list-style-type: none"> • SC27 is a mix of 27 microorganisms specially selected for their phosphate-enhancing capacity, disease-suppressant effects and ability to stimulate root growth, nitrogen-fixing capacity and residue degradation capacity. The microbes need something to feed on so blood and bone is added to the potting mix. The microorganisms live in the rhizosphere around the plant roots where they actively secrete enzymes which in turn mobilize nutrients such as P making it more plant available, improving growth and yield. www.biogen.com.au • Companion (<i>Bacillus subtilis</i> strain GBO3) in the rhizosphere improves root branching, length and density promotes ecological balance, suppressing pathogen attack. • Fulzyme Plus (<i>Bacillus subtilis</i> + amino acids and water) has been specifically designed to improve soil fertility and plant health; it can be used at any stage of growth on all horticultural crops, crowds out pathogens, aids in decomposing organic matter and plant residues, solubilizes P, Ca, K, Mg and other locked up elements making them readily available to roots. Produces natural and beneficial substances essential for plant productivity and growth.
<div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>SC27</p> <p>Companion® Biological Fungicide <i>Bacillus subtilis</i></p> <p>Fulzyme®Plus <i>Bacillus subtilis</i></p> </div>	

Physical means

BioClays	<p>The Australian Institute for Bioengineering and Nanotechnology at the University of Qld is researching BioClays to manage field and postharvest diseases.</p> <ul style="list-style-type: none"> • Current pest and disease management tends to rely on plant genetic resistance and / or genetically-modified crops coupled with insecticide and fungicide sprays, but the cost, safety and environmental issues associated with chemical sprays often act as major impediments to controlling diseases in the field. • BioClay technology has the potential be an alternative to chemical spraying that is safe, low cost and environmentally friendly. • Unlike antibiotics, which are essentially a chemical weapon against bacteria, antimicrobial clays kill through purely physical means.
-----------------	---

Inoculant standards

Review of inoculant standards	<p>There is increased availability of a broader range of microbial inoculants and the strengthening of an independent quality control system for microbial products is important to ensure consumer confidence.</p> <ul style="list-style-type: none"> • In Australia, manufacturer's involvement in the quality control program is voluntary. • What is proposed for Australia is a hybrid model based on industry self-regulation but introducing the concept and the discipline of a trademark to replace the current ALIRU (Australian Legume Inoculants Research Unit) approval. A trademark brings with it an already established legal regime that protects and enforces quality. • The European and Mediterranean Plant Protection Organization (EPPO) evaluates plant protection products containing micro-organisms in a registration procedure for crop safety and effectiveness. This standard describes the requirements for their evaluation. • Practical methods for the quality control of inoculant biofertilizers are described in article by ACIAR (Deaker et al 2011).
STANDARDS	
Management An example	<p>The Becker Underwood Australia Inoculant App will:</p> <ul style="list-style-type: none"> • Identify the right strain of inoculant for each crop. • Identify your treatment options. • Calculate the volume you need to buy to the nearest bag or container size. • Connect you to your nearest sales representative. • Biocontrols are produced by fermentation and formulated as dry powders or pellets / granules and are applied in the same way as wettable powders. • Formulations are improving all the time, claiming better flow and performance, eg dust and lump-free, uniform size and smooth surface for superior flow, high counts of live rhizobia, precision placement, consistent performance and improved nodulation. • Formulations pass the rigorous standards of storage stability demanded by the industry. The strains used have been screened for their robustness and high efficacy. http://www.nemasyspro.com/ • The products usually contain spores and need to be stored under dry stable conditions (shelf life of many products is 12 months).

Disease-suppressive soils

More study of soil biota is required

Scientists have proven microorganisms play a vital role in the soil environment and are part of the normal checks and balances that make up healthy soil. Beneficial fungi and bacteria have been isolated from soil and tested in private and government laboratories for their ability to control plant pathogens.

Definition	Disease suppression is the ability of soil to suppress the incidence or severity of disease, even in the presence of the agents which causes it. The method of suppression is not always clear.
Biotic and abiotic factors	<p><u>Suppressive soils may involve biotic and abiotic factors and may vary with the pathogen and crop.</u> In most cases by:</p> <ul style="list-style-type: none"> • Presence in soil of one or several microorganisms antagonistic to a pathogen or pathogens, due to antibodies, enzyme, competition for food or direct parasitism of the pathogen. • Not allowing the pathogen to reach high enough population levels to cause severe disease. • The presence of biological factors capable of reducing disease but which were not effective enough to suppress the disease when environmental conditions that were ideal for disease development. • General suppressiveness is dependent on continual inputs of organic matter and relatively high levels of biological activity. • Enhanced suppressiveness is considered most likely to develop in amended minimally-tilled soils under crop or pasture.
Antagonistic microorganisms	<u>Antagonistic microorganisms</u> include fungi , eg <i>Trichoderma</i> , <i>Penicillium</i> , <i>Sporidesmium</i> or bacteria , eg <i>Pseudomonas</i> , <i>Bacillus</i> and <i>Streptomyces</i> . Amoebae, protozoa and nematodes may feed on fungi. Predatory fungi assist in suppressing plant parasitic nematodes.
Which diseases are suppressed?	<p><u>Disease suppressive soils may be an important means of managing soilborne diseases</u> for which resistant plant varieties are not available (page 167). Diseases suppressed include:</p> <ul style="list-style-type: none"> • Fungal diseases, eg <i>Phytophthora</i>, <i>Rhizoctonia solani</i> <i>Fusarium oxysporum</i> (vascular wilts), take-all (<i>Gaeumannomyces graminis</i> var. <i>tritici</i>). • Nematode diseases, eg cereal or oat cyst nematode (<i>Heterodera avenae</i>) and the borrowing nematode (<i>Radopholus similis</i>). There is a large body of literature on the negative effects of organic inputs on plant-parasitic nematodes (Pattison et al 2011).
Control methods which depend on resident antagonist organisms	<p><u>Some cultural and other control methods</u> depend for their success on the presence of resident antagonistic organisms.</p> <ul style="list-style-type: none"> • Long rotations may provide time for the biological destruction of disease organisms by resident natural enemies in the soil, eg the incidence of take-all (<i>G. graminis</i> var. <i>tritici</i>) may decline in areas planted with cereals continuously for 4 years or more. • Organic manures and other organic matter stimulate high populations of soil microorganisms, some of which are antagonistic to some soilborne diseases. • Antagonistic microorganisms may enhance chemical control as many tolerate pesticides and rapidly colonize treated soils after disease organisms are eliminated. • Antagonistic microorganisms may be eliminated by pesticides and unusual outbreaks of disease can occur. <ul style="list-style-type: none"> • Some herbicides, eg simazine and propazine, can eliminate antagonistic soil organisms. • Some fungicides may destroy some antagonistic fungi and mycorrhizas.
Assessing soil suppressiveness	<p><u>Bioassay trials help researchers confirm disease suppression in soils.</u> Biological suppression could improve the profitability of WA growers. Fungal and nematode root diseases in wheat alone cost WA growers \$84 million on one year (Lee 2011). Steps involve:</p> <ul style="list-style-type: none"> • Identify beneficial microorganisms present in disease-suppressive paddocks. • Then identify which farm management practices have fostered them by investigating the history of the suppressive paddocks, focusing on: <ul style="list-style-type: none"> • Rotations. • Inputs. • Soil characteristics. • Further study should evaluate alternative methods of assessing soil suppressiveness, characterizing the chemical and biological parameters associated with the phenomenon, determining whether rhizosphere-inhabiting microorganisms and endophytes are involved, identifying the parasites and predators that are possibly regulating our understanding of how soils should be managed to enhance suppressiveness (Stirling 2011). • Disease-suppressive soils may be the only way to reduce losses of some soilborne diseases (page 167).

Understanding suppressive soil

Fungal dominance

The trophic level of an organism is the position it occupies in a food chain. The word trophic referring to food or feeding.

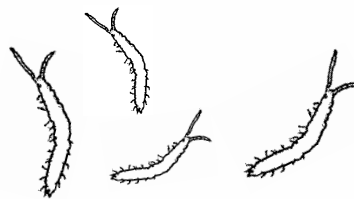
More study is required of soil biota.

- **The management of the plant-soil / microbial-faunal system** via varied organic amendments shows possibilities in the study and management of suppressive soils.
- **Conservation tillage (CT)** also helps in promoting the production of a greater amount of fungal biomass compared with conventional tillage (Coleman 2011).
- **The ratio of fungi to bacteria increases as ecosystems mature.** One of the objectives of restoration ecology is to promote and even accelerate the switch to fungal dominance at an earlier stage of ecosystem maturity. This process promotes the conditions for mycorrhizae to be more dominant.
- **Long and more complex soil food webs** with abundant predatory nematodes **in natural areas** (approximated by **zero or CT tillage**) suppress plant parasitic populations whereas **conventionally tilled soil** did not. This demonstrates a significant top-down impact of higher trophic level nematodes as a function of suppressiveness in these soils.
- **Penicillium radicum when used as an inoculant to promote growth** of wheat crops, played a significant role (along with the chemical fungicide fluquinconazole) in controlling the pathogens involved in take-all (*Guano graminis* var. *tritici*, *Rhizoctonia solani*, *Pythium irregulare*, etc) but not the beneficial fungus (*Trichoderma koningii*).
- **The more general interest in plant growth promotion (PGP)** effects of fungi and bacteria, eg *Pseudomonas fluorescens*, is ongoing research topics in several countries. More general aspects of soil management include use of:
 - Organic amendments and
 - Crops in rotation.
- **To promote greater suppression of specific pathogens** we need to manage the soil food web better and more effectively.
- See also page 115.

Conservation agriculture (CA)

CA is a combination of reduced tillage, adequate retention of residues on the soil surface and crop rotation which results in a soil with good physical and chemical qualities, and high, stable yields (see also page 374).

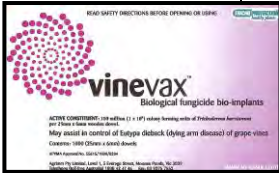

- **The combination of reduced tillage with residue retention** is responsible for increased populations of beneficial microflora.
- **The favorable effects of these two components** are due to increased soil aeration, cooler and wetter conditions, less fluctuations of temperature, moisture, and carbon content in surface soil. The increased microbial activity produced under these conditions would create an environment more antagonistic to pathogens due to competition effects.
- **Note that these management practices** used to improve soil health are **not** necessarily suitable for all crops or soils. For example, **symphylids** (up to 10mm long, white centipede-like) which feed on roots and other subterranean plant parts may cause significant crops losses. They often cause problems in organic production systems and are an increasingly important pest in situations where management practices have been modified to improve tilth, increase levels of organic matter and reduce compaction. They can be difficult to control.



Symphylids grow up to 10mm long, have 12 pairs of legs, 2 long antennae, are either white or creamy and are subterranean in habit. They are seldom seen on the soil surface. Ruth Kerruish.

Biological control of diseases

Table 6. Examples of the biological control of diseases in Australia and overseas.

DISEASES	BIOLOGICAL CONTROL AGENTS include:
<p>Blights</p>	<p>Chestnut blight (<i>Cryphonectria (Endothia) parasitica</i>) is: Controlled naturally in Italy and artificially in France through inoculation of cankers with less virulent strains of the same fungus (cross protection).</p> <p>Fireblight (<i>Erwinia amylovora</i>) by: Non-parasitic bacterium (<i>Erwinia herbicola</i>) which produces antibiotics and competes for nutrients and space in the same ecological niche. Biological control agents (mostly strains of <i>Pantoea agglomerans</i>, <i>Pseudomonas fluorescens</i> and <i>Bacillus subtilis</i>) have been registered for control of fire blight in Europe, the USA and New Zealand (APPNet monthly pathogen).</p> <p>Some bacterial disease organisms, eg <i>Erwinia amylovora</i>, <i>Pseudomonas syringae</i> pv. <i>syringae</i> and <i>P. syringae</i> pv. <i>morsprunorum</i> can live saprophytically on the surface of leaves, buds, etc before they infect and cause disease.</p>
<p>Cankers and dieback</p> 	<p>Eutypa dieback (<i>Eutypa lata</i>) by: Biological control agents, such as the fungi <i>Trichoderma</i> spp. and <i>Fusarium lateritium</i> and bacterium <i>Bacillus subtilis</i>, have controlled infection by <i>E. lata</i> in trials worldwide, but results have been variable. Fungal disease (<i>Fusarium lateritium</i>) + fungicide. Vinevax™ Biological wound dressing fungicide, Biological fungicide bio-implants and Bio-injection biological fungicide (<i>Trichoderma</i> sp.) are registered for assisting in control of Eutypa dieback. Although biological control offers long-term protection, the 1-2 weeks required for biological agents to colonize the wound provide a window of susceptibility to infection by <i>E. lata</i>.</p> <p>Bacterial canker of kiwifruit (<i>Pseudomonas syringae</i> pv. <i>actinidiae</i>) by: Several commercially available microbial-based products are being evaluated in NZ including naturally occurring, soil-based bacteria, <i>Bacillus subtilis</i>, <i>B. pumilis</i> and <i>Pseudomonas fluorescens</i> (Stewart et al 2011). www.bioprotection.org.nz and Biological Solutions</p>
<p>Foliage diseases</p>	<p>Powdery mildews by: AQ10 Biofungicide (<i>Ampelomyces quisqualis</i> isolate M-10) targets powdery mildews. Adults and larvae of the fungus-eating ladybird beetle (<i>Illeis galbulata</i>), feed on powdery mildew fungi in all host plant families on which powdery mildew occurs and possibly other leaf fungi.</p>
<p>Frost</p>	<p>Bacteria-mediated frost injury. Frost-sensitive plants are injured when temperatures drop below 0° C because ice forms within their tissues. Small volumes of pure water can be supercooled to -10° C or below without ice formation, provided no catalyst centers are present to influence ice formation. Certain strains of at least 3 epiphytic bacteria (<i>Pseudomonas syringae</i>, <i>P. fluorescens</i> and <i>Erwinia herbicola</i>) which are present on many plants, serve as ice nucleating-active catalysts for ice formation at temperatures as high as -1° C. Such bacteria are only present on plants in small proportions. By mass production of non-ice-nucleating active bacteria it has been possible to reduce and replace large numbers of ice nucleating-active bacteria on treated plants. This treatment protects frost-sensitive plants from injury at temperatures at which untreated plants may be injured.</p>
<p>Galls</p> 	<p>Crown gall (<i>Agrobacterium</i> spp.) by: Nogall® (<i>Agrobacterium</i> strain K 1026) is a nonpathogenic closely related bacterium. Crown gall can be controlled commercially in Australia by treating seeds, seedlings and cuttings in a suspension of Nogall® (<i>Agrobacterium</i> strain K 1026) during propagation and transplanting. <i>Agrobacterium</i> strain K 1026 is an efficient colonizer of host roots, it produces an antibiotic or bactericin called agrocin 84 which inhibits growth of pathogenic <i>Agrobacterium</i> spp. which cause crown gall.</p>
<p>Pre- and post-harvest diseases</p>	<p>Using and managing the existing beneficial microflora on fruit and vegetable surfaces or introducing large numbers of known antagonists against postharvest pathogens is effective in some instances. Effectiveness may be due to: Environments for the storage of harvested commodities are often controlled and maintained which should lessen the problem of introducing biocontrol agents into unpredictable and high variable environment (a limiting factor in field-releases). The ability to get the biocontrol agents to the site needed for activity is enhanced. The high value of postharvest commodities may make the application of elaborate biocontrol agents procedures more cost-effective than similar procedures in the field. For some commodities harvested for fresh market consumption, protection from postharvest disease is only needed for a short duration, the characteristics for an “ideal antagonist” for postharvest environment. Genetically stable, effective at low concentrations, not fussy in nutrient requirements, ability to survive adverse environmental conditions (including low temp and controlled atmosphere storage), effective against a wide range of pathogens on a variety of fruit and vegetables.</p>


CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

Table 6. Examples of the biological control of diseases in Australia and overseas (contd).

DISEASES	BIOLOGICAL CONTROL AGENTS include:
<p>Pre- and post-harvest diseases (contd)</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Biological products will become cost competitive with chemicals to develop effective means of controlling postharvest diseases of fruit and vegetables.</p> <p><i>Trichoderma</i> could possibly be used in IPM programs to reduce development of fungicide resistance.</p> </div>	<p>Postharvest rots of several fruits can be reduced by spraying spores of antagonistic fungi or bacteria and saprophytic yeasts at different stages of fruit development or by dipping the harvested fruit in the inoculum.</p> <p>Antagonistic bacteria. <i>Bacillus subtilis</i> protects avocado from storage fruit rots and several kinds of stone fruits from brown rot (<i>Monilinia fructicola</i>) for varying periods of time. Bio-Save® (saprophytic <i>Pseudomonas syringae</i> strains) has been approved for postharvest decay control in citrus, apples, and pears overseas. A saprophytic isolate of <i>Pseudomonas syringae</i> has been effective in reducing disease in apples and pears caused by grey mould (<i>B. cinerea</i>) and <i>Penicillium expansum</i>.</p> <p>Antagonistic fungi are particularly useful in reducing postharvest fungal diseases caused by wound-invading pathogens. Many are just at the research stage of development. Citrus green mould (<i>Penicillium digitatum</i>) by <i>Trichoderma viride</i>. Citrus green mould (<i>Penicillium digitatum</i>) on oranges by <i>Pseudomonas</i> spp. either alone or in combination with hot sodium bicarbonate dipping. Using the fluorescent <i>Pseudomonas</i> spp. in combination with a treatment of hot sodium bicarbonate, could possibly provide a practical alternative or complement to fungicide use, for postharvest control of green mold on oranges (2008). Grey mould (<i>Botrytis</i>) on grapevines by Trichodex Bio-fungicide (<i>Trichoderma</i> sp.). Grey mould, Botrytis rot (<i>Botrytis</i> sp.) on strawberries and berries <i>Trichoderma</i> spores sprayed on strawberry blossoms and young fruit can reduce preharvest and postharvest but was not as effective as fungicides in controlling <i>Botrytis cinerea</i> on berries. Penicillium rot (<i>Penicillium</i> sp.) of pineapple was considerably reduced by non-pathogenic <i>Penicillium</i> sp. Postharvest rots (<i>Aspergillus</i>, <i>Botrytis</i>, <i>Rhizopus</i> and <i>Sclerotinia</i>) by Shemer® (<i>Metschnikowia fructicola</i>), a yeast-based biocontrol agent, is an antagonist that protects fruit and vegetables against fungal diseases. It also supplements and complements pre-harvest and / or post-harvest applications and is ideal for part of resistance management and IPM programs. Shemer® can be applied flexibly in mixtures with fertilizers and crop protection products. Further advantages are the fact that the product remains effective for a long time under a wide variety of climatic conditions, leaves no residues in crops, and is safe for beneficial insects.</p>
<p>Root, crown, butt and trunk rots of trees</p>	<p>Armillaria root rot (<i>Armillaria luteobubalina</i>) by: <i>Trichoderma</i> sp. has been investigated but has not been very successful. Heart rot fungus, root and butt rot (<i>Heterobasidion annosum</i>) by: A fungal disease (<i>Peniophora gigantea</i>) competes for food and space, and produces antibiotics. Heart rot has been successfully controlled on pine stumps overseas by inoculating freshly cut stumps with spores of the <i>Peniophora</i> fungus. The spores are applied to the cut surface either as a water suspension or as a powder immediately after the tree is felled, or are added to the oil used to lubricate the cutting bar of the chainsaw.</p>
<p>Root knot nematodes</p>	<p>Root knot nematodes (<i>Meloidogyne</i> spp.) appeared to be under natural biological control in some peach orchards on Lovell rootstock by a fungus (<i>Dactylella oviparasitica</i>). The many species of nematode-trapping fungi occurring played only a minor role in regulating root knot populations. <i>D. oviparasitica</i> parasitized most of the eggs in the relatively small egg masses (300–400 eggs) produced by <i>Meloidogyne</i> spp. females on Lovell peach. The fungus was less effective on tomato and grape, rarely parasitizing more than half the eggs in the larger egg masses (1,000–1,500 eggs) produced by the nematode on these crops.</p> <p>Root knot nematodes (<i>Meloidogyne</i> spp.) also by soil fungi which parasitized eggs of root knot nematodes, eg <i>Paecilomyces lilacinus</i>. <i>Verticillium chlamydosporium</i>.</p> <p>Root knot nematodes (<i>Meloidogyne incognita</i>) and root rot (<i>Macrophomina phaseolina</i>), on chickpeas (Akhtar et al 2007) in India by inoculation of plants with: <i>Pseudomonas putida</i> (a soil bacterium) most effectively reduced galling and nematode multiplication, followed by: <i>Glomus intraradices</i> (an arbuscular mycorrhizal fungus used as a soil inoculant in agriculture and horticulture) and <i>Paenibacillus polymyxa</i> (a soil bacterium). Combined inoculation of plants with <i>G. interadices</i>, <i>P. putida</i> and <i>P. polymyxa</i> caused the greater reduction in galling, nematode multiplication and root-rot index. Pathogens had adverse effects on root colonization by <i>G. interadices</i>, while root colonization by arbuscular mycorrhizal fungi was increased in the presence of <i>P. putida</i> and <i>P. polymyxa</i>. See also Stirling 2011, 2014.</p>

CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

Table 6. Examples of the biological control of diseases in Australia and overseas (contd).

DISEASES	BIOLOGICAL CONTROL AGENTS include:
<p>Scabs</p>	<p>Apple scab, black spot (<i>Venturia inaequalis</i>) by: Biocontrol of apple scab which causes pre and postharvest loss of fruit by augmentation of natural antagonists (<i>Chaetomium globosum</i>, <i>Athelia bombacina</i>) with nutrients. Treatment of senescent apple leaves shortly before or after leaf fall with a solution of urea reduces aeciospore formation in the following spring. Saprophytic fungi and bacteria increase following application of urea and this most likely leads to enhanced degradation of leaf litter, subsequently the apple scab fungus has no substrate on which to survive.</p>
<p>Soilborne diseases</p>  <p>Although many laboratory experiments demonstrate potential biocontrol effects on soilborne diseases, few have been commercialized and used in practice for plant disease control. Reasons include costs, legal problems in registration. Biocontrol agents must be effective and safe to use.</p> <p>Strains of biocontrol agents</p>	<p>Pythium, Phytophthora, Rhizoctonia, Fusarium, Cydrocladium and Thielaviopsis by: <i>Trichoderma</i> spp. is a preventative biological fungicide for control of plant diseases. The active ingredients are microbes, certain <i>Trichoderma</i> spp. which when applied to seeds, to transplants or other propagative material, or to soil or planting mixes, grow onto plant roots as they develop and provide protection against plant root pathogens such as mentioned above. Its mode of action against the target organism is multi-faceted and uses both antibiosis and predation against many common soil-inhabiting microorganisms that cause root and crown rots such as those listed above and damping off diseases. Selection of native strains of <i>Trichoderma</i> spp. with antagonistic activity against <i>Phytophthora capsici</i> and growth promotion on pepper (<i>Capsicum annuum</i>).</p> <p>Take-all (<i>Gaeumannomyces graminis</i> var. <i>tritici</i>) by: Common soil bacterium (<i>Pseudomonas fluorescens</i>) which produces a phenazine-1-carboxylate keeps take-all in check in the USA. Seed is coated with a sticky solution of the bacteria.</p> <p>Sclerotinia blight (<i>Sclerotinia minor</i>) of peanut can be suppressed with the biological control agent <i>Coniothyrium minitans</i> which is a mycoparasite of <i>Sclerotinia</i>. There was less disease in some of the treated plots. Commercially available overseas.</p> <p>Seed and soilborne diseases by: Fungal biocontrols, eg <i>Trichoderma</i> spp., <i>Coniothyrium minitans</i> and <i>Clonostachys rosea</i>. <i>C. rosea</i> strain IK726 has proved to be an effective antagonist in several crops against seed and soilborne diseases (Jensen et al 2007). <i>C. rosea</i> f. <i>rosea</i> (syn. <i>Gliocladium roseum</i>) colonizes living plants as an endophyte. <i>Verticillium biguttatum</i> may suppress <i>Rhizoctonia solani</i> and other diseases. Mycostop (<i>Streptomyces griseoviridis</i> strain K61) suppress <i>Fusarium</i>, <i>Alternaria brassicola</i>, <i>Phomopsis</i>, <i>Botrytis</i>, <i>Pythium</i> and <i>Phytophthora</i> that cause seed, root and stem rots and wilt diseases. Not available in Australia. Bacterial biocontrols, eg Strains of <i>Agrobacterium</i>, <i>Pseudomonas</i> and <i>Streptomyces</i>. Biosurfactant-producing <i>Pseudomonas fluorescens</i> strain SS101 suppresses <i>Pythium</i> root rot in hyacinths, iris and crocus in field conditions. Results vary with the field and the seasons. <i>Bacillus sphaericus</i> soil treatments suppress peanut damping off disease. <i>Bacillus subtilis</i> suppresses peanut southern blight (<i>Sclerotium rolfsii</i>); nitrogen sources and temperatures affected its effectiveness. Biocontrol agents for the control of a range of root and crown diseases are also being tested in the Australian market for future release (Novozymes Biologicals Australia).</p>
<p>Symbiotic organisms</p>	<p>Mycobeads[®] (ectomycorrhiza) promotes growth of plantation blue gum (<i>Eucalyptus globulus</i>) seedlings in WA. MycorTree[®] (<i>Pisolithus tinctorius</i>) is injected into the root zone of established trees currently in decline or trees growing in stressed environments. Trichorhiza[®] (mixture of Trichopel[®] (pelleted <i>Trichoderma</i>) plus Vaminoc[®] (clay-based blend of vesicular-arbuscular mycorrhiza). Nitrogen-fixing bacteria (<i>Rhizobia</i> spp.) on legumes.</p>
<p>Vectors of virus diseases</p>	<p>The fungus (<i>Beauveria bassiana</i>) affects both larval and adult stages of the whitefly (<i>Bemisia tabaci</i> species complex) which is a vector of tomato leaf curl virus. Various plant oil solutions of <i>B. bassiana</i>, not only kill the adult whiteflies when sprayed on source plants but also inhibit the acquisition of virus.</p>
<p>Wilts</p>	<p>Dutch elm disease (DED) (<i>Ophiostoma novo-ulmi</i>). Overseas research includes: Using a virus disease to biologically control <i>Ophiostoma</i>. Inoculating trees with mild strains of <i>Ophiostoma</i> (cross protection).</p>

Reducing the risk of Annual Ryegrass Toxicity (ARGT)

The "holy grail" of combining plant resistance through an endophyte and biocontrol

ARGT is the poisoning of livestock by ryegrass infected with a bacterium (*Clavibacter toxicus*). The bacteria are carried into the ryegrass by a nematode (*Anguina funesta*) which may be attacked by a twist fungus (*Dilophospora alopecuri*) so that the nematode's ability to invade ryegrass is reduced and growth and reproduction of nematodes and bacterium in ryegrass is also restricted (Yan 2011).

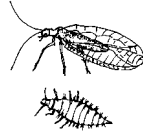
EFFECTIVE BIOLOGICAL CONTROL

<p>Suppliers, advice, training</p> <p>Check providers of training and biocontrol agents for your crop in your region</p>	<p>Growers need protocols to follow so get some advice and training in implementing a biocontrol program in you crop (Crisp 2008), eg</p> <ul style="list-style-type: none"> • Good Bugs www.goodbugs.org.au/ (hosted by The Association of Beneficial Arthropod Producers) lists commercially available beneficial insects in Australia and NZ. • Bugs for Bugs www.bugsforbugs.com.au/ • Crop consultants Qld, available for crop monitoring and IPM advice. • IPM Technologies www.ipmtechnologies.com.au/ • Organic Crop Protection (OCP) is a manufacturer and distributor of organic soil and plant health products. www.ocp.com.au/
<p>Use in an IPM framework</p> <p>Management (IPM) or Best Management Practice (BMP)</p>	<p>For the greatest chances of success use biocontrols within an IPM framework:</p> <ol style="list-style-type: none"> 1. Plan, eg use IPM protocols, train, and keep records. 2. Details of the crop, variety, region, etc. 3. Identify pests and beneficials and know their life cycles etc. 4. Prevention, eg cultural, sanitation, biocontrol, resistant varieties, diseases-tested, etc. 5. Monitor pests and beneficials throughout the season. 6. Threshold for pests and predator / prey relationships. 7. Curative, eg cultural, biocontrol, pesticides. 8. Evaluate the success / efficacy of the program. <p>Who is to carry out the program?</p> <ul style="list-style-type: none"> • Contract between supplier and grower. The supplier not only supplies the biocontrol agents but also monitors the situation in the crop and may apply corrective sprays. • Supplier provides, delivers the biocontrol agents and instructs the grower on how to introduce them into the crop and which pesticides will not harm them. • Grower rears biocontrol agents under guidance and introduces them.
<p>Read the label and SDS</p> <p>Check expiry dates</p>	<p>Follow label instructions and keep records, eg</p> <ul style="list-style-type: none"> • These products are composed of living organisms. Poor storage conditions, soil and air temperatures and the use of chemicals compromise their efficacy. • Check that they are alive before releasing. They need food, ie their prey, nectar, etc. • Check instructions for release and rate. Balancing the timing and numbers of introduction with environmental conditions can be difficult. • Ensure the correct formulations and timing of applications. • Check that they have established. • Check the success of the program (preferably by a 3rd party audit).
<p>When to release beneficials</p> <p>MAKING IT WORK</p> <ul style="list-style-type: none"> • Microclimate • Timing – When to put out traps, release beneficials, spray, etc • Spray guide for beneficials • Biosecurity • Application delivery • Pheromones 	<p>Always release beneficials when pest pressure is beginning not when it is causing damage to the plant and when pest numbers are greatest; there are exceptions.</p> <ul style="list-style-type: none"> • Diseases. Many biocontrols prevent disease by competition, ie they are preventative not curative, so they must be applied before the onset of disease, before it is noticed and at frequent intervals. They will not rescue plants already infected. • Insects and mites. It is important to release biocontrol agents early enough before the pests implement some of their defense mechanisms, eg mealybugs and scales clump in groups on top of one another so that eggs and individuals at the bottom of the pile escape attack. Thrips hide and fungus gnats tunnel into cuttings, twospotted mite produce webbing that traps predators. Key factors for success in suppressing 2 spotted mites are: <ul style="list-style-type: none"> • Plant size, plant variety. • Prey numbers, stage targeted, rate. • Timing of predator release, where to apply them and number of applications. • Favourable weather. • When predators are established, the predator / prey relationship) will determine success.
<p>Augmentative biological control</p>	<p>Parasitoid wasps released in large numbers to improve control of pest fruit flies are being assessed in Australia. Once released, these parasitoid wasps are self-dispersing, so give wide coverage, including areas where other techniques, such as pesticide spraying, cannot readily be applied, eg organic crops, populated areas, where fruit flies can breed on backyard fruits and vegetables (where spraying is often unpopular).</p> <ul style="list-style-type: none"> • Two larval parasitoid wasps (<i>Diachasmimorpha kraussii</i> and <i>D. tryoni</i>) have been identified in association with Qfly (<i>Bactrocera tryoni</i>) in NSW. • Inundative release of parasitoid wasps, together with SIT (Sterile insect technique) is more effective than either technique alone and could provide increased efficacy for the control of Qfy in exclusion zones, pest free areas and buffer zones (page 103). <p>Western flower thrips (WFT) (<i>Frankliniella occidentalis</i>) is a costly pest of hydroponic lettuce (and other crops). Trials of 2 mites to manage WFT in hydroponic lettuce have shown that they provide better protection than a single predator. One mite feeds on thrips on leaves and another on pupae in the soil. WFT control in glasshouses may involve:</p> <ul style="list-style-type: none"> • The plant-feeding mite (<i>Amblyseius cucumeris</i>) which targets first-instar larva on leaves. This probably the most important thrips predator. • A soil-dwelling mite (<i>Hypoaspis miles</i>) that preys on thrips pupae in the ground. • A predatory bug (<i>Orius laevigatus</i>) that targets larvae and adults of thrips.

Diagnosics

Aim to identify all the goodies and badies (pests, diseases and weeds and beneficials) in your crop. Divide them into badies, goodies, those under biocontrol and those not, those that might become pests, possible arrivals from interstate or overseas, and obtain fact sheets or information on them for your crop.

Recognize predatory insects they are everywhere



Lacewings, of varying sizes, and their larvae feed on small insects, eg aphids, mealybugs, mites, scales, thrips.



Soldier beetles (15 mm long) and their larvae (in the soil) feed on soft-bodied insects. Beetles occur in great numbers in summer, particularly on white flowering plants.



Transverse ladybird (*Coccinella repanda*) Common spotted ladybird (*Harmonia conformis*)
Predatory ladybirds (5-7 mm long) and their larvae feed on aphids, mealybugs, mites and scales.



Assassin bugs (*Pristhesancus* sp.) of varying sizes, feed on a wide range of insects



Brownish shield bug (*Oechalia* sp.) (9-13 mm long) preys on caterpillars of the grapevine moth and other insects.



Hover flies (some stout, like bees) hover over plants and lay eggs in aphid colonies. Green or brown maggots feed on aphids.



Praying mantis (20-150 mm long) feed on pest and beneficial insects.

Recognize parasitic insects



Parasitic wasps (1.5-16 mm long), lay eggs in bodies of other insects, eg scales, aphids, caterpillars, lerp insects or scarab grubs.

Recognize parasitized and diseased insects



Healthy aphid



Exit hole of adult wasp from parasitized aphid



Diseased caterpillar on a leaf

Recognize key insect pests under biocontrol

Learn to recognize pests which are already under biological control and so do not require control measures to be undertaken except under exceptional circumstances, eg high pest pressure or if pesticides have killed their biocontrol agents.



Left: Greenhouse whitefly (*Trialeurodes vaporariorum*) about 1.5 mm long.
Right: Green vegetable bug (*Nezara viridula*) about 15 mm long.

Recognize other pests

Lerp insect on eucalypts



Recognize other insects

Pollinators, spiders, insects that degrade organic matter, etc



Flower spider



Bee



Slater



Paper wasp nest

Microclimates and natural enemies – Triangles

If there is no food or prey, or pesticide residues are present, either way they will die

<p>Balancing act an example</p>	<p>Beneficial microorganisms and insects live on a leaf in their own microclimate, which is close to that of their hosts (pathogens and pests).</p> <ul style="list-style-type: none"> • This why it crucial to know how many eggs are laid by spider mites at particular temperature, also how long the eggs take to hatch at different temperatures, etc. • Many biocontrol fungi and bacteria need a wet host microorganism as well. • To be effective, beneficals have to live in the same ecological niche as their pest host. The dilemma – by the same token many biocontrol fungi and bacteria need a wet host microorganism too. • Understanding the individual microclimates of pests and diseases is the key to avoiding many of them; avoiding the microclimates that they like without compromising plant growth. A rule of thumb is that if it is warm enough for the pest to be active it is warm enough for the beneficial to be active but remember some are as susceptible to pesticides as the pests. • Many crops highly susceptible to particular diseases when grown in humid areas can be grown relatively free from disease under surface irrigation in more arid regions.
<p>Microclimates for pests, diseases and biocontrols</p> <div style="border: 1px solid black; padding: 5px; margin: 10px 0;"> <p>Spores of Botrytis might need 5-8 hours on a wet leaf to achieve infection, depending on the temperature</p> </div> <div style="border: 1px solid black; padding: 5px; margin: 10px 0;"> <p>Measuring microclimate is very difficult. There has to be remote sensing or guesswork or complicated calculations with assumptions to measure pressure, humidity gradients, etc - a balancing act</p> </div> <p>Vapour Pressure Deficit, or VPD, is the difference (deficit) between the amount of moisture in the air and how much moisture the air can hold when it is saturated.</p>	<p>Microclimate means different things to different people, different places and different microorganisms. Even in greenhouses the temperature, humidity, etc may vary widely from side to side and from floor to roof. So we have to specify exactly the piece of the microclimate we refer to, eg root, fungus, leaf or a fungus infecting a fruit etc or a whitefly sucking sap from the phloem of a leaf.</p> <ul style="list-style-type: none"> • The microclimate for pathogens and beneficial fungi. Floating through the air, fungal spores and bacteria have to withstand a variety of temperature, humidity and UV rays in sunlight, before coming to rest on a leaf. Those splashed on by water or deposited by sticky fingers and sappy tools get a free ride. Once there, virtually all of them depend on a wet surface to begin infection. Most biocontrol fungi and bacteria, including pathogens of insects and nematodes, also need water. There are exceptions. <ul style="list-style-type: none"> • The number No. 1 mistake in manipulating microclimates is to allow foliage, fruit and flowers to get wet. Nearly all fungi and bacteria that parasitize plants need water droplets or a wet wound to achieve infection. The dilemma – many biocontrol fungi and bacteria need a wet host microorganism too, eg <i>Ampelomyces quisqualis</i>, which is a parasite of powdery mildews, works best when its sticky spores are sprayed on in water and water sprays help keep the biocontrol epidemic going. <i>Verticillium lecanii</i> is a fungus that has been used to control insects as well as some plant pathogens and it also needs a wet base. On the other hand, <i>Sporothrix flocculosa</i> (Sporodex[®]) used to assist control of powdery mildews works better in somewhat drier conditions. So biocontrol products have to work within very fine limits, giving them a fighting chance on one hand without encouraging pathogens on the other. • The microclimate for pest and beneficial insects. Depending on their size, insects live on a leaf in their own microclimate, or as we say, in their individual ecological niche. Flying insects and the arthropod predators and parasites go through the same environments as airborne fungal spores but some of their life cycle is spent on the leaf. Spider mite eggs are on the leaf undersurface (which might have a quite different environment from the top). Predictive systems can assist with forecasting when different stages (eggs, nymphs and adults) are likely to occur. <ul style="list-style-type: none"> • It can also be extrapolated to find that Western flower thrips and most greenhouse pests can be eradicated from greenhouses between crops by keeping the temperature at certain temperatures and Vapour Pressure Deficits (VPDs). • Irrigating plants to reduce two-spotted mite (<i>Tetranychus urticae</i>) infestations. Maintenance of a plant's health is based on a regular regime of weeding pots by hand, fertilizing and monitoring pests and diseases. • Lucerne strips can be used a refuge for beneficial insects in the field (pages 106, 107).

Failure of biocontrol agents

Failure of biocontrol agents to suppress diseases in commercial trials is thought to be due to **uncontrolled environmental conditions** that influence their survival, establishment and / or activity, eg fluctuations in temperature, humidity, wetness of leaves, moisture in the root zone, air movement and the presence of gases.

- The growth of the biocontrol agent can be halted by low temperatures or dry conditions that cause the agent to dry out.
- Fluctuating environmental conditions can favor the growth of certain biological flora associated with plants that may outcompete or suppress the biocontrol agents.
- Adverse environmental conditions can also predispose plants to pathogen attack.

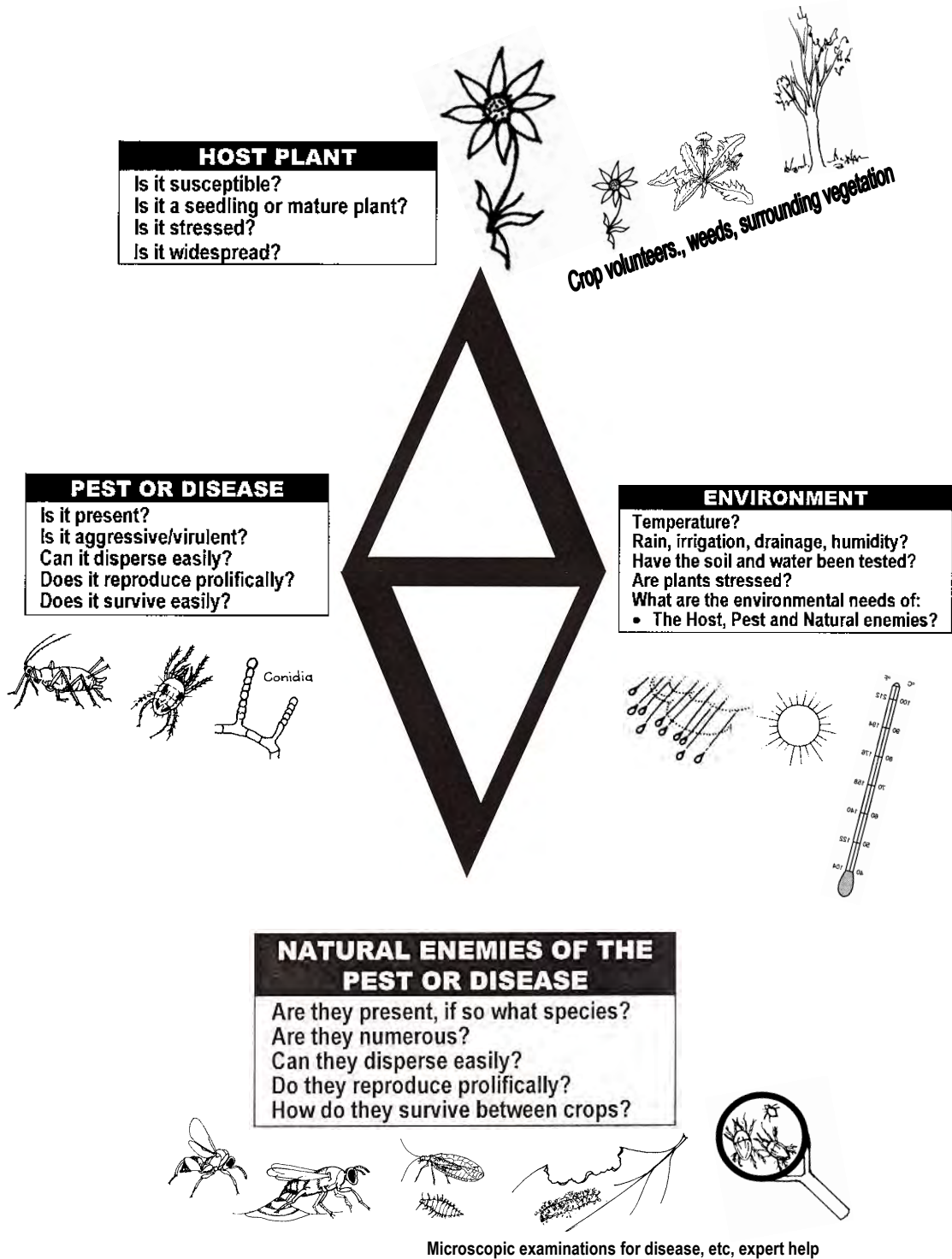


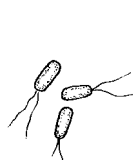
Fig. 15. Triangles – the host, pest, beneficials and the environment

Promoting the right microbial environment for beneficial soil microbes

4 billion microbes / m²

A healthy productive biologically active soil is estimated to contain more than 4 billion individual microbes in the root zone of every square meter of the soil surface. Soil microbes such as bacteria, fungi, protozoa and algae, together with macroorganisms such as nematodes and earthworms play an important and vital role in maintain a healthy root zone. Minor differences in organic matter, moisture, soil temperature, aeration and pH can all greatly affect microbe populations (Geary 2011). Populations can vary greatly depending on soil temperature and moisture levels with the numbers of bacteria, fungi and Actinomycetes (see below) at their highest during the spring / autumn months.

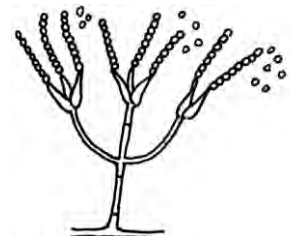
- **Moisture.** Like all living organisms micro and macroorganisms need sufficient moisture to thrive. Water is a key component of the protoplasm with the amount of water in soils controlling the movement of food sources.
 - **Optimum moisture content for aerobic organisms** is considered to be 50-70% of a soil's water-holding capacity.
 - **At soil water contents greater than 80%**, fungi and Actinomycetes are seldom observed.
 - **Actinomycetes seem able to withstand dry conditions** better than other microorganisms.
 - **Most pathogens associated with turf** are associated with excessive moisture conditions which cause the soil to be oxygen starved (anaerobic). Proper aeration and avoidance of overwatering are often helpful in developing beneficial microbial populations.
- **Temperature.** Soil microbes can be divided into 3 categories based on their temperature requirements, eg
 - **Psychrophiles** require low temperatures.
 - **Mesophiles** are most active under moderate temperatures. Most bacteria, fungi and Actinomycetes are mesophylls, are most active at soil temperatures of **23-35°C**.
 - **Thermophiles** require high temperatures. Actinomycetes are common in soil, in many compost heaps the populations can approach billions per gram of soil.
- **pH - All microorganisms have a preferred soil pH range** in which they survive and grow best.
 - **The optimum pH for most bacteria is near neutral** and it is recommended to add agricultural limestone to acid soils to greatly increase bacterial populations.
 - **Actinomycetes are most abundant at a soil pH of 6.5-8.0.** When the soil pH falls below 5.0, Actinomycetes display very little activity. Actinomycetes have large threadlike structures which break apart to form rods or spherical shapes. They have characteristics common to both bacteria and fungi and are numerous and widely distributed in soil and are next to bacteria in abundance. Many species occur in soil and are harmless to animals and higher plants.
 - **Fungi are well adapted to a variety of soil conditions;** however, they are particularly suited to acid environments. At pH levels below 4 most fungi have the ability to outcompete other organisms such as bacteria and Actinomycetes which struggle to survive in such acid soils.



Bacterial cells with motile flagella



Actinomycete have threadlike structures which break apart to form spherical or rod shapes (*Streptomyces* sp.). Ruth Kerruish.



Fungal mycelium and spores (*Penicillium* sp.)

- **Decomposition of organic matter** is the primary role of microorganisms, thus a soil rich in carbon containing (organic) materials such as humus, organic matter and roots favor increased populations of microorganisms.
 - **Heavier textured soils** generally contain enough organic matters to support a diverse microbial population; on sand-based root zones it is important to incorporate organic material which can be quickly degraded such as seaweed-based fertilizer or some other source of carbon which can be used as a food source to encourage microbes.
- **Aeration** – given that the most beneficial microorganisms require adequate oxygen to sustain growth, it is only natural that they are most abundant under well aerated conditions. It is vital to undertake cultural practices such as regular aerating to encourage healthy soil microbial populations (page 45).
- **Non-target effects of broad spectrum pesticides** have been widely studied and it is no surprise that some insecticides will kill beneficial insects and some fungicides will kill beneficial fungi. Information on the toxicity of individual pesticides on specific beneficial microorganisms is readily available (pages 130, 349).

Using chemicals with beneficials

Integration of pesticides with the action of natural enemies or biological control agents is an important technique of IPM systems

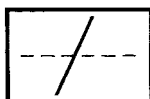
Spray Guides for beneficial insects



Many websites have current spray guides for beneficial insects, including:

- **Good Bugs** (Australasian Biological Control). www.goodbugs.org
- **Bugs for bugs**. www.bugsforbugs.com.au/
- **Cotton Catchment Communities CRC** guide to the impact of individual insecticides on beneficial insects that act as natural predators of cotton pests. www.cottoncrc.org.au/
- **IPM Technologies** carries out pesticide bioassays and researches the effects of pesticides on insect and mite pests and beneficials. www.ipmtechnologies.com.au
- **Sustainable Gardening Australia (SGA)** and **University of Melbourne Burnley's College** have developed a rating system that **groups horticultural chemicals into 3 levels** that indicate degree of environmental harm so nurseries can promote products with low effects on the environment.
- **Label directions** may indicate a pesticide's effect on **predators and parasitoids** and other beneficials, eg bees.
- See also **IPM** page 349.

Minimizing the impact of pesticides on beneficials



Beneficials can be encouraged by not spraying broad spectrum insecticides.

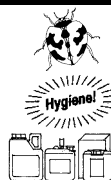

Delay use of disruptive insecticides as long as possible.



Even a good biocontrol program may need correction with pesticides. Biocontrol is rarely the only tool needed especially in floriculture industry with its low damage tolerance. But with new selective chemicals available you can combine biocontrol with pesticides and reduce sprays. **Some biocontrol agents are resistant to pesticides**, eg insecticide-resistant predatory mites; many though do **not** have any significant resistance to pesticides. The challenge in combining these 2 strategies is to preserve the built-in biobontrols while minimizing the indirect effects of pesticides (see also page 349).




- **Reconsider spray thresholds.** Growers often spray long before pests reach damaging levels. This is prudent practice if a grower knows from experience that 10 thrips on a sticky card will grow to 30 in a week if he doesn't spray today. However if there is a healthy population of predators, thrips numbers will grow more slowly or may decline.
 - Do not spray at the first sign of mite activity, eg be prepared to suffer minor mite damage in the center of say orchard trees; this will not affect your present or future crops.
- **Choosing the RIGHT CHEMICAL and applying it at the RIGHT TIME** can allow beneficials to thrive. A single application of many chemicals can end biocontrol programs for weeks or months. Your application technique is important.
 - **Selective pesticides are usually more toxic to pests than beneficials**, eg **Bt** formula specific for caterpillars, etc has no direct impact on most beneficials.
 - **Difficulties with biocontrol on purchased cuttings.** Difficulties can often result from **residues on foliage** from previous treatments.
 - **Complete spray coverage of plants.** If all plants in a crop are to be sprayed, chemicals must be selective.
 - **Characteristics of the pesticide.** There are many ways of selecting or applying chemicals so that they are least harmful to natural enemies.
- **Timing.** Be selective about the timing and scope of pesticide applications.
 - **Nonselective with very short residuals** can be applied before introducing beneficials or in hot spots.
 - **Horticultural oils and insecticidal soaps** suppress soft bodied pests (aphids, whiteflies, mites). They will kill many beneficials on direct contact but after the spray has dried they won't be harmed. This allows the option of spraying individual plants while leaving beneficials on adjacent plants as sources of recolonization.
 - **Life cycles of beneficials.** Organophosphates, carbamates and synthetic pyrethroids are generally toxic to beneficials.
 - **Parasites are less susceptible** when developing inside their hosts and soil-dwelling predators are quite resistant in foliar sprays.
 - **Trichogramma wasps manage to survive** even after application of hazardous chemicals because they spend much of their life cycle developing inside the host egg and are protected. Adults may be killed but eggs survive.
 - **Spray retention is rarely perfect**, eggs under leaves and in crevices may not be covered by the chemical.
 - **Aphid wasp parasites work best** when numbers of wasps are released on a regular basis to suppress aphid populations rather than when aphid numbers have gone out of control (Crawford 2006a).
 - **Nematodes are the most resistant beneficials**, compatible with many broad spectrum insecticides that would decimate most beneficial insects. Check with your supplier.
- **Enhance existing natural controls** by:
 - **Generally reducing pesticide use** or switching to **more selective products**. Parasitic wasps and bees are very susceptible to many insecticides as some insects belonging to this group (Hymenoptera) tend to lack resistance to insecticides.
 - **Be more pro-active**, eg design landscapes so there is a range of plant material that provides season-long blooms so there is a supplementary diet of nectar and pollen for natural enemies when their usual prey is lacking (pages 106, 120).

MANAGING BIOCONTROL METHODS

For the greatest chances of success use biocontrols within an IPM framework

<p>Integrated Weed Management (IWM) Best Management Guides</p>	<p>Because some weeds are so widespread and in different environments a number of approaches are needed. Incorporating biocontrols, along with other appropriate management practices, into <i>IWM</i> systems gives them the greatest chance of success, eg</p> <ul style="list-style-type: none"> • Noogoora burr by the mycoherbicide (<i>Alternaria zinniae</i>) and a chemical herbicide. • Skeleton weed by a combination of a rust fungus, 2 introduced arthropods, chemical herbicides and cultural practices, eg rotating cereals crops with legumes. • Nodding thistle by crown weevil (<i>Trichosirocalus horridus</i>), grazing management and chemical herbicides. • Best Management Guides has been developed incorporating the use of herbicides, fire and other techniques for many weeds available online, eg bridal creeper, St Johns' wort. www.weeds.org.au/
<p>Mealybugs in greenhouses</p> 	<p>Mealybugs in the Melbourne nursery of the Royal Botanic Gardens of Australia cannot be eradicated so accept an acceptable level of infestation (Sherwood 2005).</p> <ul style="list-style-type: none"> • Mealybug ladybirds (<i>Cryptolaemus</i>) are released and feed on the eggs and larvae of the pest mealybugs. • Infested plant material is disposed of correctly. • Good hygiene practices footbaths, floors, etc is maintained. • Soil is kept separate from potting mixes. • Target chemicals to be most effective against the pest to be controlled.
<p>GE and the varroa mite</p>	<p>Varroa mites are a major pest of honeybees overseas including NZ and it is only a matter of time until they reach Australia.</p> <ul style="list-style-type: none"> • An experimental novel treatment at the University of Aberdeen in Scotland targets the immune system of the varroa destructor mites, tricking them into self-destructing. New Zealanders are not convinced.
<p>Fruit flies</p> 	<p>Both modeling and studies worldwide show that sterile insect technique (SIT) in combination with the inundative release of parasitoids is more effective than either technique alone.</p> <ul style="list-style-type: none"> • Parasitoid wasps released in large numbers to improve control of pest fruit flies in several regions of the world are now being assessed in Australia (page125). • SIT is used in Australia. Future trials will determine the effectiveness of parasitoid wasps, both alone and together with SIT. • Spinosad is a relatively new insecticide that is made up of two complex organic spinosyn compounds, which are produced by certain microbes that were first discovered in soil (<i>Saccharopolyspora spinosa</i>). Kills through both contact and ingestion action, but is much more effective if insects ingest it. Follow label direction for use to ensure effectiveness.
<p>Floriculture</p>	<p>Biocontrol is rarely the only tool needed especially in floriculture industry with its low damage tolerance.</p>
<p>Post-harvest diseases</p> <p>Biological control of postharvest diseases of fruits and vegetables using microorganisms</p>	<p>The withdrawal of several fungicides from the market for some or all postharvest use has greatly diminished ability to control postharvest diseases of many commodities. There is clearly a need to develop new and effective methods of controlling postharvest diseases that are perceived to be safe by the public and pose negligible risk to human health and the environment, eg</p> <ul style="list-style-type: none"> • Inoculum reduction can be achieved through sanitation and exclusion, the use of non-selective fungicides (sodium carbonate, sodium bicarbonate, active chlorine and sorbic acid). Heat and cooling treatments can significantly lower the disease pressure on harvested commodities. • Harvesting and handling techniques that minimize injury to the commodity along with storage conditions that are optimum for maintain host resistance will aid in suppressing disease development after harvest.
<p>Economic analysis</p>	<p>Make sure you conduct an economic analysis as this is so often missing in biological-control projects.</p>
<p>Soilborne diseases and fungicides</p>	<p>Companion (<i>Bacillus subtilis</i> GB03) which is supplied dormant in a specially designed pack and the product is activated by contact with air or water. It is an inoculant drench for some ornamental plants.</p> <ul style="list-style-type: none"> • Should a problem still arise, growers can still drench with a curative fungicide.

<p>Habitat manipulation Revegetation by design Ecological manipulation</p>	<p>In the high-density vegetable production area on the North Adelaide Plains major crop losses are caused by WFT through transmission of TSWV. A current project, Revegetation by Design, aims to reduce WFT habitat and promote populations of beneficial mites and insects (Travermer 2006). www.sardi.sa.gov.au/</p> <ul style="list-style-type: none"> • The aim is to replace exotic weeds species which are ideal haven for WFT with native plant species which are less suited to pests and provide food and protection for beneficial species. Pest thrips are abundant on many weeds but not on some native species while the parasitoids and other beneficial insects were the most abundant and diverse invertebrates on endemic plants. • Crops adjacent to strips of native vegetation should benefit from reduced pest pressure and reduce pesticide use.
<p>Habitat manipulation in a vineyard</p> <p>Food source for parasitic wasps</p> <p>Parasitoid performance can be constrained by lack of a suitable adult food</p>	<p>One aim is to improve the field performance of <i>Trichogramma carverae</i> and maybe other natural enemies of lightbrown apple moth (LBAM) (<i>Epiphyas postvittana</i>) in Australian vineyards by providing the <i>Trichogramma</i> wasp with a food source (Begum 2004).</p> <ul style="list-style-type: none"> • Common buckwheat (<i>Fagopyrum esculentum</i>) is a good nectar source for both LBAM and <i>T. carverae</i>, so is less suitable groundcover choice for habitat manipulation. • Coriander (<i>Coriandrum sativum</i>) and sweet alyssum (<i>Lobularia maritima</i>) appear to be relatively selective groundcover species for <i>T. carverae</i> that are unlikely to benefit LBAM. This shows promise for improving field performance of <i>T. carverae</i>. • Exudates from ripening grapes may be an important late season food for <i>T. carverae</i> or may be for other natural enemies of vineyard pests. Therefore fruit can play an important role in habitat manipulation. • This study is the first report of flower discrimination by <i>T. carevera</i> which is an important factor for the development of habitat manipulation strategies for this and most likely other biocontrol agents.
<p>Organic producers</p> 	<p>Research projects in SARDI Entomology include information on the life cycle and developing IPM programs for thrips and other pests (Crisp 2008).</p> <ul style="list-style-type: none"> • Kelly's citrus thrips (KCT) causes cosmetic damage and downgrading of fruit. It is resistant to many of the insecticides used in Australian citrus orchards today. <ul style="list-style-type: none"> • They pupate in the soil. In a low input organic orchard and a low input conventional orchard pupal mortality is higher than for high input conventional orchards. • This correlated closely with populations of soil dwelling predatory mites, which in turn positively related to levels of soil carbon. • Soil amendments have provided suppression of KCT and have added benefits of increased yield, increased fruit size and improved water use efficiency. • Onion thrips in addition to yield losses cause significant cosmetic damage and market downgrade on stored onions. Two approaches are being assessed: <ul style="list-style-type: none"> • The addition of predatory mites (<i>Neoseiulus cucumeris</i>) to bins of harvested onions and as in the case of KCT, the use of soil amendments. • The release of <i>Hypoaspis aculifer</i> produced encouraging reductions of thrips densities. • Western flower thrips (WFT) causes cosmetic damage to a wide range of horticultural crops and in some crops its ability to transmit virus diseases can result in near total crop loss. <ul style="list-style-type: none"> • WFT is resistant to most common insecticides and is the major insect threat to many greenhouse and field crops. • Where broad spectrum insecticides are withheld options include predatory mites (<i>Microsaris</i> spp., <i>Pergamasus</i> spp.), <i>Hippodamia</i> ladybird, parasitoid wasps, and lacewings. Maintaining their populations at levels to control incoming WFT is difficult. • Efforts to improve the environment in and around the crop are being assessed to reduce pest populations around crops and greenhouses and provide a suitable environment for beneficial organisms. <i>Microsaris</i> spp. is a predator of both WFT and whitefly and has established in greenhouses but is susceptible to pesticides.
<p>Citrus exports Fuller's rose weevil</p> 	<p>Fuller's rose weevil (FRW) does not damage citrus fruit but is a biosecurity pest in South Korea and other Asian countries. Eggs are laid under the buttons of the fruit which are difficult to detect and survive packing and transport. If eggs are detected on fruit received by the importing country, the shipment is either fumigated or more likely rejected. There are strict residue limits on some broad spectrum insecticides which also disrupts IPM strategies.</p> <ul style="list-style-type: none"> • Because they are flightless they must climb the trunk to get to the fruit. Control measures include: <ul style="list-style-type: none"> • Skirting trees to stop adults climbing up low-lying branches. • Keep weeds away from the canopy for the same reason. • Spray the tree trunks as recommended to stop adults from getting into the canopy. SARDI is developing a spray unit that will target tree trunks thereby reducing the amount of chemical and hence avoid the disruption of beneficial organisms in the soil. • Implementing a new method of orchard inspection for FRW and a training program acceptable to Australia's trading partners. • Trials are under way into pre-shipment disinfection of FRW with ethyl formate, a fumigant, which can kill FRW eggs under laboratory conditions. • Soil applied fungal and entopathogenic nematodes (ENSs) are being trialed for FRW larval and pupal control. Soil amendments may also assist the survival of these fungi and ENSs.

<p>Red scale on citrus</p>	<p>Biological Services in South Australia, offers a field service to control red scale, eg regular releases of a parasitoid wasp (<i>Aphytis melinus</i>) and the application of sprays which are not toxic to the wasps, eg petroleum oil (see also page 109).</p>
<p>Soilborne diseases</p> <p>Biocontrol agents and fungicides, type of soil</p> <p>Regulatory approval would be required to reduce rates</p> <p>Efficacy</p>	<p>Some fungicides are harmful to beneficial microorganisms such as <i>Trichoderma</i> spp. <i>Azospirillum</i> sp, <i>Bradyrhizobium</i>, <i>Pseudomonas fluorescens</i> – so compatibility between pesticides and antagonistic microorganisms will affect efficacy. However, overseas combined treatments of biocontrol agents and a reduced rate of fungicide are effective for the control of some soilborne pathogens in some crops.</p> <ul style="list-style-type: none"> • Strains of several bacteria, ie <i>Bacillus thermoglucisidasus</i>, <i>Streptomyces misionensis</i> have the potential for use in commercial production of lily bulbs as they can be used alone or in combination with the fungicide Sporgon (prochloraz-Mn complex) at low concentrations. Commonly used as a soil drench treatment for Fusarium to control seedling blight of lily in Taiwan, reducing fungicide use (Chung et al 2011). • Bacillus commonly suppresses fungal pathogens by antibiosis (antibiotics), eg <ul style="list-style-type: none"> • <i>Pythium aphanidermatum</i> by <i>B. subtilis</i>. • <i>Phytophthora medicaginis</i> and <i>P. aphanidermatum</i> by <i>B. cereus</i>. • <i>Fusarium oxysporum</i> and <i>B. cinerea</i> by <i>B. amyloliquefaciens</i>. • However the production of antibiotic by Bacillus spp. can be affected by soil types (such as clay soil), organic matter (such as crop residues), plant root exudates (such as carbohydrates and amino acids) and minerals (such as phosphate). • Colonization of plant roots by microbial agents, competition for space and nutrients also affect efficacy of control of plant pathogens by other biocontrol agents.
<p>Hydroponic lettuce and root diseases</p> <p>Manage pests, eg fungus gnats that carry and spread disease</p>	<p>Good practice in managing root diseases in hydroponics includes:</p> <ul style="list-style-type: none"> • Sanitation, eg effective disinfection and sanitation of tanks, pipes, surrounding areas and appropriate disposal of diseased plants and plant material. • Cultural methods, eg recommendations for producing seedlings, the importance of managing moisture stress and the temperature of nutrient solutions. • Biological control, eg microbial biocontrol agents, eg Fulzyme Plus™. • Biosecurity, eg plan layout to provide separation between plants of different stages. • Using varieties with resistance to key diseases. • Physical methods, eg light combined UV and sonic unit has been trialed. • Fungicides used appropriately.
<p>Helicoverpa (summary)</p> <p>Hertel, K., Roberts, K. and Bowden, P. 2013. <i>Insect and Mite Control in Field Crops</i>. NSW Management Guide. NSW DPI.</p>  <p><i>Helicoverpa</i> sp. on sweetcorn. Has a very wide host range.</p> <p>The Cotton Pest and Beneficial Guide. Cotton R&DC</p> <p>GEMSTAR</p>  	<p>Seasonal biology of <i>Helicoverpa</i> spp. in eastern Australia.</p> <ul style="list-style-type: none"> • Corn earworm is mainly restricted to within 15km of the coast and to inland irrigated summer crops. It mainly overwinters locally as pupae in the soil which are a source of the moths which produce the spring and summer generations of caterpillars. • Native budworm is widely distributed throughout mainland Australia and during winter breeds in semi arid parts of WA, SA and SW Qld. These vast inland areas are the sources of moths which produce the spring generation of caterpillars in NSW (local overwintering pupae in the soil are of little concern). Moths are strong fliers and assisted by wind they can be carried very long distances to initiate infections in localities far from where they developed as caterpillars. <p>Helicoverpa management strategy. Where large <i>Helicoverpa</i> caterpillars are present in crops during March there is a risk of carryover of resistance to the next season. And a number of basic steps during summer and pre-sowing periods could help increase the chances of a successful start to the next season.</p> <ul style="list-style-type: none"> • Cultivate these paddocks to bust the overseasoning pupae as soon after harvest as possible and complete by the end of August. Ensure disturbance occurs to at least a depth of 10cm. • Sanitation. Control farm vegetation likely to encourage the breeding of insect pests either by spraying herbicide or by cultivation. As a priority control summer weeds which provide a green bridge for pests such as aphids, mites, snails and diamondback moth to survive over the hot summer months (oversummering populations give rise to new generations the following autumn which can then move onto emerging crops). • Biopesticides. Use the most selective pesticides available including appropriate use of Gemstar®, Vivirus® Gold (nuclear polyhedrosis virus of <i>Helicoverpa</i> spp.) and Bt. <ul style="list-style-type: none"> • Monitor natural enemies and be aware of their activity in different crop types, however, they are often not robust enough to handle high density infestations, large range of larval sizes and persistent egg lays. • Many natural enemies including assassin bugs, damsel bugs, ladybirds and lacewings eat the eggs or caterpillars while parasites larvae feed inside budworm eggs, grubs or pupae eventually killing their host when emerging as adults. • Pesticides – resistance management strategies: <ul style="list-style-type: none"> • Scout crops regularly to detect eggs and very small caterpillars. Infestations often occur after heavy rainfall. Before deciding to spray consider the likely extent of the infestation, ability of the crop to either tolerate caterpillar damage without any significant loss or to replace leaves, estimated value of likely loss if crop is left untreated, anticipated cost of treatment. Use information from pheromone traps. • Rotate chemical groups when spraying crops as recommended, eg by Croplife Australia. Use selective pesticides to preserve beneficial insects and mites.

PROS, CONS AND CHALLENGES

PROS

- Biocontrol agents can give good control under low levels of disease and can be an efficient and cost-effective way to manage significant pests.
- **Compatible with other non-chemical control methods**, eg sanitation, resistant varieties.
- It can be a long term sustainable solution which is most effective as part of an **IPM** approach.
- With care, can be used with some pesticides, in **IPM** and **BMP** programs and with **organic standards**.
- **For many diseases, pests and weeds**, biological control may be the only feasible method of control.
- **There are strict regulatory procedures** for the importation, development and release of biocontrol agents under current regulations and intensive specificity testing.
- **Biocontrol agents** can be effective, **target specific**, genetically stable, **relatively easy** to mass produce, store and transport, with adequate shelf life and **safe to use**.
- **Public perception is that biological control is benign**, so using it is good for public relations and staff.
- Non-toxic and non-polluting.
- **Some** biological control agents, eg nematodes, **do not** require registration.
- Known biocontrol agents are almost always protectants; many modern fungicides are systemic and may be used **after** infection if biocontrol doesn't work.
- With selective chemicals, biocontrol products can be combined with pesticides and reduce sprays lowering residues in air, soil, water, plants, animals and food.
- New soft biological and chemical insecticides are now available to make it easier to incorporate biocontrol agents into IPM programs, eg pheromones.
- **Lower operator hazard** and lower re-entry intervals.
- **Some biocontrol agents are self-propagating**, eg under favorable conditions a parasitic fungus will spread through an insect population throughout the crop cycle.
- The biocontrol of many weeds and insect pests does not necessarily require continuous input after the initial releases. Exceptions include:
 - Where pesticides have been used.
 - After weather unfavorable the biocontrol agent.
 - If the biocontrol agent is used as a dip or spray.
- Reduced risk of pathogens developing resistance to biocontrol agents.
- Biocontrols are less likely to cause toxic effects on the host plant if rates are miscalculated.
- **Imported agents** are often **particularly effective** in Australia, where there are many introduced diseases, pests and weeds that are geographically distant from their origin and isolated from their natural enemies.
- **More than 200 insect and pathogens** have been released as biocontrol agents to 73 weeds targeted in Australia over 100 years (Julien 2112) with very little damage to non-weedy plants. Weed biocontrol is cost-effective, many programs are successful and the risks are very small and even smaller when using biocontrol agents already successful in another country (McFadyen 2012).

CONS

- **In the past biocontrol agents have jumped species**, or become pests themselves, but with improved risk analyses this is unlikely to happen today.
- Cost of biocontrol products in protected culture.
- Biocontrol is generally **not suitable** when fast control or total eradication is required.
- **Zero pest tolerance** may be mandatory for some exports.
- Often the grower and the consumer have to accept a certain amount of damage.
- Economic and risk analyses are required.
- Biocontrol may be **incompatible** with some chemicals.
- Where predatory mites are used to control spider mites, growers are likely to experience a greater spectrum of pests. Pests previously controlled by pesticides may emerge (secondary pest outbreaks).
- Growers need **expert help** in working out **IPM** programs which include biocontrol agents.
- Biocontrols generally must be introduced **before** the onset of disease.

- **Delay in effect of agents** may allow pests to increase and cause damage.
- Searching and evaluating for suitable natural enemies may take many years and is costly.
- **There is no guarantee** that biocontrol agents when released, will be successful. They may fail to establish, or if they do establish, fail to provide sufficient control.
- **Occasionally the biocontrol agent may lose** its virulence or be checked by its own natural enemies.
- **Target pests may develop resistance** to the biocontrol agent, so that new strains may be required.
- Sometimes there is a lengthy and complicated legal conflict about a release and / or need for registration.
- **Some may be difficult to mass produce**, transport, store and apply. Some may need special formulations to ensure that moisture is available for the delivery of nematodes and fungal spores.
- Many have a short shelf life if not stored properly.
- **There can be unusual problems**, eg predation by ants or cannibalism by green lacewing after release.
- **Grower acceptance has been slow** in some situations.
- Many are only available to **commercial producers** for use in area-wide programs.
- **Some biocontrol agents** released on a large scale are not a cost to growers, but other have to be purchased.
- Agents are subject to environmental factors, eg heat, wind, dust, natural enemies, that reduce their impact.
- **Biopesticides may result in higher application costs** but this is outweighed by growers' concerns about operator safety and need to reduce pesticide use.
- Most biocontrols are formulated as a dust which can be skin and / or eye irritant.

CHALLENGES

- **There is an apparent absence** of suitable biocontrol agents for many target diseases, pests and weeds.
- **Economics** of biological control.
- **Even a good biocontrol program** may need correction with pesticides, ie preserving biocontrol agents while minimizing the indirect effects of pesticides.
- **Biocontrol agents must be used in IPM programs** which are becoming more sophisticated, eg inoculum reduction through sanitation, and exclusion.
- **IPM in the UK now exists for the main horticultural pests** – whitefly, mites, thrips, leafminers, sciarids, vine weevils and aphids. The development of new biocontrol agents is likely to be slow unless a new "exotic" pest emerges to justify the cost. So the main thrust of research is on:
 - Improving effectiveness of existing products, eg extending the host range, environmental tolerance.
 - Researching the biology of insects and mites to improve programs, eg the potential of *Fettiella acarisuga* as a control agent for twospotted mite, as it can withstand lower humidities than *Phytoseiulus*.
- **The potential to use existing products** on other high value crops like tropical fruit.
- **Limiting factors of biocontrol products** include their variability, reliability, efficacy and spectrum of activity when compared with synthetic chemical pesticides, eg virus (Gemstar) was withdrawn due to low biological efficacy. After a stringent review of quality assurance (QA) it was reintroduced.
- **Reading the label and SDS** is just as important with biological chemical products as it is with chemical product to ensure efficacy and safety.
- **Outdoor grown crops**. At present the economics of pest and disease control often does not allow inundative release of beneficials.
- **Biocontrol agents**, and fertilizers can still have difficulty in making it to the marketplace and field conditions. Often they become ineffective when exposed to the uncontrolled field environment.
- **Changing growing practices** may change the way biocontrols work.
- **Resistance** developing to biocontrol agents, eg **Bt** crops.
- **Only a few bioherbicides** have been commercialized. There is a desperate need to find better ways to control weeds in agriculture, horticulture and the environment. Despite the resources that have been dedicated to traditional weed control, particularly chemical herbicides, weeds continue to thrive.

- **The development** of successful microbial products for **foliar diseases** has been slow due to lack of moisture and retention of moisture on leaves, etc. The challenge is to integrate their use with other management practices to achieve maximum benefit.
- **Augmentative control.** **IPM** programs themselves are increasingly sophisticated and often consist of more than one biocontrol for each pest.
- Biocontrol of virus vectors, eg **WFT**.
- **Biocontrol programs against a particular pest** vary between crops, varieties and regions. In leafminer control in tomatoes, variety can be a major factor influencing buildup of the pest and must be reflected in the introduction rate and pattern of parasitoids.
- **New packaging and delivery systems** for predators and parasitoids. Today they are packaged in a variety of ways including breeder packs and mating chambers.
- **Soft pesticides and Green Products** cause minimum disruption to beneficial insects, fungi and bacteria, can be used to treat **hot spots** of pests, eg spider mite, thrips, and aphids will become more important, eg
 - Green Products based on seeds, traits and combined chemical and biological crop protection treatments.
 - Manufacturers of agrochemicals are changing focus and developing selective products which cause minimum disruption to beneficial insects.
- **Genetically modifying biocontrol agents** to make them more effective still meets with consumer resistance.
- **A bacteria** (*Burkholderia capacia*) which causes slippery skin of onions has been widely promoted as a possible biocontrol agent for root knot nematode. Some species are associated with human diseases and are resistant to a broad range of antibiotics (Walker, 2006).

REVIEW QUESTIONS AND ACTIVITES

Natural controls

1. Describe natural controls for the following:

Twospotted mite	Aphids	Rust diseases
Caterpillars	Snails	Lantana
2. Define **classical biological control**.
3. **Recognise by observation**, the following predators and parasitoids and which insects they suppress:

Lacewings	Wasps	Mites
Ladybird beetles	Assassin bugs	

Biological control

4. List 3 ways by which the **biocontrol of weeds** may take place, name 1 example of each.
5. List 5 ways by which the **biocontrol of insects and mites** may take place, name 1 example of each.
6. List 5 ways by which the **biocontrol of diseases** of plants may take place, name 1 example of each.
7. Explain why biocontrol agents are often **imported**.
8. Explain the meaning of the **following terms**:

- | | | |
|-----------|------------------|------------|
| Pheromone | Cross protection | Antagonist |
|-----------|------------------|------------|
9. Describe how the following **diseases, pests and weeds may be controlled biologically**:

Twospotted mite	Codling moth	Prickly pear
Fruit fly	San Jose scale	Salvinia
Green vegetable bug	Crown gall	<i>Phytophthora</i>
 10. Name 1 **supplier** of the following biocontrol agents:

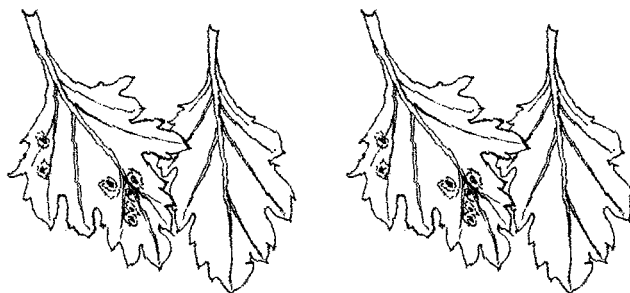
Predatory mites	Dipel®	Nogall®
Mealybug predators	Trichopel®	Isomate® LBAM
 11. **Explain to a member of the public** how they can use biocontrol methods in their nursery, orchard.
 12. **Locate resource material** on biocontrol methods.
 13. Explain how biocontrol agents can be used in **IPM** and **BMP** programs and with **organic standards**.
 14. Explain the **advantages and disadvantages** of using biocontrol methods to control weeds.
 15. Perform a **practical exercise** in pest and/or disease control using biocontrol methods.

SELECTED RESOURCES

- Agriculture Today. Sept 2011. *Two Mites Making a Mighty Mean Tag Team*. NSW DPI.
- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- Akhtar, M. S. and Siddiqui, Z. A. 2007. *Biocontrol of a Chickpea Root-Rot Complex with Glomus intraradices, Pseudomonas putida and Paenibacillus polymyxa*. Aust. Plant Path. 36 (2) 175-180.
- Baker, S. C., Elek, J. A., Bashford, R., Paterson, S. C., Madden, J. and Battaglia, M. 2003. *Inundative Release of Coccinellid Beetles into Eucalypt Plantations for Biological Control of Chrysomelid Leaf Beetles*. Agric. and Forest Ent. 5:97-106.
- Barclay, A. 2010. *Sniffer Dogs Switched on to Mammal Protection*. Ecos Issue 156.
- Beaulieu, F. and Weeks, A. R. 2005. *Free-living Mesostigmatic Mites in Australia: Their Roles in Biological Control and Bioindication*. Jn. of Exp. Agric. CSIRO Pub.
- Bedding, R., Akhurst, R. and Kaya, H. (eds). 1993. *Nematodes and the Biological Control of Insect Pests*. CSIRO Pub.
- Begum, M. 2004. *Habitat Manipulation to Enhance Biological Control of Lightbrown Apple Moth (Epiphyas postvittana)*. Thesis. The University of Sydney.
- Bowman, R. 2012. *Native Vegetation On-farm Important to Fight Grain Pests*. Ground Cover Jan-Feb.
- Campbell, A. and Brown, G. 1998. *Biological Control of Scarabs Causing Eucalyptus Dieback*. No.98/003. RIRDC, Kingston, ACT
- Campbell, M. H., Holtkamp, R. H., McCormick, L. H., Wykes, P. J., Davidson, P. J., Gullan, P. J. and Gillespie, P. S. 1994. *Biological Control of the Native Shrubs Cassinia spp. Using Native Scale Insects Austrotachardia sp. and Paratachardina sp. (Hemiptera: Kerridae) in New South Wales*. PPO Vol 9(2).
- Caradus, G. and Hume, D. 2011. "Phytin" the Good Fight. GRDC July-Aug.
- Chung, W., Wu, R., Hsu, C. et al. 2011. *Application of Antagonistic Rhizobacteria for Control of Fusarium Blight Seedling Blight and Basal Rot of Lily*. Aust. Plant Path. 40:269-276.
- Coleman, D. C. 2011. *Understanding Soil: One of the Last Frontiers in Biological and Ecological Research*. Aust. Plant Path. 40:207-214.
- Cooke, B. D. 2014. *Australia's War against Rabbits: The Story of Rabbit Haemorrhagic Disease*. CSIRO Pub.
- Cooke, B., Chudleigh, P., Simpson, S. and Saunders, G. 2013. *The Economic Benefits of the Biological Control of Rabbits in Australia, 1950-2011*. Australian Economic History Review. Volume 53, 1, 91-107, Mar.
- Crawford, D. 2006a. *Revenge in the Mummy*. Aust. Hort. Nov.
- Crawford, D. 2006b. *Tiny but Tricky Killer*. Aust. Hort. March.
- Crawford, D. 2008. *Assassin Bugs: Bloodsuckers and Bee-killers*. Aust. Hort. Jan.
- Crisp, P. 2008. *Developments in IPM and Biological Control*. SARDI. Aust. Organic Producer Summer.
- Deaker, R., Kecskés, M.L., Rose, M.T., Khanok-on Amprayn, Ganisan Krishnen, Tran Thi Kim Cuc, Vu Thuy Nga, Phan Thi Cong, Nguyen Thanh Hien and Kennedy, I.R. 2011. *Practical Methods for the Quality Control of Inoculant Biofertilisers*. ACIAR Mon.No.147, Canberra.
- Dodd, S.L., Hill, R. H. and Stewart, A. 2004. *Monitoring the Survival and Spread of the Biocontrol Fungus Trichoderma atroviride (C65) on Kiwifruit using a Molecular Marker*. Aust. Plant Path. 33:189-196.
- Doody, J. S., Castellano, C. M., Osborne, W., Corey, B. and Ross, S. 2010. *Reconciling Farming with Wildlife*. RIRDC Pub. No. 10/007.
- El-Mougy, N. S. and Abdel-Kader, M. M. 2008. *Long-term Activity of Bio-priming Seed Treatments for Biological Control of Faba bean Root Rot Pathogens*. Aust. Plant Path. 37:464-471.
- El-Sayed, A. M., Suckling, D. M., Byers, J. A., Jang E. B. and Wearing, C. H. 2009. *Potential of "Lure and Kill" in Long-Term Pest Management and Eradication of Invasive Species*. Jn. Econ. Ent. 102(3): 815-835.
- Ensbeay, R. 2011. *Noxious and Environmental Weed Control Handbook*. 5th ed. NSW DPI.
- EPPO (European and Mediterranean Plant Protection Organization). 2012. *Standards Efficacy Evaluation of Plant Protection Products* Volume 42:3, 345-347, Dec.

- Ferguson, J. J. and Rathinasabapathi, B. 2003 (reviewed 2009). *Allelopathy: How Plants Suppress other Plants*. Florida Coop. Ext. Service, Uni. of Florida.
- Geary, J. 2010. *The Biology of Turfgrass Soils*. Australian Turfgrass. May-June.
- Geary, J. 2011. *Promoting the Right Microbial Environment*. Aust. Turfgrass Man. July-Aug.
- Goodwin, S., Steiner, M., Parker, R., Tesoriera, L., Connellan, G., Keskula, E., Cowper, B., Medford, A. and Rodriguez, C. 2000. *Integrated Pest Management in Ornamentals: Information Guide*. NSW Agric/HRDC, NSW Agric., Sydney. Also *Pests, Diseases, Disorders and Beneficials in Ornamentals: Field Identification Guide*.
- Grewal, P. S., Ehlers, R. U. and Shapiro-Ilan, D.E. I. 2005. *Nematodes as Biocontrol Agents*. CABI Pub.
- Guenther, L. 2013. *The Future of Weed Control*. GrainNews 39, (9).
- Gurr, G. M., Wrattan, S. D. and Altieri, M. A. (eds). 2004. *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*. CSIRO Pub.
- Gurr, G. M., Wratten, S.D., Hossain, N. Z., Baggen, Z., Mensah, L. R. and Walker, P. W. 1998. *Habitat Manipulation in Australasia*. 6th Appl. Ent. Res. Conf.
- Hertel, K., Roberts, K. and Bowden, P. 2013. *Insect and Mite Control in Field Crops. NSW Management Guide*. NSW DPI.
- Hetherington, S. 2009. *Integrated Pest Management for Australian Apples & Pears*. NSW Industry & Investment, Apple and Pear Australia.
- Heinz, K. M., Van Dresche, R. G. and Perella, M. P. (eds). 2004. *BioControl in Protected Culture*. Ball Pub.
- Helyer, N., Brown, K. and Cattlin, N. 2003. *A Colour Book of Biological Control in Plant Protection*. Manson Pub.
- Hocking, F. D. 2014. *Pests, Diseases and Beneficials: Friends and Foes of Australian Gardens*. CSIRO Pub.
- Huang, N., Enkegaard A., Osborne, L. S., Ramakers, P. M., Messelink, G. J., Pijnakker, J. and Murphy, G. 2011. *The Banker Plant Method in Biological Control* Critical Reviews in PlantSciences (3) 259-278.
- Jensen, D. F., Knudsen, M. B., Lubeck, M., Marmaraback, M., Hockenhuil, J and Jensen, B. 2007. *Development of a Biocontrol Agent for Plant Disease Control with Special Emphasis on the Near Commercial Antagonist Clostridium rosea strain 'IK726'*. Aust. Plant Path 36 (2) 95-101.
- Julien, M., McFadyen, R. and Cullen, J. 2012. *Biological Control of Weeds in Australia*. CSIRO Pub.
- Landis, D. A., Wrattan, S. D. and Gurr, G. M. 2000. *Habitat Management to Conserving Natural Enemies of Arthropod Pests in Agriculture*. Ann. Rev. Ent. 45:175-201.
- Lawrence, L., Tann, C. and Baker, G. 2007. *Refuges Harbour Pests and Beneficial Insects*. Farming Ahead. 183. April.
- Lee, N. 2011. *Soils Probed for Clues to Natural Disease Resistance*. Ground Cover. Sep-Oct.
- Llewellyn, R. 2002. *The Good Bug Book: Beneficial Organisms Commercially Available in Australia and New Zealand for Biological Pest Control*. 2nd ed. Goodbugs.
- Lintz, H. E., Huso, M., Stanley, K. C. and Taylor, T. 2011. *Composting One Invasive Species to Control Another*. Restoration Ecology 19:4.
- Macey, R. 2005. *Boffins' Revenge: Dirty Weeds Done Dirt Cheap*. SMH 18/9/2005.
- McLaren, D. and Anderson, F. 2011. *Biological Control of Serrated Tussock and Chilean Needle Grass*. RIRDC.
- Mahr, S. 2000. *Monitoring the Field of Pest Management*. The IPM Practitioner. April.
- Maxwell, A. and Scott, J. K. 2008. *Pathogens on Wild Radish Raphanus raphanistrum (Brassicaceae) in south-western Australia – Implications for Biological Control*. Aust. Plant Path. 37, 523-533.
- MacCartney, R. 2005. *Biostimulants – Their Place in Turf Management*. Golf and Sportsturf Australia Feb-March.
- McLeod, S. R., Saunders, G., Twigg, L. E., Arthur, A. D., Ramsey, D. and Hinds, L. A. 2007. *Prospects for the Future: Is there a Role for Virally-vectored Immune-Contraception in Vertebrate Pest Management?* Wildlife Research 34(7) 555-566.
- McFadyen, R. 2012. *Benefits from Biological Control of Weeds in Australia*. Pak. Jn. Weed Sci. Res., 18: 333-340.
- Mensah, R. 2011. *Managing Helicoverpa spp. and Sucking Pests on Cotton using Semiochemicals*. NSW Ind. & Inv.
- Mensah, R. and Singleton, A. 2003. *Optimum Timing and Placement of a Supplementary Food Spray Envirofeast® for the Establishment of Predatory Insects of Helicoverpa spp. in Cotton Systems in Australia*. Inter. Jn. of Pest Man. (49)2.
- Miles, M. and Ferguson, J. 2003. *Trap cropping: A Fad or a 'Useful Helicoverpa Management Tool'?* DPI Farming Systems Institute.
- Moody, H. 2004. *Explore the Potential for Companion Plants*. 2004. Aust. Hort. Dec.
- Narayanasamy, P. 2013. *Biological Management of Diseases in Crops: Vol 2. Integration of Biological Control Strategies with Crop Disease Management Systems*. Springer.
- Narwal, S. S. 2012. *Allelopathy in Crop Production*. Sci. Pub. NGIA. 2002. *Biological Control for Diseases of Nursery Plants*. The Nursery papers Issue 2002/14.
- Nicholls, C. and Altieri, M. A. 2013. *Plant Biodiversity enhances Bees and other Insect Pollinators in Agroecosystems. A Review*. Agron. for Sustainable Dev. 33(2), 257-274.
- Norwood, C. 2012. *Legume Nitrogen Fixing may be Clue to Drought Tolerance*. Ground Cover Jan-Feb.
- Pattison, A. B., Badcock, K. and Sikora, R. A. 2011. *Influence of Soil Organic Amendments on Suppression of the Burrowing Nematode, Radopholus similis on the Growth of Bananas*. Aust. Plant Path. 40:385-396.
- Pottinger, B. M., Ridgway, H. J., Bourdot, G. W. and Stewart, A. 2002. *Pathogenicity of Sclerotinia sclerotiorum on Giant Buttercup (Ranunculus acris)*. 55th NZ Plant Protection Conf.
- Stirling, G. R., Smith, M. K., Smith, J. P., Stirling, A. M. and Hamill, S. D. 2012. *Organic Inputs, Tillage and Rotation Practices Influence Soil Health and Suppressiveness to Soilborne Pests and Pathogens of Ginger*. Aust. Plant Path. 41:99-112.
- Rhodes, J. and Scott, M. 2006. *Pesticides: A Guide to their Effects on Honey Bees*. NSW DPI Primefacts.
- RIRDC. 2010. *National Weeds and Productivity Research Program-R&D Plan 2010 to 2015*. RIRDC Pub No 10/209.
- RIRDC. 2012. *National Weeds Research: a Summary of Research Outcomes from the National Weeds and Productivity Research Program 2011-2012*. RIRDC.
- Roossinck, M. 2013. *Viruses, Fungi and other Microbials Team up to Help to Protect Plants from Stress*. Huck., Penn State.
- Shellhorn, N. 2011. *Pest-suppressive Landscapes*. Ground Cover Supplement Nov-Dec.
- Sherwood, N. 2005. *Bug against Bug*. Royal Botanic Gardens Melbourne. Aust. Hort. Dec.
- Sikora, R. A., Schafer, K. and Dababat, A. A. 2007. *Modes of Action associated with Microbially Induced in planta Suppression of Plant Parasitic Nematodes*. Aust. Plant Path. 36:124-134.
- Stirling, G. R. 2014. *Biological Control of Plant-parasitic Nematodes: Soil Ecosystem Management in Sustainable Agriculture*. CAB International, Wallingford.
- Stirling, G. R. 2011. *Suppressive Biological Factors influence Populations of Root lesion nematode (Pratylenchus thornei) on Wheat in Vertosols from the Northern Grain-growing Region Australia*. Aust. Plant Path. 40:416-429.
- Stanghellini, M. E. and Miller, R. M. 1997. *Biosurfactants: Their Identity and Potential Efficacy in the Biological Control of Zoosporic Plant Pathogens*. Plant Disease, Vol.81(8), Jan.
- Stewart, A., Hill, R. and Stark, C. 2011. *Desktop Evaluation on Commercially Available Microbial-based Products for Control or Suppression of Pseudomonas syringae pv. Actinidiae*. Bio-Protection Research Centre, NZ.
- Traverer, P., Wood, G., Jevromov, D. and Doyle, B. 2006. *Revegetation by Design Guidebook*. SARDAI.
- Uni. of California. 2002. *Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control*.
- Wakelin, S. A., and Ryder, M. H. 2004. *Plant Growth-promoting Inoculants in Australian Agriculture*. Online. Crop Management. CSIRO Land and Water.
- Walker, G. 2006. *Biocontrol Organisms and Human Health*. Australian Nematology Newsletter Vol 17.1. Jan.
- Waterhouse, D. F. and Sands, D. P. A. 2001. *Classical Biological Control of Arthropods in Australia*. ACIAR, Canberra.
- Williams, S., Wilson, L. and Vogel, S. 2011-2012. *Pests and Beneficials in Australian Cotton Landscape*. The Australian Cotton Industry Development & Delivery Team.
- Wu, J., Ridgway, H., Carpenter, M. and Glare, T. 2008. *Efficient Transformation of Beauveria bassiana by Agrobacterium tumefaciens-mediated Insertional Mutagenesis*. Aust. Plant Path 37. 537-542.
- Yan, G. 2011. *Field Guide for Using the Twist Fungus (Dilophospora alopecuri) Inoculum*. Farmnote (WA. Dept. of Agric.) no. 22/2002.
- Aglinks www.aglinks.com.au Kondinin www.kondinin.com.au Biocontrol News and Information Biocontrol Science and Technology Biological Crop Protection Pty Ltd Good bugs www.goodbugs.org.au/ www.bugsforbugs.com.au Pest Management tools International Organization for Biological Control (IOBC) Lucid Identification tools Marrone Bio Innovations www.marronebioinnovat Organic Crop Protectants Plant Protection Quarterly Target Species for Biological Control www.weed.org.au/ Uni. of Sydney <http://bugs.bio.usyd.edu.au/learning/resources/>

RESISTANT VARIETIES, TOLERANT VARIETIES



INTRODUCTION	138
Some useful terms	140
WHEN TO USE RESISTANT, TOLERANT VARIETIES	142
ABIOTIC TRAITS BEING LOOKED AT TODAY	144
HOW PLANTS DEFEND THEMSELVES	148
Color	148
Morphology	148
Hypersensitivity	149
Chemicals present in the plant	149
Chemicals produced in response to attack	149
Mycorrhiza	150
Endophytes	150
Mutualistic viruses	150
Other factors	150
SOURCES OF RESISTANT GENES	151
Biodiversity	151
Wide geographic area	151
Survivor species	151
Seed banks, seed vaults, gene banks	151
Provenances	152
Induced mutations	152
Other plants or animals	152
Genetic engineering	152
Assessing gene banks for climate change	152
International Maize & Wheat Improvement Centre	153
Resistance in necrotrophic fungi	153
Salt tolerance	153
HOW RESISTANT, TOLERANT PLANTS ARE PRODUCED	154
Conventional breeding	154
Genetic engineering	154
Resistant rootstock	154
Seeds	155
Resistance in fruit	155
Environment, nutrition	155
Symbiotic relationships	155
Systemic acquired resistance (SAR)	156
SAR - trigger by biological agents	156
SAR - triggered by chemical agents	157
SCREENING PLANTS FOR RESISTANCE, TOLERANCE	159
Minimum disease resistance standards	161
BREAKDOWN OF RESISTANCE	162
MANAGING PLANT RESISTANCE	164
Prolonging plant resistance	164
Difficulties - The Tough Nuts	167
PROS, CONS AND CHALLENGES	169
REVIEW QUESTIONS AND ACTIVITIES	169
SELECTED RESOURCES	170

INTRODUCTION

The best solution to any plant problem is to use resistant or tolerant varieties of plants if available; it is a preventative method of control (Aust. Hort. Feb 2011).

However, if you don't have nutrition and time-of sowing right, if you don't check seed quality and carry out soil tests, the resistant or best varieties aren't going to save you!

New and old approaches

The purpose of most plant breeding is to develop varieties that produce greater yields of better quality.

- **When such varieties become available** they are usually tested for resistance against some of the more important diseases and pests present in the area where the variety is expected to be grown.
 - If the variety is resistant to these problems it may be released to growers for assessment.
 - It may be subject to further breeding in an attempt to make it more resistant.
 - If other means are found to control the problem in the meantime, it may be shelved.
- **Plant breeding still relies on traditional methods of plant breeding**, but genetic engineering and associated technologies provide new opportunities. Many breeders use micropropagation to bulk up inbred parent lines for the production of hybrid seed. Plant breeding can be:
 - Very simple (using pollination or selection via conventional breeding) or
 - Very complex (using genetic modification).

Legislation

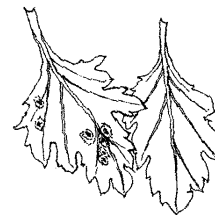


Environment Acts, Pesticide Acts, Biosecurity Acts or other legislation may prescribe the growing of varieties which do not require pesticide applications in some areas, eg

- Buffer zones close to urban settlements, waterways, or
- Area freedom zones, eg pest-free biosecurity areas.

Genetically modified plant material is regulated in various ways, eg

- Its importation is regulated by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the current Commonwealth Quarantine Act, 1908 (there is a proposed Biosecurity Bill, 2012).
- Food labeling is regulated by Australian and New Zealand Food Authority (ANZFA) and other regulators.



Plant improvement schemes may require the planting of resistant varieties in certain situations, eg

- Australian Pome Fruit Improvement program.
- Vine Improvement Schemes.
- Fruit and Vegetable Programs.

Communication and biotechnology



Queensland Alliance for Agriculture and Food Innovation (QAAFI)
Biological Information Technology

Computers and biotechnologies are used by researchers to:

- Target appropriate chromosomes and genes.
- Locate additional resistance in the germplasm of wild and cultivated species.
- Better understand resistance in plants and how pathogens and pests attack the host.
- Simulate 'crop-pest' genetic interactions.
- Compile tolerance lists.
- Transferring desired traits to prebreeding companies providing greater certainty and time to deliver rebreeding programs.
- Training via workshops on major national problems, including drought, salinity, frost and quality.
- **QBIT** develops, distributes and supports commercial quality software for application in training, education and research, eg identification and diagnostic guides for biological taxa and e-learning scenarios that provide interactive learning experiences.

Growers use a vast array of computer programs for plant selection, eg

- **Various companies**, eg **Plant Growers Australia (PGA)** of Victoria can provide detailed information to customers and provide a photograph of a plant, name, foliage, flower, color, height and spread and the plant's cultural requirements.
- **CropMate®** is a web-based decision-support tool to help farmers in south-eastern Australia make agronomic decisions using historic, forecast and climate data. Grain growers will be able to integrate this information into their management systems, eg
 - **Growers** will be able to put in their location and review historic data and predicted climate information that relates to pre-season planning, sowing, spraying and harvesting, important components will be Crop Chooser and Variety Chooser tools.

National Plant Labelling Guidelines (2013) have been developed to help industry provide clear and accurate information on plant labels, these guidelines aim to establish an accepted standard in the preparation of plant labels and marketing material.

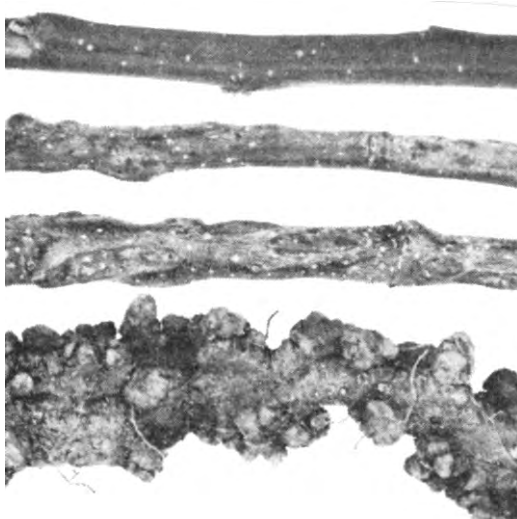
- **They are recommended** for adoption by all plant producers, suppliers of plant material, plant retailers and label manufacturers.
- **They may include information** on resistance to specified diseases.



Black spot (*Marssonina rosea*) of rose. Feathery black spots may completely cover the leaf. Severely affected leaves yellow then fall.



Gumtree scale (*Eriococcus coriaceus*) on eucalypt twigs. Small male scales and larger female scales. Photo©State Forests of NSW.



Woolly aphid rootstock (*Eriosoma lanigerum*)
Top: Undamaged apple twig.
Middle: Two slightly damaged apple twigs.
Lower: Severely damaged apple root.
 Photo©NSW Dept. of Industry & Investment.



Oak leafminer (*Phyllonorycter messaniella*) damage. Tiny moth larvae feed inside the leaf resulting in small brown blotches. Several blotches may occur on one leaf. Oak trees seem to tolerate damage. Photo©Canberra Institute of Technology.

Genetic engineering	
Resistance/Tolerance	Examples
Disease and pest resistance	Virus and virus-like diseases Fungal diseases Some insect pests
Tolerance	Chilling tolerance Low temperatures Waterlogging
Herbicide Resistant Crops from Biotechnology (HRCBs)	glyphosate (Roundup®Ready) 2,4-D bromoxynil (Bromicide®) glufosinate-ammonium (Basta®) simazine

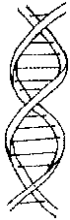


Left: Rust (*Puccinia pelargonium-zonalis*) on geranium. Small reddish-brown powdery pustules form in rings on leaves of susceptible varieties. Photo©NSW Dept. of Industry & Investment.
Right: Rust (*Puccinia antirrhini*) on snapdragon. Photo©Canberra Institute of Technology.

Fig. 16. Resistant species, cultivars or rootstocks are available for the above diseases and pests on particular plants. Many plant species do not suffer from major pests and diseases

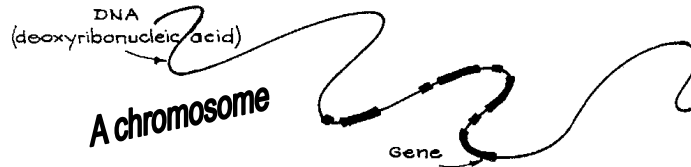
Some useful terms

Genes and chromosomes



Deoxyribonucleic acid (DNA) is the genetic code that contains all the information needed to build and maintain an organism.

1. **DNA is packaged into thread-like structures called chromosomes** which are found in the nucleus of each cell.
2. **Sections of chromosomes are called genes.** A **gene** is a linear portion of the chromosome that determines or conditions one of more hereditary characters; the smallest functioning unit of the genetic material (Agrios 2005). They determine the shape and size of leaves, flower color and other plant characteristics.



Host-pathogen interactions

Whatever the kind of defense or resistance a host plant employs against a pathogen or an abiotic agent, it is ultimately controlled, directly or indirectly by the genes of the host plant and of the pathogen.

The **gene-for-gene concept** states that for **each** gene for virulence in a disease organism there is a corresponding gene for resistance in the host towards that pathogen (Agrios 2005).

Host plant



Resistance is the ability of a plant to exclude, or overcome, completely or to some degree, the effect of a disease organism or other damaging factor (Agrios 2005). A plant may be slightly, moderately or highly resistant.



Non-host resistance. A plant may find it easy to defend itself, ie to stay resistant (immune) when it is brought in contact with a pathogenic biotic agent to which the **plant is not a host**. This is the most common form of resistance (or defense from attack) in nature, eg eucalypts are not affected by the pathogens that attack tomatoes.

Each plant is of course attacked by its own pathogens but there is often a big difference in how effectively the plant can defend itself (how resistant the plant is against each pathogen).

- **Even when conditions for infection are favorable** for infection and disease development, a plant upon infection with a particular pathogen, may develop no disease, only mild disease, or severe disease depending on the specific genetic makeup of the plant and of the pathogen that attacks it.
- **Race specific resistance.** The ability of a plant to remain completely free from infection by a **given race** of a disease organism.
- **Tolerance.** The ability of a plant to yield well in spite of disease and pest attack.
- **Susceptibility.** The inability of a plant to resist the effect of a disease organism or other damaging factor.
- **Escape.** The plant possesses **no genetic resistance** but escapes from attack by specified diseases and pests for a variety of reasons, eg
 - **The pest or disease organism,** or strains of it which can attack the host, may **not** be present in the locality where the host is grown.
 - **Unfavorable** environmental factors towards the **disease or pest.**
 - **Favorable** environmental factors towards the **host plant.**
- **A combination of resistance and race specific resistance** is, as a rule, the most desirable genetic makeup for any plant variety.

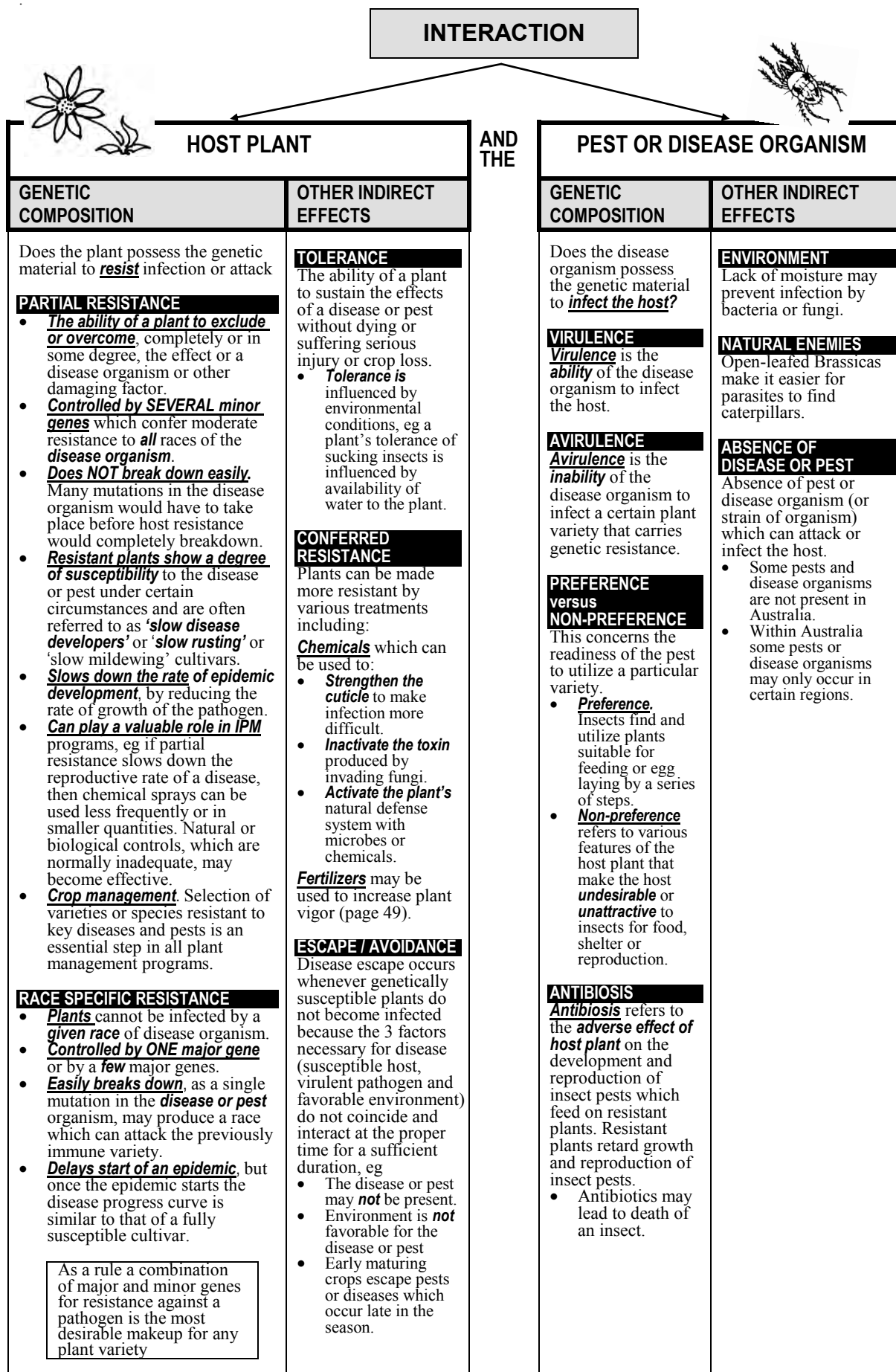
Pest or disease organism



Strains, biotypes, physiological races are **subgroups within a species**, usually distinguished from the rest of the species by criteria other than morphology, eg a difference in parasitic ability. The occurrence of different strains of a pest or disease organism may result in cultivars, rated as being highly resistant in one area, being susceptible in another area.

- **Avirulence** is the **inability** of the disease organism to infect a certain plant variety that carries genetic resistance.
- **Virulence** is the **ability** of the disease organism to infect the host.

Table 7. Interaction between plant and pest or disease organism.



WHEN TO USE RESISTANT, TOLERANT VARIETIES

Varieties with some resistance or tolerance to key problems may be selected or their use even mandated. These traits may either prevent infection or slow down disease and pest development or allow species to be grown in areas that otherwise would not be suitable.

For particular types of plants or crops

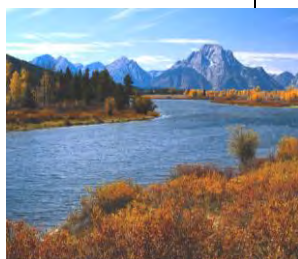
Examples include:

- Perennial plantings.
- Very large trees.
- Specimen trees.
- Hedges and groundcover.
- Edible crops such as fruit and vegetables, where excess residues are illegal.
- Field crops such as wheat; house plants in enclosed environments.

For particular situations

Examples include:

- **Sites subject to particular environmental conditions**, eg
 - **In areas where frost occurs**, it is important either to select frost tolerant species for growing during the colder months, locate frost-sensitive plants in frost-free sites or have in place steps to minimize frost risk.
 - **In fire-prone areas** plants may be a given a fire-resistant status because they do not contain highly volatile oils or have other attributes and are referred to as fire resistant.
 - **Other environmental conditions** include drought, waterlogging, excessive sun, shade, shallow soil and wind. *Casuarina cunninghamiana* tolerates moderately saline soils and can be planted in areas affected by salinity.
- **Where the application of pesticides is not desirable or not permitted**, eg
 - **Pesticide-free zones**, eg childcare centres.
 - **Nature strips**, along neighboring fence lines and public areas where the application of pesticides is limited due to the inability to restrict public access.
 - **Close to swimming pools**, barbecue and similar areas.
 - **Greenhouses open to the public**, eg in nurseries.
 - When growers seek to obtain **organic certification**.
 - **Pesticide labels may list prohibited uses** including applying it on certain edible crops, in a certain manner, in certain situations or in some States or Territories.
 - **To prevent spraying in sensitive areas**.
 - **Buffer or exclusion zones** (protection or spray-free zones) close to population centers, residences, resources, other sensitive areas and to stop the spread of diseases, eg sigatoka (*Mycosphaerella fijiensis*) occurs in Papua New Guinea and Torres Strait islands but not in Australia. In Cape York a banana replacement program is under way to replace susceptible banana varieties with resistant types denying the fungus 'stepping stones' between the Torres Strait and the commercial industry near Cairns which grows susceptible cultivars. Over the years outbreaks in Australia have been eradicated.
- **To reduce epidemics and prevent buildup of disease** in order to prolong resistance of the host plant. Diseases which recognize no property boundaries, eg spores of wheat rust are spread by wind are initially unseen and so spread very rapidly. These diseases require a community / industry strategy to manage them. All growers need to participate in minimizing the level of rust by growing rust resistant varieties to ensure that the number of rusts spores that can mutate are kept to a minimum.



Sensitive waterways

For parasitic pests and diseases for which there is no practical control



Powdery mildew on susceptible *Euonymus* sp.

Examples include:

- Rust diseases, eg wheat rusts, antirrhinum rusts.
- Powdery mildews on hedges, eg powdery mildew of photinia, lagerstroemia.
- Soil fungal diseases eg *Phytophthora* root rot, *Verticillium* and *Fusarium* diseases.
- Borer attack to trees.
- Many non-parasitic problems such as frost, low temperatures, sunscorch, drought.
- Some virus diseases are of increasing economic importance worldwide and their vectors are becoming increasingly resistant to insecticides. Only the use of resistant cultivars is a feasible long-term control. Knowledge of virus diversity and their vector species is a necessary precursor to implementing control.
- The biocontrol agent *Agrobacterium radiobacter* K84 affords some protection against a limited number of strains of *A. tumefaciens*, so we need another control. GM rootstocks can silence the *A. tumefaciens* gene providing a simple and effective means to prevent crown gall in nursery species.

Crop rotations, break crops

Canola is considered one of the best break crops for cereal production. Canola crops can improve subsequent wheat yields by an average of 20% in certain rainfall areas and in certain seasons. New varieties may improve this.

- **The benefits** come largely from the root disease break a broadleaf crop provides.
- **Weed control** is also a major factor, especially when using herbicide tolerant crops.

Multiple traits

Plant breeders that are also working to **provide multi-gene resistance** that is capable of providing protection even when a disease mutates.

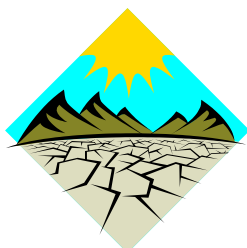
<p>Abiotic problems Drought, water use efficiency (WUE)</p>	<p>Management Environment Facilities (MEFs) are being established in various locations in Australia to help scientists unlock the genetic drivers for drought tolerance and better water use efficiency and allow crop breeders to produce less susceptible varieties faster.</p> <p>Australian National Botanic Gardens (ANBG). With some difficult to grow species, a common practice is choosing a stronger clone, eg</p> <ul style="list-style-type: none"> • More fragile species are grafted onto more hardy rootstocks of the same genera. • ANBG Plant Hardiness Zones for Australia are available. List of cultivars of Australian native plants are registered by Australian Cultivar Registration Authority (ACRA). <p>There is a need for higher yielding rice varieties with improved drought resistance.</p>
<p>Pre-emptive breeding Biosecurity</p>	<p>Having resistant or tolerant varieties commercialized or in the later stages of breeding provides immediate protection and risk minimization should insects and diseases that attack a key economic crop enter Australia. Examples of such exotic pests include:</p> <ul style="list-style-type: none"> • Myrtle rust. Tasmania, SA and WA want to develop a pre-emptive approach in case myrtle rust reaches them (Shaw 2013). A standardized disease rating system applied across Myrtaceous species has been requested by NGIA to enable trade in disease-free species and provide advice to councils etc. A resistance breeding program is part of the National Transition to Management program www.myrtlerust.net.au • Ug99 stem rust of wheat, diseases of lentils and bee viruses. • Russian wheat aphid (RWA). Australia is the only major wheat growing country free of RWA. Protecting Australia from a potential incursion such as RWA requires collaboration with countries where the pest is already established. Germplasm with broad resistance to RWA has been identified and is being bred into some Australian wheat and barley varieties.
<p>Crop Improvement programs Achieving more with less, Reducing inputs</p> <p style="text-align: center; color: red; font-weight: bold; font-size: 2em;">PH</p>	<p>The aim of Crop Improvement Programs is to achieve more with less, eg to provide horticulturists with new plant varieties which:</p> <ul style="list-style-type: none"> • Require fewer fertilizer and pesticide inputs than older varieties. • Yield more without corresponding more fertilizer inputs. • Are less demanding of water. • Satisfying market expectations, and • Are more sustainable and environmentally kind. • Maximize biological potential of their fields, despite the vagaries of soils and microclimates, eg selecting strawberries for plants tolerant of soilborne diseases. There are similar objectives in other breeding projects on potatoes, pears, raspberries, Australian cut flowers, pot plants and plants for landscape use. • Reducing pesticide inputs to food production. Biotechnology projects involve responsible use of technology to achieve outcomes simply not possible via conventional breeding, eg transform the rootstock with a gene whose product can move to the scion and protect against insect pests while the foreign gene is confined to the part of the apple tree that is mostly below ground. • Precision Horticulture (PH) with automated measurement of the environment, plant and soil characteristics, fruit and vegetable quality, aims to assist industry achieve greater productivity and quality, with reduced inputs, eg water and fertilizer, and less impact on the environment.
<p>Disease resistance versus fungicides</p>	<p>Many growers of susceptible varieties of barley were hit hard by barley powdery mildew in 2011 due to resistance to triazole fungicides. Researchers aim to identify different virulence genes expressed by the powdery mildew pathogen which will help plant breeders select genes resistant to powdery mildew resulting in new barley varieties with improved resistance.</p> <ul style="list-style-type: none"> • Efforts are also to be made at broadening the range of fungicides available to cereal growers, reducing the threat of future fungicide shortages and helping farmers manage fungicide resistance to diseases such as powdery mildew. • Growers are being urged to consider replacing very susceptible varieties. • Foliar fungicide applications on cereal crops have become more common in Australia. <ul style="list-style-type: none"> • This has been the result of the falling costs of fungicides with the appearance of many generic products and the clear benefits of controlling diseases in susceptible varieties. • Serious disease out-breaks do not occur each year and, in many situations, varieties that don't have adequate resistance but have yield or other advantages, may make them more attractive than more resistant varieties. • However, when multiplied across many farms around the country, this reasoning brings significantly greater risks to cereal growing and threatens the sustainability of profitable wheat production in a relatively low-input, low-yielding environment. • It is unlikely that all growers will apply adequate fungicide at the first sign of rust and keep the infection sufficiently under control so that the disease will not spread to neighboring properties. • Equally it is unrealistic to expect that all growers will sufficiently monitor or destroy volunteers growing between seasons to ensure that those volunteers will not harbor rust infections which may be responsible for starting new epidemics.

ABIOTIC TRAITS BEING LOOKED AT TODAY

Quest for Wheat's Holy grail - Drought Tolerance (Food & Fibre Feb 2011).

With a degree of climate change inevitable, there is a need to start breeding new crop varieties for the anticipated conditions in 20 to 50 years' time, eg breeding in the future for heat and drought stress.

Drought tolerance & better water use efficiency



Plant Drought Alarm Signal. Aust.Hort.Mar. 2012.

All plants needs some water for establishment. Follow water restrictions, know your aspect, surrounding structures and how the soil drains or holds water. Adding compost and organic matter is one of the best ways to increase water retention. Also use mulch. Select plants from areas that are also hot and dry. Look for plants (native and exotic) that have adaptations that enable them to withstand drought, eg small, narrow leaves, grey or silver foliage, furry texture, water-retaining succulent leaves or stems, modified or absent leaves, summer dormancy.

- **Water Use Efficiency (WUE)** is a major factor in determining the yield of crops suffering drought or water stress. Some traits such as alternative dwarfing genes, high temperature efficiency or reduced tillering have been demonstrated to improve **WUE**; many have not yet been incorporated into commercial varieties.
- **Drought resilient crops.** If current climate change emissions continue then Australia's next generation of growers must prepare to face at least a 2°C temperature rise by 2050. Some rural growers might switch to **drought-resilient crops**, eg pomegranate orchards and date palms or red-flowering quinoa grain. **Hotter and drier conditions** across the Murray-darling basin taking a heavy toll on irrigated industries such as rice and citrus.
 - **New crops could include bush tucker foods** such as quandongs, bush tomatoes and desert limes as well as native grasses cultivated for grain and fodder crops for livestock. Other drought-tolerant crops include dragonfruit, jojoba, capers, buffalo gourd and quinoa, a gluten free grain with higher protein and fibre content than cereals.
 - **Possibly new industrial-use crops** suitable for Australia.
 - **Newer varieties** of many crops, eg cotton, are less sensitive to water stress.
- **A plant drought alarm signal.** A molecular signal has been found in plants which may act as a drought alarm, allowing them to adapt to drought conditions. Consequently these plants survived 50% longer in drought conditions. This trait can be used by plant breeders. The Australian Research Council Centre of Excellence in Plant Energy Biology (PEB) focuses on how plants produce and use their energy in response to environmental change. www.plantenergy.edu.au
- **Links between legume root nodulation.** reduced root development and drought sensitivity have been observed, eg nodulated root systems are smaller than those on uninoculated plants (page 117). If this finding is verified there will be implications for crop improvement programs (Norwood 2012).

Wet feet, flood tolerance



Wet feet

Turfgrass flood tolerance tested. There are no hard and fast numbers such as Kentucky bluegrass which will survive 35 days and creeping bentgrass, 38 days (Nickson 2011). Turf species have been ranked according to their **submersion tolerance**.

- **As the depth of water increases** the potential for injury increases. Water temperature and light intensity also affect survival.
- **Flood injury increases as water temperature increases.** During cooler times of the year such as spring the degree of turfgrass injury will likely be less because of lower temperatures and light intensity.
- **Damage can also occur** due to silt, possible elevated salt levels and other toxic compounds, loss of soil N, etc. Kikuyu has poor resistance to high salinity and prolonged periods of submergence.
- **There has been a limited and controlled release** of GM waterlogging tolerant cotton.

Waterwise gardens struggle

Gardens designed and altered over the last decade to cope with ever-decreasing amounts of water are suddenly awash and the landscape industry has to seriously re-evaluate how it deals with water in the landscape (Johnson 2011).

- **Landscapes need to be adaptable;** amendments to gardens must ensure good drainage to avoid waterlogging. Mulching to maximize water retention and minimize evaporation will help all plants survive the extremes.
- **Choose plants which are tolerant** of a range of rainfall conditions, eg *Scaevola* Mauve clusters, *Hymenosporium flavum*.

Selecting plants for drought tolerance

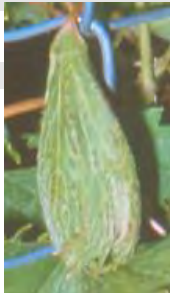



Many plants survive on little water but there are several factors to take into account when selecting plants for drought tolerance. Practice water restriction guidelines.

- All plants need some water, especially when first planted or in a hot and sunny position. They should be **carefully monitored until established**.
- Avoid planting out in the hottest months, plant at night, use temporary shade structures.
- Some plants are only drought tolerant if planted **in the shade**.
- Know aspect, soil. Adding compost and organic matter is one of the best ways to increase water retention, commercial water saving products are available.
- Look for plants that have adaptations that enable them to withstand drought, eg small narrow leaves, grey or silver foliage, furry texture, water retaining succulent leaves, modified or absent leaves, summer dormancy.

<p>Chilling tolerance</p> <p>COLD</p>	<p>Chilling tolerance in chickpea is linked to the ability of the plant to produce pollen which germinates and grows a tube even at low temperatures. The ability of chickpea pollen to fertilize ovules has been linked to a variety's degree of chilling tolerance, allowing breeders to exploit variation in pollen virility within pulse breeding programs.</p>
<p>Salt tolerance</p> <p>SALT</p>	<p>The Australian Centre for Plant Functional Genomics (ACPGF) first patent application covering salinity tolerance in plants has been accepted in Eurasia. The patent is for a protein that sits in a plant cell's outer membrane and pumps sodium ions from the cell to improve the plant's salinity tolerance. The genes are already present in Australian wheat and barley and are currently being trialed.</p> <ul style="list-style-type: none"> • Salinity effects on turfgrass growth can be summarized as reduced water uptake due to osmotic stress; uptake of nutrients such as K may be depressed by absorption of Na; root biomass may increase to improve water absorbing ability and Na and Cl reduce growth by interfering with photosynthesis. The relative salt and drought tolerances of many turfgrasses have been well documented, to such an extent that you can select the turf grass most suited for your geographical location. • Using trees to help stop soil salinity. Although the yield of annual crops and pastures in Australia is often limited by insufficient water, during wet periods water can drain beyond the reach of shallow-rooted annual crops. This results in rising water tables which in turn mobilizes salt closer to the soil surface and to the root zone of crops. The problem has already arrived in some areas and will be severe in others unless deep rooted perennial species can be integrated into farming systems in a bid to increase overall water use. <ul style="list-style-type: none"> • Water use of different species of trees in different parts of the catchment and agroforestry designs is being measured and the best combinations of trees and crops will be tested in different States / Territories. Land managers will have robust-tested guidelines to help choose appropriate agroforestry designs and the optimal size and location of plantations in a catchment. • Researchers are looking for cereals with greater tolerance to salinity. It is known that a plant's ability to store sodium ions in a cell vacuole is an essential part of salinity tolerance. Using Confocal Microscopy Imaging Technique (CMIT) the intensity of Sodium Green™ dye that is loaded into the plant can be measured. This fluorescence is proportional to the amount of sodium stored in the vacuole (the largest storage compartment within the cell). This method will be applied to 50 varieties of wheat and barley considered to have different levels of salinity tolerance. The project will advise breeders on best varieties from which to select genes for some of the specific mechanisms conferring salinity tolerance in cereals.
<p>Photosynthesis</p> <p>C4 CAM (many are weeds)</p>	<p>Photosynthesis is the combination of carbon dioxide (CO₂) with water (H₂O) in the presence of chlorophyll to produce plant tissue. Plants use one of 3 different chemical pathways to achieve this reaction, and are grouped according to the pathway used:</p> <p>C3 or Calvin cycle plants C4 or dicarboxylic acid plants or CAM or crassulacean acid cycle plants</p> <p>While only a small portion of all plants are either C4 or CAM, many plants falling into these two groups are weeds. The competitive advantages conferred on C4 and CAM plants, which include reduced transpiration rate, increased high light-intensity and temperature tolerance, as well as greater efficiency of net photosynthesis, makes them more suited to semi- and subtropical and tropical areas and more efficient as weeds than most C3 plants.</p>
<p>Canopy and root architecture and vigor</p>	<p>Ornamental bedding plants with mounding habits, eg some petunias, have long been recognized as good weed suppressants when the mounds quickly meet to provide a complete ground cover (pages 62, 146). Other aspects of plant architecture being researched today include:</p> <ul style="list-style-type: none"> • Impact of canopy architecture. <ul style="list-style-type: none"> • Integrated pest-disease-weed management programs. • Impact on disease epidemics and pest development. • Selecting wheat varieties with wider leaves which can suppress weeds by up to 50% and have early vigor and faster growth rates. • Roots. In some plant species, when it comes to water productivity breeders select genes to promote root vigor and more root branching.



<p>Adverse weather Bedding plants</p>	<p>Simba marigold, has been a Flower of the Year from Bedding Plant Australia (BPA). Simba marigold is a hardy, waterwise annual with 4 colors – yellow, red, tangerine and ‘bolero’ which has red and yellow mottled flowers.</p> <ul style="list-style-type: none"> • The variety is compact, growing to about 30cm, long-lasting flowers of about 5 cm wide which are produced over several months. Simba has good branching habit, producing many flowers per plant and suits pots and makes a great choice for Australia’s hot dry summers and low maintenance gardens and courtyards. <p>Petunia Limbo has become a top-selling petunia for Highsun Express Plugs; it is the first genetic dwarf type of grandiflora petunia on the market, growing to about 15-20cm.</p> <ul style="list-style-type: none"> • The dwarf nature means that growth regulators are not needed for long shelf life; it retains a round shape and branching habit through the entire season. • Limbo is described as early flowering, does not stretch, and has a good shelf life. This habit and the variety’s garden performance have earned Limbo Violet the All American Selections Award and the Fleuroselect Quality Award. <p>New petunias from Oasis Horticulture Flowers may resist fading under the summer sun, form sizeable mounds, mixes are popular, combining shades of light and dark, or blue and lavender. Surfinia Colourwave was the World’s No 1 selling petunia for 2012. Pruning or pinching is not necessary as Surfinia® is self-cleaning.</p> <ul style="list-style-type: none"> • Surfinia® Classic varieties have a vigorous, spreading habit, so are ideal ground covers with a remarkable resilience to heavy rain and low temperatures. • Surfinia® Patio varieties have a mounding habit, and the benefit of early flowering and the toughness of Classic above.
<p>Sustainability</p>	<p>Sustainably produced fruit and vegetables are becoming increasingly important to retailers and their suppliers (page 370). Seeds are available for professional and sustainable vegetable production, eg</p> <ul style="list-style-type: none"> • Intense™ tomato range has been extended with the addition of new shapes and larger sizes, making it an attractive option for new sectors and the marketplace. • Kirene, a Gala melon, changes its skin color from green to brilliant yellow when it is ready to harvest, a fail-safe way of avoiding unripe product without affecting its fragrance, taste and firmness from paddock to plate.
<p>To lift yield</p>	<p>Exchange between the World Vegetable Centre in Taiwan and the Queensland Dept. of Employment, Economic Development and Innovation (DEEDI) is intended to lift the breeding potential of mung beans in Australia and overseas, building on the 20% yield gain delivered by the last variety released ‘Crystal’.</p> <ul style="list-style-type: none"> • Global demand for mung beans is forecast to rise considerably because much of the world’s predicted population growth is concentrated in countries that are major consumers of the crop.

Table 8. Resistance, tolerance of some crops and varieties to some key abiotic and biotic pests and diseases. Contact your industry association for information for your crop.

<p>Salinity</p>	<p>TOLERANT <i>Ornamentals</i>, eg carnation <i>Vegetables</i>, eg asparagus, spinach, garden beets <i>Grasses</i>, eg couch grass, rye, grass, kikuyu <i>Field crops</i>, eg sugar beet, cotton, rape</p> <p>INTERMEDIATE <i>Ornamentals</i>, eg hibiscus, oleander, stock, chrysanthemum <i>Vegetables</i>, eg carrot, lettuce, onion, pea, tomato, cucurbits, crucifers <i>Grasses</i>, eg paspalum, phalaris <i>Field crops</i>, eg maize, lucerne</p>	<p>POOR TOLERANCE <i>Ornamentals</i>, eg rose, aster, azalea, camellia, gladiolus, magnolia, violet <i>Fruit</i>, eg most fruit varieties <i>Vegetables</i>, eg seedling carrots <i>Field crops</i>, eg most clovers</p> <p>Check, new cultivars may be salt tolerant</p>
<p>Hormone herbicide injury 2,4-D, MCPA</p>	<p>TOLERANT Most turf and pasture grasses</p> <p>INTERMEDIATE Cereals, bent and buffalo grasses, strawberry</p>  <p>2,4-D damage to grapevine. Photo©Canberra Institute of Technology.</p>	<p>SENSITIVE Most trees and shrubs, roses fruits, legumes eg lucerne, clover, also crucifers, cucurbits</p> <p>VERY SENSITIVE Chrysanthemum, zinnia, hibiscus, grape, lettuce, cotton, tomato</p>  <p>Hormone herbicide injury to ash</p>
<p>Phytophthora root rot <i>Phytophthora cinnamomi</i></p>	<p>HIGHLY TOLERANT Silver wattle (<i>Acacia dealbata</i>) Crimson bottlebrush (<i>Callistemon citrinus</i>) Woolly tea-tree (<i>Leptospermum lanigerum</i>) White bottlebrush (<i>Callistemon salignus</i>) Bracelet honey myrtle (<i>Melaleuca armillaris</i>) Tasmanian blue gum (<i>Eucalyptus globulus</i>) Tall kangaroo-paw (<i>Anigozanthos flavidus</i>)</p>	<p>There are many websites relating to the susceptibility and resistance of plants to various species of <i>Phytophthora</i>.</p>
<p>Myrtle rust <i>Uredo rangellii</i> (attacks plants in the Myrtaceae family)</p> <p>Varieties of the same species can differ in resistance</p> <p>Myrtle Rust Management Plan 2012 provides a detailed framework for growers and retailers to apply on-site for the management of Myrtle Rust on all plants from the Myrtaceae family.</p>	<p>HIGHLY RESISTANT (after testing) Callistemons Slim™, Green John™ and Flora Burst™ were given the status of highly resistant to Myrtle Rust after testing. The Lilly Pillies Sublime™ and Red Head™ were also highly resistant. Tristaniopsis Luscious® and Waterhousea Sweeper™ were also rated as highly resistant.</p> <p>RESISTANT (after testing) Callistemon Macarthur™ was found to be resistant.</p> <p>MODERATELY RESISTANT (after testing) Callistemons Red Alert™, Scarlet Flame™ and Better John™</p> <p>Testing Plants for Myrtle Rust Resistance www.ozbreed.com.au/plant-turf-research.html A resistance breeding program is part of the National Transition to Management Program http://myrtlerust.net.au</p>	<p>Other Callistemons were susceptible to Myrtle Rust</p>  <p>The fungal disease myrtle rust on <i>Agonis flexuosa</i> (willow myrtle). Photo©Dr Louise Morin, CSIRO.</p> <p>A standardized disease rating system to be applied across Myrtaceous species to enable trade in disease-free species and provide advice, to councils, etc on the level of myrtle rust susceptibility or tolerance for a particular species and varieties has been requested by Tas, SA and WA NGIA.</p>
<p>Twospotted mite <i>Tetranychus urticae</i></p>	<p>SOME TOLERANCE <i>Ornamentals</i>, eg begonia, camellia, geranium <i>Fruit</i>, eg fig <i>Vegetables</i>, eg broad beans, onion, sweetcorn <i>Grasses</i>, eg rye grass</p>	<p>VERY SUSCEPTIBLE <i>Ornamentals</i>, eg dahlia, orchid, rose, violet <i>Fruit</i>, eg apple, pear, strawberry <i>Vegetables</i>, eg French bean, cucurbits, tomato <i>Field crops</i>, eg cotton <i>Weeds</i>, eg legumes</p>  <p>Twospotted mite damage to frangipani . Photo©Canberra Institute of Technology</p>

HOW PLANTS DEFEND THEMSELVES

Whatever the kind of defense or resistance a host plant employs against a pathogen or against an abiotic agent, it is ultimately controlled, directly or indirectly by the **genes of the host plant and of the pathogen** (Agrios 2005). Although all pathogens have many virulence factors and their own unique pathways to infect host plants, plants always have intricate defense mechanisms to recognize the pathogen and defend themselves against the invader.

<p>Color</p>  <p>Nectar scarab (about 6 mm long)</p>	<p>Insects are attracted to colored flowers for food, eg nectar. Insect pests may be attracted by the color of the flower or leaves, or the amount of ultraviolet light reflected from leaves. The attraction may be for feeding or egg laying.</p> <ul style="list-style-type: none"> • Gladiolus thrips (<i>Thrips simplex</i>) are not attracted to pale colored or white gladiolus flowers. Mauve Attraction, Mauve Lohengrin, Yellow Golden Bay and Red Oscar are very susceptible to flower damage. • Nectar scarabs (<i>Phyllotocus</i> spp.) are small native beetles which feed on the nectar of roses, dahlias and other flower. They are particularly attracted to white varieties. • Cabbage aphid (<i>Brevicoryne brassicae</i>) is reputed to avoid red cabbage varieties. Resistance of brassica plants to the cabbage aphid and the green peach aphid is considered to be linked to changes in the amino acid spectrum, • Onion thrips (<i>Thrips tabaci</i>). The light green color of 'Spanish White' onions seems to deter onion thrips from colonizing this variety.
<p>Morphology</p>  <p>Soft-textured leaves make chewing and digestion easy</p> <p style="text-align: right;">Crop competition</p>	<p>Some plants have visible external defences, while others have not so obvious internal morphological defences, eg</p> <ul style="list-style-type: none"> • Large thorns make it physically difficult for a pest to feed. • Plants with a large number of glandular hairs on the epidermis, eg tomatoes and potatoes, have some resistance to aphids. The aphids break the hairs when walking over the surface and the fluid exuded by the broken hairs either fixes the aphid to the plant or clogs their gripping structures so that they fall off the plant. • Solid-stemmed varieties of wheat can resist attacks by a sawfly (<i>Cephus cinctus</i>), partly because eggs are often damaged during insertion and partly because larvae cannot move as freely within the stem as they can in hollow-stemmed varieties. • Thickness of epidermis. Resistance in some varieties of plum to brown rot (<i>Monilinia fructicola</i>) is partly due to the relative thickness of the cuticle. • Leaf shape, size or texture may make eucalypt species less favored by insects, eg a very wide leaf prevents female sawflies laying eggs on leaves as they are unable to grasp both leaf margins to obtain a secure foothold essential while eggs are laid. • Soft textured leaves make chewing and digestion easy for some insects and allow others to roll up a leaf to create a hiding place. • Wax covers all the aerial plant surfaces providing a water resistant barrier between plants and their environment. Waxy glaucous surfaces of juvenile foliage also provide some resistance to insect and fungal attack. <ul style="list-style-type: none"> • Some flying insects have difficulty in landing on slippery surfaces. Crawling insects avoid slippery surfaces as suction pads on their feet cannot adhere to the surface. • The components of wax and their chemical characteristics on summer grass or crab grass (<i>Digitaria sanguinalis</i>) and tall fescue (<i>Festuca arundinacea</i>) determine how effectively these plants are able to combat invasion by the fungus <i>Curvularia eragrostidis</i>. <ul style="list-style-type: none"> • The constituents of the 2 epicuticular waxes are remarkably different. Summer grass is susceptible while tall fescue is more tolerant. • The aim is to develop a bioherbicide for the management of summer grass (Wang et al 2008). • Toothed-leaf margins are more active in photosynthesis and transpiration than untoothed leaf margins especially early in the growing season. Loss of water helps to pull up more sap from the roots. The colder the area, the more it is beneficial to have toothed leaf margins as they are more active in species native to colder climates with shorter growing seasons. • Plant canopy and architecture. Highly vigorous wheat lines have been developed that can produce up to double the biomass of conventional varieties by early tillering stage, effectively shading out weeds (Lee 2011). Increased root growth also enables the wheat to out-compete weeds for water and nutrients. <ul style="list-style-type: none"> • Due to increasing herbicide resistance, it is important for growers to use more non-herbicide options to control weeds and there is significant potential for crop competition to be better utilized for weed control.

Hypersensitivity

The plant is so sensitive to attack that immediate death of the affected area follows. This phenomenon is a **common cause** of resistance to **fungal parasites** but is only rarely the cause of resistance to insect pests.

- **Woolly aphids** (*Aphelinus mali*) require the host plant to react to attack by producing new callus tissue on which they can feed. Resistant apple varieties react with a rapid, protective death of cells so that the pest is **unable** to feed.

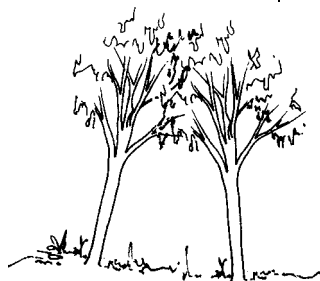
Chemicals present in the plant



Many plants contain chemicals which suppress attack by diseases and pests, eg

- **Some plants naturally produce well known chemicals** which are **registered** as insecticides such as pyrethrum and rotenone (Derris® Dust).
- **Oil glands** in skin of **some oranges and lemons** may kill eggs of the Mediterranean fruit fly (*Ceratitis capitata*) soon after laying, providing some resistance to attack.
- **Azadirachtin** is derived from the **neem tree** (*Azadirachta indica*), a native of Burma, and effectively controls caterpillars and aphids.
- **Sinigrin**. Cabbage white butterflies carry hairs on their feet that allow them to recognize chemicals, eg sinigrin, in the foliage upon which it lights. The taste is rapidly savored and the female lays a single egg under the leaf.
- **Cineole**, a component of eucalyptus oil, repels Christmas beetles but not other important insect pests of eucalypts. Cineole appears to be only a warning agent against **sideroxylonal**, the product which actually slows down the feeding of the beetles. Resistance to insect attack varies widely not only between species but also between provenances (populations of a species from different regions), individual trees within provenances and even different branches of one tree.
- **Gossypol** in cotton retards the growth of the corn earworm (*Helicoverpa armigera*) to a very limited extent.
- **Odour shields**. Brassicas protect themselves by accumulating unpalatable glucosinolates in their tissue which breaks down into pungent **isothiocyanates** which smell strongly of mustard which is objectionable.

Chemicals produced in response to attack SOS signals



Talking trees

Instances of plant communication through the air have been documented, in which chemicals emitted by a damaged plant can be picked up by a neighbor. Many plants have a chemical armory that they deploy when aphids attack, with chemicals that both repel the aphids and attract parasitic wasps.

Some plants only produce or release volatile odors when damaged.

- **Volatile odors may repel pests**, eg beans produce methyl salicylate (**MS**) which repels bean aphids.
- **Chemicals may attract parasitic wasps and predatory mites (SOS signals)**. Being able to recognize the **SOS** call could therefore be an advantage to a wide range of predators. The **MS** produced by beans also attracts predators to eat pests. Plants may time their **SOS** signal to coincide with predator activity. Lures have been developed to attract insect parasites to cotton plants (Envirofeast®) (page 102).
- **Talking trees**. Damage to one tree sometimes leads to fewer pests on neighbouring trees, the suggestion being that the damaged trees might be sending warnings to nearby trees telling them to arm themselves against attack.
 - **Infected plants may communicate with healthy plants**. **MS** is the **first airborne signal** shown to be involved in the communication between infected and healthy plants.
 - **Damaged and undamaged maize and cotton leaves** produce an **SOS** signal that **attracts parasitic wasps**. Females of certain parasitic wasps home in on the scent and parasitize the caterpillars. Several hours after maize leaves are eaten by caterpillars, the maize shoots including the undamaged leaves release the **SOS** signal.
 - **Crops selected for high yields and direct resistance to pests and diseases** may be losing their ability to cry for help, eg modern varieties of sweet peas and roses have very showy flowers but little scent. A **wild variety of cotton** that releases 8-10 times as much of these materials when attacked, than any domestic varieties. If correct, then genetic engineering or conventional breeding may be needed to get varieties with strong **SOS** signals.
- **Phytoalexins** are toxic antimicrobial substances produced in appreciable amounts in plants only after stimulation by fungal diseases and other pathogens, or by chemicals and chemical injury (Agrios 2005). Their significance in disease resistance is unknown. They have possible use as fungicides, but they cannot be extracted from healthy plants. **Sugarbeet plants** and more than 30 beet relatives, produce phytoalexins which are toxic to *Cecospora* leaf spot and other invading fungi.
- **Polyphenols** may restrict the growth of fungi, bacteria or nematodes or kill them. The astringent taste of **privet leaves** is caused by polyphenols. Some insects contain defense chemicals to counter the effects of the polyphenols (Clare 1997).
- **Anticholinesterase** is produced by at least one variety of asparagus when it is infected with root knot nematode.
- **Systemic Acquire Resistance (SAR)** is a **natural defense response to fungal attack** which can be triggered by biological or chemical agents (page 156). In at least some types of plants, infection of **an early leaf** with an avirulent pathotype can cause heightened resistance of later-developing plant parts to virulent pathotypes (Spencer 2008).

Mycorrhiza

Information highways



The roots of most land plants are colonized by a network of underground mycorrhizal fungi

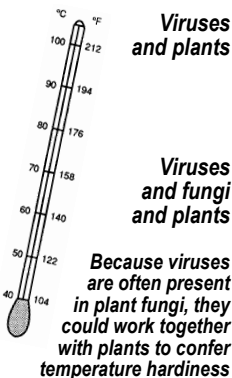
(page 116). Physiological changes take place in the host plant upon root colonization which affect the interactions with a wide range of organisms below and above-ground, eg

- **Providing plants with mineral nutrients in exchange for products of photosynthesis.**
 - **Mycorrhiza-Induced Resistance and Priming of Plant Defenses.** Symbioses between plants and some beneficial soil microorganisms are known to promote plant growth and help plants to cope with biotic and abiotic stresses (Jung et al 2002).
- **Protective effects of the symbiosis against pathogens, pests, and parasitic plants** have been described for many plant species, including agriculturally important crops.
 - **Plant-feeding insects cause systemic changes in the production of plant volatiles,** particularly **methyl salicylate,** eg making broad bean plants (*Vicia faba*) **repellent** to aphids but **attractive** to aphid enemies such as parasitoids.
 - **These effects can also occur in aphid-free** plants but only when they are connected to aphid-infested plants via a common mycorrhizal mycelial network.
 - **This underground messaging system** allows neighboring plants to invoke defences against plant feeding insects **before** attack.
- **Serving as superhighways directly connecting plants below ground** which act as a conduit for signaling between plants, acting as an early warning system for insect attack (Babikova et al 2013).
 - The finding could be put to use in many crops that suffer aphid damage, by arranging for a particular, "sacrificial" plant to be more susceptible to aphid infestation, so that when aphids threaten, the network can provide advance notice for the rest of the crop.
 - Because the defense is only switched on when needed, it could **reduce the development of resistance** (of the aphids) to the plant's defenses.

Endophytes

Endophytes are usually fungi that live within healthy plant tissue, relying on the plant for protection, nutrition and dispersal (page 116). The fungi can benefit their hosts by preventing colonization by other organisms that may cause disease (Caradus and Hume 2011).

Mutualistic viruses may confer drought, cold, heat tolerance



An example of collaboration between plants and viruses that confer drought tolerance to many different crop plants has been demonstrated (Roossinck 2013).

- **Drought and cold tolerance.** Researchers tested 4 different viruses and several different plants, including crops such as **rice, tomato, squash and beets,** and showed that the viruses increased the plants' ability to tolerate drought. Virus infection also provided cold tolerance in some cases. Cucumber mosaic virus confers cold tolerance in red beet.
 - **A leafy plant, related to a common weed known as lamb's quarter,** was also infected with a virus that caused a local infection. The infection was enough to boost the plant's drought tolerance and may mean that the virus does not have to actively replicate in the cells where the resistance to drought occurs.
- **Heat tolerance.** In studies on plants that thrive in the volcanic soils of Costa Rica and in the hot, geothermal ground in Yellowstone National Park, **viruses and fungi work together with plants** to confer temperature hardiness.
 - Plants in this environment harbor endophytes that are infected with a virus. All 3 partners are required for thermal tolerance. **Fungi and tropical panic grass** found in Yellowstone National Park grow together in temperatures above **51.5°C.**
 - If you cure the fungus of the virus, you no longer have the thermal tolerance - if the plant and fungus are separated, both die at the same heat levels. A virus is required for thermal tolerance.
- **While researchers do not entirely understand the role of viruses** in helping plants withstand extreme conditions, future research may help the agricultural industry naturally develop hardier plants rather than rely on chemical solutions.

Other factors, eg environment, nutrition, salt stress, combined traits stomates, allelochemicals

The means by which plants can defend themselves are almost infinite.

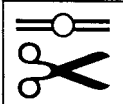
- **Environmental parameters** largely determine the **expression of resistance.** Infection may only take place under specific cultural or environmental conditions.
- **In general the effect of nutrition on plant resistance to diseases is unclear.** Many factors, eg the cultivar itself, environmental conditions, presence or absence of disease and nutrient elements all have to be considered. It is only when **one of these factors remains extreme** that the effect becomes a problem.
- **Salt stress enhanced Phytophthora root rot (Phytophthora sp.)** infection in some tomato cultivars (Snapp and Shennan 1994).
- **Rootstocks.** Strategy for improving salt tolerance of **citrus and grapevines** is based mainly on **breeding and selecting rootstocks** that combine salt tolerance with as many as possible of the other desirable rootstock traits.
- **Functional properties,** eg plant varieties which have late opening stomates, may be resistant to certain diseases, eg downy mildews.
- **De-activating enzymes** are commonly used in genetic engineering to develop herbicide resistant crops.
- **Allelochemicals** are produced by some plants growing in nature in order to survive. Allelochemicals are used to ward off attack by potential plant-feeding insects and mites. These compounds may be directly harmful to herbivores or slow their development, thus increasing their susceptibility to natural enemies such as parasitic wasp (parasitoids) and / or predators (Cloyd 2004). See also page 59.

SOURCES OF RESISTANT GENES

The ability to produce disease-resistant cultivars depends on a number of factors including the **availability of resistant genes**. Strategies include a mixture of both traditional selection breeding techniques and modern biotechnology, to try and identify the genes responsible for resistance.

Biodiversity	<p><u>Genetic diversity helps plants withstand diseases and pests</u> and enables them to tolerate climatic fluctuations. Desired genes are bred into commercial crop cultivars to control diseases and pests.</p> <ul style="list-style-type: none"> • Regions of diversity. Genes for disease resistance are especially common in the region where the crop species evolved, eg the genes for resistance to Irish blight (<i>Phytophthora infestans</i>) of potato were all collected from populations of <i>Solanum demissum</i>, a wild relative of the potato in Mexico. • Wild and cultivated plants. Genes that control pests and diseases have been identified in both wild and agricultural plants and are used extensively to breed agricultural plants which are resistant. • The genetic resources of native plants have been used to enhance resistance of crop plants, eg <ul style="list-style-type: none"> • Genes from species of wild cotton (<i>Gossypium</i> sp.) have been used to improve cold tolerance and disease and pest resistance in commercial cotton cultivars. • Genes for rust resistance in a native climber (<i>Glycine</i> sp.) can be transferred to the related commercial soya bean which is very susceptible. • The Environmental Protection and Biodiversity Conservation (EPBC) Act 1999 aims to conserve genetic resources by: <ul style="list-style-type: none"> • Conserving diversity in plants and in economic plants particularly. • Collecting material of specific use in agricultural and horticultural crops. • Reducing the continual loss of bio-diversity due to changes in climate and land use, eg agriculture, monocultures, urban development.
Wide geographic area	<p><u>Another method is to screen cultivated species and varieties</u> collected from a wide geographic area, following either artificial inoculation or exposure to natural infection in the field.</p>
Survivor species	<p><u>Survivor plants are plants which can withstand attacks</u> by diseases or pests, although most of the other plants of that species or varieties in the same area are affected.</p> <ul style="list-style-type: none"> • If these plants are propagated vegetatively and continue to be resistant, they may become stock plants for the development of one or more resistant varieties.
Seed banks seed vaults gene banks	<p><u>There are about 6 million samples of a particular population, stored as seeds</u> in about 1,300 gene banks throughout the world (2006). They are really an insurance policy.</p> <ul style="list-style-type: none"> • The Millennium Seed Bank Project is an international conservation project coordinated by the Royal Botanic Gardens, Kew in partnerships with other countries. It is the largest global plant conservation project in the world focusing on global plant life faced with the threat of extinction and plants of most use for the future. Australia is particularly significant as its flora constitutes 15% of the world's total of species, with 22% of them identified as under threat of extinction. • A "Doomsday vault" built deep in an Artic mountain holds a key to the world's food security. The Svalbard Global Seed Vault in a Norwegian island, stores samples of the world's most important seeds to protect food crops from disease, potential climate change, natural disasters, war and political strife (Papadakis 2011). <ul style="list-style-type: none"> • The Seed Vault is a repository for seed varieties around the globe. • In Australia, grain seed (34,000 varieties) have been processed and approved for transport to the Svalbard Global Seed Vault located in the Norwegian Svalbard islands permafrost, halfway between mainland Norway and the North Pole. • This first consignment from Australia included 301 pea accessions originally from China and 42 chickpea landrace seeds (traditional farmer's varieties) from the Middle East (Biosecurity 2011).



<p>Provenances cross resistance, eucalypts</p>	<p><i>Mycosphaerella leaf disease.</i> A northern NSW provenance of shining gum (<i>Eucalyptus nitens</i>) under the same environmental conditions and inoculum load as a southern NSW provenance, is more resistant to <i>Mycosphaerella leaf disease</i>.</p> <ul style="list-style-type: none"> Leaves from the resistant provenance were consistently thinner and had a higher proportion of palisade mesophyll, reduced intracellular airspace and the periderm formed was more organized, continuous, suberized and lignified than periderm palisade layers in susceptible leaves (Smith et al 2006). <p><i>Resistance to insects and vertebrate pests.</i> Many eucalypt species have shown differences among individual trees in resistance to insect and vertebrate pests. Studies on southern blue gum (<i>E. globulus</i>) found differences among 18 provenances and individual trees within each provenance. Resistance traits were due to sideroxylyonal and cineole (Floyd and Foley 2001).</p> <ul style="list-style-type: none"> There is cross resistance between marsupial herbivores and Christmas beetles (<i>Anoplognathus</i> spp.), one major group of insect defoliators. This is the first time cross resistance has been demonstrated between vertebrate and invertebrate herbivores. There are major differences between the chemical composition of seedlings and adult leaves of some eucalypt species. In the case of vertebrates, trees with high concentrations of sideroxylyonal, will confer partial resistance to herbivore marsupials – not all eucalypts contain sideroxylyonal and it is absent from several commercially important species such as <i>E. globulus</i>, <i>E. camaldulaneis</i> and <i>E. dunnii</i>. In these species there is a related group of chemicals called macrocarpals that are believed to confer resistance against marsupial herbivores. However, <ul style="list-style-type: none"> As resistance is based on leaf chemistry, trees are not likely to be fast growing and strongly resistant all at the same time. Secondly, insects may adapt.
<p>Cross resistance is the tolerance to a usually toxic substance as a result of exposure to a similarly acting substance.</p>	
<p>Induced mutations</p>	<p><i>A mutation is an abrupt appearance</i> of a new characteristic in an individual as the result of a spontaneous change in genes or chromosomes, eg</p> <ul style="list-style-type: none"> Because the spontaneous mutation rate is so low, breeders must rely on induced mutations as a source of variability. This is frequently achieved by subjecting seeds, buds, meristems or cuttings to ionizing radiation. Radiation or mutagenic chemicals may be applied to the chromosomes in seed or in the growing tips of plants. Occasionally, plants grown from cells containing changes in a gene or chromosome, may exhibit greater resistance to a disease or pest than the parent.
<p>Other plants or animals</p>	<p><i>Genes with the desired resistance can be transferred from other plants</i> either by conventional breeding or by genetic engineering.</p> <ul style="list-style-type: none"> Probably the commonest source of plant resistance is closely related species. Genetic engineering also enables genes to be transferred to plants from animals.
<p>Genetic engineering</p> 	<p><i>Genetic engineering has been mostly used to make crops more resistant or tolerant</i> (page 409), eg</p> <ul style="list-style-type: none"> Disease and pest resistance, eg <ul style="list-style-type: none"> Ornamental crops, eg carnations resistant to fungal diseases. Fruit and vegetables, eg resistance to virus and fungal diseases and some insect pests. Field crops, eg resistance to virus and fungal diseases, some insect pests. Enhanced tolerance to waterlogging, salinity, chilling resistance in plants. Herbicide Resistant Crops from Biotechnology (HRCBs). <ul style="list-style-type: none"> Roundup®-Ready crops are GM crops which are resistant to glyphosate (Roundup®). Crops can be sprayed several times during growth with glyphosate. HRCBs may be resistant to other herbicides, eg 2,4-D, bromoxynil, Basta® (glufosinate-ammonium), paraquat, simazine. <p><i>The part that genes play in tolerance to drought, frost, salinity and poor soils</i> is by no means clear.</p> <ul style="list-style-type: none"> It is not certain that genetic engineering of such multigenic traits will be more successful than conventional plant breeding. Drought-tolerant plants, for example, need deep roots that can penetrate a clay pan, thick leaf cuticles and the ability to make certain adjustments in balancing salt concentrations within cells.
<p>Assessing gene banks for climate change</p>	<p><i>Modern breeding tools helps plant breeders to scan large amounts of germplasm quickly</i>, which in turn enables them to assess gene banks around the world for traits of specific interest to Australian producers, eg improved tolerance to drought, frost and extreme heat are traits of particular interest in relation to adaptation to climate change.</p> <ul style="list-style-type: none"> An important advantage of modern pre-breeding research is the improved ability to add new traits to existing, proven varieties without diminishing their current characteristics.

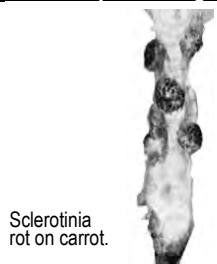
International Maize and Wheat Improvement Centre (CIMMYT)

This is the largest ever effort to comprehensively characterize the genetic resources available for 2 of the world's most important food crops

Unique collections of germplasm are housed overseas in the **International Maize and Wheat Improvement Centre (CIMMYT)** in Mexico and the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria.

- **Collections include wild relatives and modern cultivars of** cereal and pulse crops grown in Australia which have provided Australian plant breeders with unique new sources of genes for disease resistance, climate adaptation and to meet market requirements.
- **While this project only deals with wheat** it is hoped it may provide a blueprint for a coordinated approach to sourcing germplasm for other crops.
- **An important global aim** is to maintain rust resistance – each year's wheat lines with good rust resistance are distributed around the world for multiplication, safekeeping and sourcing germplasm for developing new varieties.
- **Stem rust** has re-emerged as a serious threat to wheat production in East Africa. The University of Sydney trains young African scientists in rust resistance breeding.
- **The MasAgro project** (Sustainable Modernization of Traditional Agriculture) which is based at the CIMMYT, has various components including:
 - **The "Seeds of Discovery Program" aims** to identify previously undiscovered genes for crop traits that can lift yields while using less water and adjusting to rising temperatures.
 - **Grain growers worldwide will benefit** from the program's intention to make it easier to identify sought-after characteristics, including resistance or tolerance to existing and newly emerging pests and diseases.
 - **Field trials are a key element of the Seeds of Discovery** for drought and heat tolerance and then the most successful entries will be assessed for other high priority traits including resistance to wheat blast, spot blotch, tan spot and karnal bunt, rust resistance in durum wheat and phosphorus use efficiency.
 - **An international strategy to raise wheat yield** potential by 50% over the next 20 years by improved photosynthetic efficiency and plant architecture, etc.
 - **An international Strategy to raise maize yields** to help seed producers to make diverse maize varieties and hybrids available to Mexican farmers at affordable prices. Extension programs will strengthen Mexican farmers' capacity to grow improved seeds and preserve water and soil nutrients through precision farming and conservation agriculture.

Resistance in necrotrophic fungi



Sclerotinia rot on carrot.



Grey mould (*Botrytis cinerea*) on Callistemon. Photo© State of Victoria.

Plant pathogens are categorized based on their modes of nutrition.

- **Biotrophic pathogens** derive nutrients from living cells and therefore must maintain host viability, eg powdery and downy mildews.
- **Hemibiotrophs**, display both forms of nutrient acquisition shifting from an early biotrophic phase to necrotrophy at later stages of disease, eg opportunistic apple scab.
- **Necrotrophic pathogens** first kill host tissue then colonize and thrive on the contents of dead or dying cells. They cause major pre- and post-harvest diseases in numerous ornamental and vegetable crops inflicting significant economic losses and are difficult and costly to control.
 - **Sclerotinia sclerotiorum** and **Botrytis cinerea** both have wide host ranges and cause vast economic damage during crop cultivation as well as in harvested produce.
 - **Septoria blotch disease** (*Stagonospora nodorum*) of wheat.
 - **Yellow or tan spot** (*Pyrenophora tritici-repentis*.) of wheat.
 - **Ascochyta spp., Phoma medicaginis and Fusarium oxysporum** in the model *Medicago truncatula* (Barrel Medic or Barrel Medick or Barrel Clover).
 - **The Australian Centre for Necrotrophic Fungal Pathogens (ACNFP)** is an established research group based at Curtin University (Perth, WA) undertakes research into the mechanisms of pathogenicity and resistance in these fungi www.acnfp.curtin.edu.au/
- **Improving resistance is difficult.** A protein MED18 regulates fruit production and disease resistance and could lead to improved resistance to necrotrophic fungal diseases in plants.
 - **When necrotrophs attack**, they stimulate an increase in the expression of two plant genes that render a plant more susceptible to infection. MED18 works with other proteins to "turn off" these genes, contributing to disease resistance. MED18 also helps activate a gene that bolsters a plant's defense against wounding and infection by necrotrophs.
 - **Disease resistance** could be enhanced by selecting natural variants with desirable characteristics in plant populations or by generating GM plants.

Salt tolerance

Salt tolerant wheat and barley to follow rice genetic breakthrough



Arabidopsis Photo©TAIR (www.arabidopsis.org)

The **Australian Centre for Plant Functional Genomics (ACPFPG)** have added to **rice varieties** a gene from *Arabidopsis* (Brassicaceae) which traps salt in the root of the rice plant stopping the salt travelling to the shoot where it does the most damage (at this stage mainly south east Asian rice varieties rather than lines grown in Australia). For Australia the main focus is on imparting the characteristic to **wheat and barley**.

Eucalypts tolerant of salinity. Genetic breeding and selection will aim for faster growth rates, improved adaptation to the **target environments**, eg drought, temperature extremes and **salinity**, and improved tree form and wood properties.

- Tissue culture makes it possible to create plant clones with identical characteristics.
- ForBios, an Australian biotechnology company uses robots for some of the propagation work. This robot program is coupled with a program to develop better trees such as faster growth, denser wood or **resistance to disease** and map their genomes.
- They then locate the genes for key traits and find markers that go with them so that seedlings that carry the **required traits can be identified early**, rather than waiting several decades for a tree to mature to determine the same information.

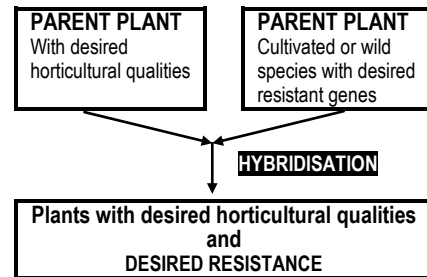
HOW RESISTANT, TOLERANT PLANTS ARE PRODUCED

It is expected that conventional plant breeding, combined with genetic engineering will provide effective tools for controlling plant diseases and pests in susceptible plants. Strategies to try and identify the genes responsible for drought tolerance will involve a mixture of both traditional breeding techniques and modern biotechnology.

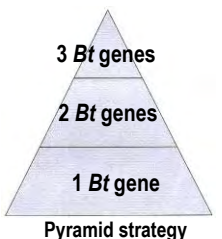
Conventional plant breeding
Hybridisation is the crossing or mating of two related plants to produce new varieties with desirable properties (Moody 2009)

Traditional plant-breeding involves selecting plants with new or desired features from a divergent population and cross pollinating them.

- The progeny of the selected individuals is grown and screened and the process is repeated for several generations until a uniform plant population with the desired characteristics is produced and multiplied.
- Progeny from the cross are then back crossed with the favoured parent to ensure that the progeny is most like that parent.
- Backcrossing is repeated until the desired result is obtained.
- Interspecific and intergeneric hybrids are produced by crossing distantly related species or genera that do not normally sexually reproduce with each other.
- Tissue culture techniques may be needed to assist germination and propagation. Embryo rescue involves rescuing immature hybrid embryos to prevent them aborting and germinated them in tissue culture.



Genetic engineering



- Herbicide resistance 1
 - Herbicide resistance 2
 - Insect resistance 1
 - Insect resistance 2
 - Insect resistance 3
 - Insect resistance 4
 - Insect resistance 5
 - Insect resistance 6
- Stacked genes (traits)

New sophisticated laboratory procedures using tools such as molecular markers or DNA fingerprinting can distinguish the genes that influence a desirable trait and identify plants that possess the trait

Molecular biology techniques can be used to select, or in the case of genetic modification, to insert, desirable traits into plants. Traditionally breeders relied on the visual identification of plants with desired characteristics.

Genetic engineering (GE) is the manipulation of genes within organisms and the transfer of genes between organisms. By far the most common improvement of host resistance to almost any pathogen is brought about by improving the genetic resistance of the host.

- **GE allows useful genes to be transferred** from one unrelated species to another, such as from plants to other plants, or animals to plants, to achieve characteristics not possible by conventional cross-breeding (page 409).
- **GE should not** be regarded as replacing presently accepted methods of plant breeding, but rather as an **additional technique**.
- **GE will allow for quick transfer of individual genes or combination of genes** for resistance into susceptible crop varieties, thereby reducing the time required to develop new resistant varieties (Agrios 2005).
- **Insecticide resistant Bt crops** play an important role in the management of *Helicoverpa* in cotton but may not be robust enough to handle high density infestations.
- **Pyramid strategy.** Each GM plant produces **two or more toxins** that kill the same pest (pages 166, 412).
- **Stacked genes.** If more than one gene from another organism has been transferred, the created GMO has stacked genes (or stacked traits), eg insect resistance and herbicide resistance. Gene stacking has become an important in plant breeding (pages 166, 412).
- **Switching genes on and off.** Scientists have moved from unraveling the genome to being able to switch genes on and off in selected plant cells. Until recently it was only possible to isolate genes that gave a very clear phenotype such as resistance to a specific disease. Genes controlling complex traits such as drought tolerance were beyond the scope of the technologies.
 - **Researchers would simply transfer a new gene** into the plant and turn it on, so the gene was expressed in every cell of the plant.
 - **This often caused problems** as genes can have very different effects on a plant, depending on where they are expressed. It has been found that when some genes are turned on they help protect the plant against damage caused by drought but they do this by slowing the growth of the plant.
 - **For these types of genes researchers want to express the gene** only in the cells where it is needed and only when it is really required. Now we have **gene regulators (promoters)** that only turn on when the plants are under drought stress but turn off again as soon as plants receive water. This means that plants grow normally when water is available but can rapidly change their behavior when exposed to drought.

Resistant rootstock

The use of resistant rootstocks, if available, is a way of growing susceptible species on an infected site, or reducing the risk of losses from infection.

- **Root rots**, eg
 - *Prostanthera* can be grafted onto *Phytophthora* resistant rootstock of *Westringia fruticosa*.
 - *Eremophila* can be grafted onto *Myoporium insulare* root stocks which tolerate a wide range of soil types and demonstrates some disease resistance.
 - Tomato varieties susceptible to *Fusarium* can be grafted onto resistant rootstock.
- **Insect pests**, eg
 - Phylloxera resistant grapevine rootstock.
 - Woolly aphid resistant apple rootstock.

Seeds	Herbicide resistance. Seeds of some crops are coated with a chemical to protect them against certain herbicides.
Resistance in fruit	<p>Mechanisms of resistance in fruit include:</p> <ul style="list-style-type: none"> • Fruit ripening and defense mechanisms. • Use of elicitors to control postharvest diseases in fruit and vegetables, eg jasmonic acid and chitosan (pages 157, 158). • Enhanced biocontrol of postharvest diseases of apple. • Induced resistance in citrus fruit. • Studies on endophytic fungi of citrus. • The role of insects in dispersing the fungus, <i>Lasiodiplodia theobromae</i>, which has a very wide host range causing rotting and dieback in most species it infects, eg the post harvest fungus disease of citrus known as stem-end rot. • Detection and isolation of antifungal compounds from peel of pomelo. • Antifungal defenses in cucurbit fruit. • Sources of durian resistance to <i>Phytophthora palmivora</i>. • Antifungal agents in regulating quiescent diseases in mango. • Antifungal compounds in mango peel. • Effect on stem-end rot and anthracnose levels of dipping mango fruit in host-defending-promoting compounds. • Resistance of immature papaya to fungal infections.
Environment, nutrition	<p>Environment can affect both the host plant and the pest organism (Fig. 17 below).</p> <ul style="list-style-type: none"> • Resistance of the host plant to a particular pest or disease organism can be improved simply by improving the growing conditions, eg fertilization, irrigation, drainage. • Virulence of the disease or pest organism can be also affected by the environment.
Symbiotic relationships	<p>Symbiotic and mutualistic relationships enhance plant health and may in some instances, improve resistance.</p> <ul style="list-style-type: none"> • Nitrogen-fixing bacteria forming nodules on legumes, eg beans, peas, acacias (page 117). • Mycorrhizas are symbiotic associations of fungi with the roots of many plants (page 116) • Endophytes are fungi growing inside a plant which confer insect resistance to the plant. <p>Environment-smart grasses (endophyte-enhanced) are being developed (page 156).</p>

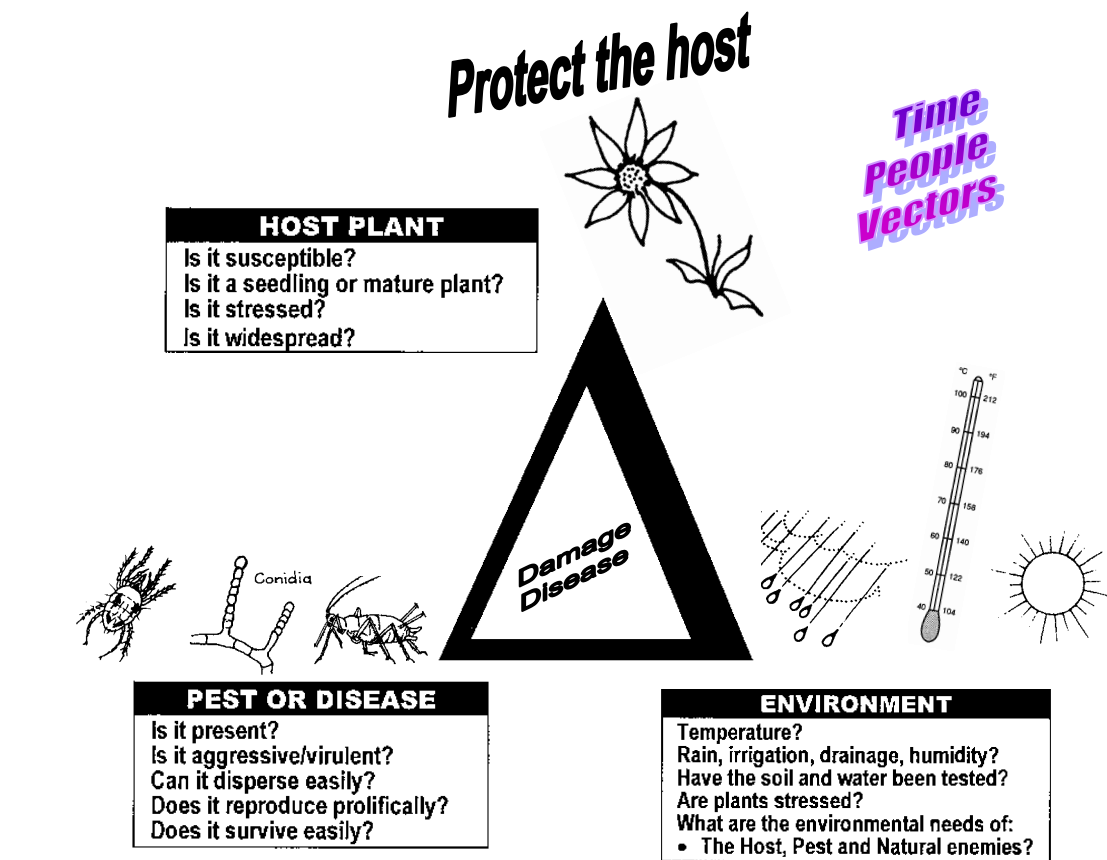


Fig. 17. The DISEASE TRIANGLE. For disease to occur all 3 **elements must be present**. An epidemic will only occur if all 3 continue to be present. Any one might be removed from the equation though, eg the environment changes and is not conducive for the pathogen, or the disease is controlled through a fungicide application.

Systemic acquired resistance (SAR)

SAR is a **whole-plant resistance response** that occurs following an earlier attack that triggers natural defense mechanisms throughout the plant. **SAR** is a mechanism of induced defense that confers long-lasting protection against a broad spectrum of microorganisms; they are often called **plant defense activators**.

Defense activators are applied before infection to activate the plant's inherent resistance mechanisms and are used in conjunction with traditional methods of disease management.

Of the many natural defense mechanisms plants have evolved to survive in nature, only a few can be triggered by **biological** (non-pathogenic microorganisms or their products) or **chemical agents** (non-pesticides, formulated chemicals) without deleterious side effects and in a sufficiently controlled way for practical use.

SAR – Triggered by biological agents

The best-known example of **SAR** in nature, is activated by localized infections with certain pathogens or non-pathogens including viruses, bacteria, or fungi. Some biocontrol organisms seem to trigger the plant to turn on its own defense mechanisms.

- **Plants surviving attack by a pathogen** become systemically protected against later infections. The infected plant becomes more resistant to other infections.
- **Plants are protected against a wide range of pathogens**, not just the pathogen that induced the response.
- **SAR** reduces disease severity rather than providing immunity.
- **Non-pathogenic** strains of the disease organism can be used to trigger the effect.

Cross protection

Cross protection (sometimes called mild strain protection) is the phenomenon in which plant tissue infected with a mild strain of an organism, usually a virus, is protected from infection by other more severe strains of the same organism.

- **Cross protection appears to be a general phenomenon among virus strains**, but its use in controlling virus diseases has met with limited success.
- **Mild strains of many viruses are not available** and they may not be effective against all severe strains. Examples of cross protection include:
 - **Tomatoes** can be protected from virulent strains of tobacco mosaic virus (TMV) by inoculating them with a symptomless strain of tobacco mosaic virus.
 - In **Citrus Bud Certification Schemes**, citrus trees are indexed for tristeza virus as well as several other viruses as it is preferred that citrus trees, especially Marsh and Thompson grapefruit varieties, carry a mild strain of **tristeza virus** as a protection against being infected with a severe strain by the aphid vector.
 - **Papaya** trees can be protected from virulent strains of papaya ringspot virus by inoculating them with mild strain of papaya ringspot virus.
 - **Dutch elm disease (DED)** (*Ophiostoma novo-ulmi*) is carried from tree to tree by the elm bark beetle (*Scolytus multistriatus*) which burrows beneath the bark of elm trees. Control is possible by induced resistance either by conditioning the tree with a glycoprotein isolated from the fungus or by a low virulent strain of *O. ulmi* (Hubbes 2004).

Endophytes

Endophytes may help meet demands for reduced pesticide use and for lower inputs in maintenance of turf.



Endophytic fungal mycelium within a plant. Diagrammatic.

Endophytes are usually fungi or bacteria that live for at least part of their life cycle **symbiotically within plants**, ie within healthy plant tissue, relying on it for protection, nutrition and dispersal. **Usually they do not cause any disease symptoms** but can be detected by examining plant sections with a microscope or by laboratory tests (page 116). Such organisms can benefit their host by preventing colonization by other organisms that may cause disease (Caradus and Hume 2011). Endophytes are arguably best known for increasing pest and disease resistance in **turf**, eg Argentine stem weevil.

- **Cereals**. While endophytes have been isolated from wild relatives of barley and wheat and previous work has found that a single endophyte can affect **pests** across multiple grass species, no research has achieved a successful endophyte relationship in modern cereals. The aim is to do field trials of cereal lines associated with endophytes to demonstrate endophytic activity **against insect and plant diseases** in wild relatives of modern cereals (Caradus and Hume 2011).
 - **Endophytes may be used as bioprotectants and biofumigants**. What we predict is that the endophytes will provide a **form** of systemic natural resistance so there is no need to spray crops routinely. Essentially the plant will be protected by organisms that remain active throughout the entire season.
 - **Soilborne pathogens and pests**. Another applications being trialed is to inoculate the endophyte onto a substrate wheat or barley seed for example, and then use the biocidal metabolites from the endophyte as a form of **biofumigant** or **mycofumigant**. Under natural mycofumigation, the endophyte can suppress soilborne pests and pathogens. In the USA an endophyte isolated from the cinnamon tree in Honduras demonstrated broad biocidal activity against a wide range of destructive pathogens and is being commercially developed as a mycofumigant. It is **placed into the soil prior to planting to disinfest soils**.
 - **Insect heat and water stress**. Cereal endophytes that may have a role in controlling heat and water stress and insect damage in cereals.

Endophytes (contd)	<ul style="list-style-type: none"> • Soilborne diseases. Utilizing endophytic fungi (fungi contained in healthy plant tissue that do not cause disease) to counteract the some of the most problematic soilborne diseases identified in Australian horticulture: <ul style="list-style-type: none"> • <i>Fusarium</i> (wilt diseases). • <i>Rhizoctonia</i> (root and stem rots). • <i>Pythium</i> root rot. • <i>Sclerotinia</i> stem rot. • Clubroot (<i>Plasmodiophora</i>) which cause huge galls or swellings on the roots of Brassicas. • AVANEX™ endophyte-infected grasses which deter birds is already growing at Auckland Airport to dramatically reduce bird populations and improve safety (<i>New grass may beat the bird menace</i>. Aust. Hort. July 2011). <ul style="list-style-type: none"> • The bird-deterrent ability stems from a natural fungus (endophyte) that lives in the grass and produces chemicals that makes birds feel sick but does not appear to harm them. • The endophyte grass is also credited with reducing insect numbers, making the area less attractive to insect-feeding birds, which are then deterred from flocking in grassed areas; the grass has potential use in airports around the world as well as in orchards, sports fields and golf courses in temperate environments. • The grasses that carry these endophytic properties are suited to the cooler temperate regions of Australia where perennial ryegrass and tall fescue are found. • Toxins are produced in perennial ryegrass only if it is infected with the common endophyte fungus, <i>Neotyphodium lolii</i>. <ul style="list-style-type: none"> • In most old pasture about 90% of perennial ryegrass plants are infected. • The plants signal the endophyte to produce secondary metabolites depending on the conditions/stress on the plant. Some of these include the toxins described below which can impact adversely on the performance and health of most species of livestock.
------------------------------	--

SAR – Triggered by chemical agents

Plant Defense Activators turn on a plant's own defense system to fight or prevent disease and are used commercially to protect plants. Some are registered by the Australian Pesticide and Veterinary Association (APVMA). Chemical activation of disease resistance in plants represents an additional option to maintain healthy crops and to prevent losses due to plant diseases.

Elicitors are compounds that when introduced into a living organism signals the activation or synthesis of another compound.

Resistance in plants to several viruses, eg tobacco mosaic virus (TMV), **fungi**, eg downy mildew of tobacco (*Peronospora tabacina*) and **bacteria**, eg *Pseudomonas syringae*, can be induced with **several types of synthetic compounds** applied by **injection** into the plant, **spraying** onto leaves, or absorption through the **petiole** or **roots**.

Salicylic acid (SA)	<p>SA effectively induces SAR against several disease organisms (Daw 2008, Spencer 2008).</p> <ul style="list-style-type: none"> • Club root (<i>Plasmodiophora brassicae</i>) severely disrupts the roots of Brassicas by inducing galls which leads to malformation and reduced growth of the roots and a reduced ability to take up water and nutrients. Control of clubroot is difficult because it has a number of survival and dissemination strategies that involve both motile and resting stages that need to be targeted by any control agent. There is potential of SA to reduce infection by clubroot in broccoli (<i>Brassicae oleracea</i> var. <i>italica</i>) (Lovelock et al 2013).
Jasmonic acid Pathway	<p>Jasmonic Acid Pathway induces the production of disease and insect defense compounds. Insect predation also causes the synthesis of jasmonic acid and its ester methyl jasmonate.</p> <ul style="list-style-type: none"> • Jasmonate is highly volatile and can be detected by surrounding plants to warn them of potential insect predation by inducing the production of systemin and the synthesis of proteinase inhibitors (Spencer 2008).
Salicylic acid (SA) and methyl jasmonate (MeJ)	<p>SA and MeJ have been investigated as a means of minimizing the incidence and severity of citrus green and blue molds (<i>Penicillium digitatum</i>, <i>P. italicum</i>) under long term cold storage of sweet orange fruit prior to their commercial release.</p> <ul style="list-style-type: none"> • A fungitoxic effect has previously been reported on a range of pathogens such as <i>P. expansum</i>, <i>Alternaria alternata</i> and <i>Monilinia fructicola</i> in sweet cherry. • Pre-harvest application possibly allows the host to develop induced resistance, consequently providing fruit protection. • The increase in fruit resistance to fungal infection through the use of natural and low toxicity substances has become more acceptable and an effective strategy for the management of pre-and postharvest fungal pathogens (Iqbal 2012).

Acibenzolar-S-methyl (ASM)	<p>ASM protects plants in a number of ways, eg creating localized thickening in cell walls to resist invading spores. ASM activates natural disease resistance at very low rates on many dicotyledonous plants.</p>
<div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>BION Plant Activator Seed treatment</p> </div>	<ul style="list-style-type: none"> • Bion (acibenzolar-S-methyl) activates the SAR process in many crop plants. It can offer broad protection against fungi, bacteria and viruses without having any direct activity on them. It is registered in Australia for suppression of Fusarium wilt and black root rot of cotton. Bion is scheduled as a DANGEROUS POISON. • ASM has performed best when incorporated into a program of chemical sprays as the inherent level of disease control has seldom been sufficient when applied alone. • Bacterial spot of tomato (<i>Xanthomonas campestris</i> pv. <i>vesicatoria</i>) is a perennial problem in commercial fields in Florida. Although copper compounds and streptomycin were initially effective in disease control, the presence of strains resistant to these compounds has reduced the efficacy of these compounds. <ul style="list-style-type: none"> • Systemic acquired resistance (SAR) compounds have become a popular alternative to conventional bactericides without reducing yields, offering growers an additional component in an integrated management program (Jones et al 2005). • Although ASM applications controlled bacterial spot, yield was not significantly improved compared to plots receiving no ASM applications.
Chitin	<p>Chitosan compounds occurs naturally and are capable of degrading chitin that makes up the shells of nearly all insects and crustaceans as well as most fungi, algae and yeast and nematode eggs. Chitin is insoluble in water, organic and inorganic acids. Chitinases are expressed at low levels in healthy plants but increased when under pathogen attack when they breaks down fungal cell walls, and can break down insect exo-skeletons (Spencer 2008).</p> <ul style="list-style-type: none"> • When acetylated chitosan (SoftGard) is sprayed onto the leaves of plants, the chitosan triggers the plants natural defense mechanisms into thinking the plant is under attack by fungi and defends itself. If the treatment is carried out regularly and before the outbreak of fungal activity it can prevent many forms of fungal outbreaks. <ul style="list-style-type: none"> • It has also become known that chemical activators can be applied to the early leaf instead of infection and that they also give rise resistance to later leaves to pathogens. Most of these experiments have been done in the laboratory. • Addition of chitin to soil can stimulate growth of bacteria, actinomycetes and a limited number of fungal species with chitinolytic properties which may attack and destroy disease organisms. Various trials have been carried out to control plant parasitic nematodes, eg <ul style="list-style-type: none"> • An inducer of systemic resistance against root knot (<i>Meloidogune incognita</i>) on tomato. • Treatment significantly reduced <i>Pratylenchus zae</i> infection of maize. • Reduced <i>Heterodera schachtii</i> on sugar beets and <i>Globodera pallida</i> on potato tubers. • These organic amendments significantly affected soil microorganisms and soil nematode communities and improved soil structure, increased soil water retention or increased plant nutrient. Other non-identified bacteria might have also played a role such as stimulation of phytohormones, N-fixation or suppression of deleterious microorganisms (Mulawarman 2010).
Polymers Fungicides	<p>Polymers produced from plants or nanoparticles may provide methods of controlling fungal pathogens in the near future. These fungicides could result in induced resistance that is passed to the next generation on seed.</p> <ul style="list-style-type: none"> • Over the past decade the use of fungicides in grain crops has dramatically increased. • Application of polymers extracted from cereal bran reduced fungal infections in barley. Glasshouse trials looking at the biopolymers effect on black spot (<i>Ascochyta</i>) and powdery mildew in field peas is progressing (Davidson 2011).
RNA silencing	<p>There is the possibility that RNA silencing might be involved in the overall process of SAR has been raised (Spencer 2008).</p>
<div style="border: 1px solid black; padding: 5px;"> <p>Regalia® Biofungicide</p> <div style="border: 1px solid black; padding: 5px; text-align: center; margin-top: 10px;"> <p>REGALIA®</p> </div> </div>	<p>Regalia protects food and ornamental crops from both fungal and bacterial diseases.</p> <ul style="list-style-type: none"> • Regalia inhibits the development of major economic diseases, including powdery mildew, downy mildew, botrytis gray mold, bacterial leaf spot, greasy spot, target spot, brown rot, gummy stem blight, walnut blight, citrus canker, anthracnose, mummy berry, and others. • Regalia has an unique mode of action that induces systemic resistance and switches on the natural defense mechanisms of plants. • Regalia is a patented formulation of an extract from the giant knotweed plant (<i>Reynoutria sachalinensis</i>). • Plants treated with Regalia produce and accumulate elevated levels of specialized proteins and other compounds known to greatly inhibit disease development. • See also Regalia® Marrone Bio Innovations www.marronebioinnovations.com.au/

SCREENING PLANTS FOR RESISTANCE, TOLERANCE

Nuflora International	<p>The ornamental plant breeding program undertaken by NuFlora International continues to succeed. There are now over 150 varieties from 20 genera (including <i>Argyranthemum</i>, petunia, verbena and Sutura) on sale or licensed overseas and in Australia. In other ornamental work, new grevillea lines from RIRDC-sponsored breeding were licensed out for commercial production. NuFlora is one of our most successful ornamental plant breeding and research and development bodies and has had great success with both traditional ornamentals and Australian native plants.</p>
Florabank	<p>An adequate supply of native seed is of great strategic significance in the fight against salinity, erosion, vegetation decline and loss of biodiversity (page 210).</p> <ul style="list-style-type: none"> • Florabank is an initiative of the Australian Government, Greening Australia and CSIRO and is Australia's premier resource for native seed. www.florabank.org.au • Florabank recognises and shares the best available knowledge from research and practice in native species seed management and supports a professional and informed seed sector, encouraging quality and choice for buyers of native Australian seed.
Turfgrass trials One example of the many ongoing turfgrass trials	<p>Bentgrass trials from 2008-2012 in south eastern Australia demonstrated varietal differences at various locations, eg hot/humid (Sydney), warm/dry and temperate (Melbourne), hot/dry and high salinity water (Adelaide), hot/dry (Perth), also with treated effluent (Neylan 2013). The emphasis is on giving more choice and improve the selection and management of turfgrass in tropical environments:</p> <ul style="list-style-type: none"> • Cultivars well suited to tropical settings. • Cultivars that will potentially perform best in a particular function (sports, urban parkland, roadsides etc). • Products with minimal cultural requirements and substantial environmental tolerance (drought, wear, shade). • The specific maintenance needs that are important for turf producers and for end users.
Laboratory screening	<p>Different techniques can be used to screen for resistance, eg</p> <ul style="list-style-type: none"> • A rapid and reliable method for screening for resistance against Sclerotinia sclerotiorum in <i>Brassica napus</i> crops has been developed by drop-inoculating cotyledons of 32 <i>Brassica napus</i> genotypes using macerated mycelium. Significant differences were recorded between the <i>B. napus</i> genotypes. • More than one method should be used for screening fruit resistance to brown rot (<i>Monilinia</i> spp.), eg lesion area assessments on fruits can be used in combination with storage rot and / or cuticle thickness, for screening apricot resistance to brown rot disease.
National Variety Trials (NVTs)	<p>The NVT is managed by the Australian Crop Accreditation System Ltd (ACAS) under a service agreement with GRDC. The NVT provides state-based information about disease-resistance ratings for wheat, barley, triticale, oats, canola, lupins, lentils, field peas, faba beans, chickpeas www.nvonline.com.au NVT takes into account:</p> <ul style="list-style-type: none"> • Where the trials are located. • Environmental data and its relationship to yield. • Management practices that improve beneficial conditions or negate detrimental ones. • Disease resistance and frost and drought tolerance (priority traits). • Disease resistance and management practices which reflect the disease management a farmer would normally practice, eg nematodes, black leg of canola. <ul style="list-style-type: none"> • The trials are also designed to enable the comparison of varieties across different herbicide tolerance classes (glyphosate, triazine and imidazolinone) and the fungicide management trials reflect district best practice with all the trials sprayed for control of stripe rust when required. • Nutrient efficiency, water use efficiency. • Grower involvement, eg District Best Practice, quality issues. • The GRDC, supported by the Australian Centre for Necrotrophic Fungal Pathogens (ACNFP), is cloning and sequencing a gene to fight these diseases. Growers will eventually be able to choose wheat varieties resistant to several rusts, tan spot or yellow spot (<i>Triticum aestivum</i>) and septoria (<i>Stagonospora nodorum</i>), if they farm in areas prone to these diseases.

<p>Salinity tolerance Testing cereals</p> <p>Sodium Green imaging</p>	<p><u>It is known that a plant's ability to store sodium ions in a cell vacuole</u> (the largest storage compartment within a cell) is an essential part of salinity tolerance. The mechanism controlling this sequestration is known but none of the existing methods to quantify this mechanism has been suitable for screening large numbers of plants.</p> <ul style="list-style-type: none"> • Sodium Green™ dye can be loaded into the plant and measured. The resulting fluorescence is proportional to the amount of sodium stored in the vacuole and can be used to screen wheat and barley for different levels of salinity tolerance. The project will be able to advise breeders on best varieties from which to select genes for some of the specific mechanisms conferring salinity tolerance in cereals.
<p>Conductivity test for estimating resistance</p>	<p><u>Soybean seedling emergence in Fusarium-infested media</u> or cool saturated field soil was negatively correlated with conductivity in some experiments. A conductivity test could be developed to estimate soybean seed susceptibility to invasion by <i>Fusarium oxysporum</i>.</p>
<p>TREENET</p>	<p><u>The Waite Arboretum in SA is the home of TREENET</u> (Tree and Roadway Experimental and Educational Network), a not-for-profit collaborative of the nursery and arboriculture industries, state and local government, educational institutions, engineers, planners and landscape professionals. www.treenet.com.au</p> <ul style="list-style-type: none"> • The aim of TREENET is to improve Australian urban streetscapes through better selection, production, establishment and management of street trees in the urban environment – information will be freely available over the internet.
<p>ANFIC</p>	<p><u>Australian Nurseryman's Fruit Improvement Company (ANFIC)</u> is a non-profit company of Nurserymen which aims to be at the forefront in supplying new and improved varieties to enhance growers' position in the market place. www.anfic.com.au/</p> <ul style="list-style-type: none"> • ANFIC will continue to negotiate and introduce new varieties for evaluation and possible release to the orchard industry. Their work in the future could well be in disease resistant edible crops. • ANFIC evaluates new varieties from overseas (protected by overseas patent or agreement) and lists varieties and rootstocks soon to be released from quarantine, eg for cherry, nectarine, peach, pear and plum. • PlantNet® is a trading name for Horticulture Fresh Australia (HFA), a fully owned subsidiary company of ANFIC. HFA was initially established to manage some of ANFIC's exceptional fruit varieties. This role was expanded to sell unique and new fruit varieties into the retail / home garden sector. www.plantnet.com.au/
<p>Centralized Test Centres (CTCs) Plant Breeder's Rights</p>	<p><u>Under Plant Breeder's Rights (PBRs)</u>, establishments may be officially authorized by the PBR office to conduct test growing. More often than not, trials by several breeders are being conducted concurrently at different sites. This makes valid comparisons difficult and often results in costly duplication. Centralized testing is one such optional system.</p> <ul style="list-style-type: none"> • Centralized Test Centers (CTCs) are officially authorized to conduct comparative growing trials for applicants. An updated list of CTCs is published in each issue of the <i>Plant Varieties Journal</i>. • The advantage of using a CTC allows the testing a larger number of candidate varieties in a single comprehensive trial. There is an increase in scientific rigor as well as overall cost savings.
<p>China's thirst for beer</p>	<p><u>Collaboration between barley pre-breeders in Australia and China</u> is bringing benefits at many levels. Although barley has the reputation for adapting to a wider range of environments than wheat, this is not the case with Australian barley varieties.</p> <ul style="list-style-type: none"> • Australia and China are collaborating to help deliver barley varieties suited to more marginal soils and variable environments. • Since 2009 more than 2000 accessions of barley with the potential for improved tolerance to drought, salinity, acid soil or frost were sourced from worldwide collections. Lines will soon be field tested in Australia and overseas.
<p>Field testing grain varieties frost tolerance</p>	<p><u>The GRDC's gene discovery manager</u> says improvement to genotyping (the scoring of genetic traits) will allow more precise field evaluations of frost tolerance in both existing varieties and new germplasm and improve the screening applied to multiple crops and affected regions. In the past 10 years GRDC has invested approximately \$10million in frost research aimed at varietal improvement (Thyer and Penfold 2010).</p>
<p>Sunflower industry threat</p>	<p><u>Rust disease is a major constraint to sunflower production in Australia.</u></p> <ul style="list-style-type: none"> • Without resistance to this disease, the industry would fail. • The rust fungus is evolving at an alarmingly rapid rate, placing considerable pressure on the availability and durability of commercial sources of resistance. • Due to recent changes in the rust population, there are currently no rust resistant commercial sunflower hybrids available. • This situation applies equally to oats and oat rust.

Minimum disease resistance standards


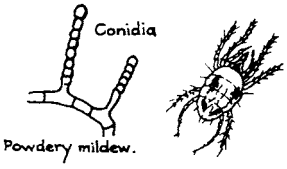


Disease ratings are readily available for many field, vegetable, fruit and ornamental crops.

<p>Minimum Disease Resistance Standards (MDRS)</p>	<p>Wheat-breeding programs around the country have agreed to abide by a set of Minimum Disease Resistance Standards (MDRS) for the release of new varieties. These standards must be supported by growers and susceptible varieties discarded as soon as possible. A set of MDRS has been developed for rust resistance in new wheat varieties in Australia (Wallmark 2006, Park et al 2010). These standards aim to reduce or delay the development of epidemics in the short term and the likelihoods of more durable resistance in the long term, eg</p> <ul style="list-style-type: none"> • To protect growers from varieties that produce large amounts of inoculum, growers should replace Susceptible (S) and Very Susceptible (V) cultivars with more resistant, well adapted cultivars. • Major diseases included in these MDRS are stripe rust, stem rust, and leaf rust and <i>Septoria</i> blotch (<i>Septoria tritici</i>). • Protect the usefulness of resistance genes by reducing the probability of new pathotypes evolving with virulences that can overcome them. • There are protocols for release of wheat breeding lines which include agronomic, disease resistance and quality standards. • Wheat Quality Australia (WQA) manages wheat variety classification, ie the assessment of new varieties to determine their inherent processing and end product quality, eg flour extraction, dough strength, extensibility, starch quality, baking performance and noodle quality. Receival standards assess grain quality attributes that are largely determined by the environment, eg protein, moisture, screenings, test weight, disease and contaminants (Mills 2011). • Minimum Disease Resistance Standards in the United Kingdom and other countries have been in use for decades and are required to have a National List of cultivars which may be marketed. Resistance to disease is a major factor in qualifying for these lists, even though fungicides are widely used. In the Australian wheat industry the use of fungicide is often not feasible so the level of resistance of the cultivars is of greater relevance. <p>Canola standards ratings. The blackleg resistance ratings of all Australian canola varieties are published by the Canola Association of Australia in February each year. To find the most up to date ratings, go to the Australian Oilseeds Federation (AOF) website</p> <p>The Australian Cotton CRC's Fuscom Committee has developed a standard protocol to describe levels of disease resistance of current commercial cotton varieties available to the Australian industry. Resistance rankings have been developed for the cotton diseases Fusarium wilt (F-rank) and Verticillium wilt (V-Rank).</p>
<p>Avoid growing susceptible varieties</p>	
<p>Vegetable disease ratings</p>	<p>Disease ratings are readily available for most vegetables, eg</p> <ul style="list-style-type: none"> • Disease resistance ratings of faba bean and broad bean varieties in southern Australia are available for <i>Ascochyta</i> blight, chocolate spot, <i>Cercospora</i> leaf spot and rust. <ul style="list-style-type: none"> • Varieties have been rated: Resistant, Moderately Resistant, Moderately Susceptible, Susceptible, and Very Susceptible. • The resistance to downy mildew of lettuce caused by <i>Bremia</i> present in many cultivars now being grown is under challenge. • Many resistant cultivars of vegetables are introduced from overseas. • Grafting can be used to unite the soilborne disease resistance and enhanced vigor of hybrid tomato cultivars with the high fruit quality of heirloom varieties. • There are now many varieties summer squash and zucchini with resistance to one or more of the diseases that affect the late-season supply (and thus price) of squash.
<p>Fruit disease ratings</p>	<p>Disease ratings are readily available for most fruit crops, eg</p> <ul style="list-style-type: none"> • Bacteria spot (<i>Xanthomonas arboricola</i> pv. <i>pruni</i>). Plum varieties have been rated: 1 (very susceptible) to 5 (less susceptible) • In WA, eight strawberry cultivars have been rated for their resistance or susceptibility to <i>Rhizoctonia</i>, <i>Cylindrocarpon destructans</i>, <i>Gnomonia fructicola</i>, <i>Phoma exigua</i>, <i>Phytophthora cactorum</i>, <i>Pythium ultimum</i>, <i>Macrophomina phaseolina</i>: S (susceptible) and R (resistant)
<p>Ornamentals disease ratings</p>	<p>Disease ratings are readily available for many ornamentals, eg</p> <ul style="list-style-type: none"> • A wide range of ornamental plants (annuals, ground cover, shrubs and small trees) have been rated for their resistance to root knot nematodes overseas, ie Resistant, Susceptible and Highly Susceptible (Texas Plant Disease Handbook). • Plant may labels include resistance traits.

BREAKDOWN OF RESISTANCE

Newly released resistant cultivars often do not remain resistant for long

Modern monocultures	<p>The gene-for-gene concept states that each gene conditioning resistance or susceptibility in the host has a corresponding gene in the disease organism controlling avirulence or virulence.</p> <ul style="list-style-type: none"> • While the 'gene-for-gene' system is thought to stabilize disease in natural plant populations, it cannot do so in monoculture crops which lack the diversity and adaptability of natural populations. • Widespread use of a cultivar of a single crop species with a single resistance gene initially gives good disease control and is therefore popular with growers, but it creates enormous selection pressure for the build-up of strains able to invade and reproduce on that cultivar. • The more popular the cultivar, the greater the selection pressure for the build-up of new virulent strains.
Boom and bust cycles	<p>The gene-for-gene concept provides a logical explanation for boom and bust cycles.</p> <ul style="list-style-type: none"> • The breakdown of disease-resistance in plants is based on 2 fundamental properties of disease organisms: <ul style="list-style-type: none"> • Their genetic variability and • High rates of reproduction. • Boom and bust cycles are most frequent with diseases which produce many generations of airborne spores during the growing season, eg rusts, powdery and downy mildews. Races virulent to (able to attack) the resistant variety become widespread. As a result varieties with single major resistance need to be replaced periodically, eg every 3, 5 to 10 years. • It is considered that virulent races that already exist at very low frequencies in pathogen populations are selected by cultivars with new resistant genes. New virulence combinations can also arise during various genetic recombinations or be introduced from other countries. • Resistance to diseases which produce only one generation in a growing season is less prone to breakdown. The inoculum produced often remains where it is formed, eg soilborne <i>Fusarium</i> wilt (<i>Fusarium oxysporum</i>). • The breeding of resistant varieties must be ongoing, so that when resistance of one variety breaks down after several years of cultivation, others should be ready to take its place in the field. <div style="text-align: center; margin-top: 20px;"> <pre> graph TD 1["1. Cultivar with new resistance RELEASED"] --> 2["2. BOOM Area sown INCREASES"] 2 --> 3["3. EPIDEMIC"] 3 --> 4["4. BUST Area sown DECREASES"] 4 --> 1 Note["New virulence detected in the pathogen population and its frequency increases"] -.-> 3 </pre> <p style="text-align: center;">Boom and bust cycles (after Brown and Ogle 1997).</p> </div>
Escape	<p>The plant possesses no genetic resistance but escapes from attack by specified diseases or pests for a variety of other reasons, including:</p> <ul style="list-style-type: none"> • The disease or pest organism, or strains of it, which can attack the host, may not be present in the locality where the host is grown. • Unfavorable environmental factors towards the disease or pest organism. • Favorable environmental factors towards the host.
Selection of virulent strains of the pathogen	<p>The planting of a certain variety or the use of certain chemicals, may lead to selection of virulent strains of the pathogen that can overcome the resistance of the variety, or are resistant to the chemicals, leading to epidemics.</p>

<p>Mutations in the host</p>	<p>Any alteration in the genetic composition of the host can alter the characteristics which make it resistant to a disease or pest. This can happen naturally or during plant breeding.</p> <ul style="list-style-type: none"> Occasionally plant breeders achieve resistance to a particular disease or pest but inadvertently breed in susceptibility to another problem. 	
<p>Mutations in the disease or pest</p>	<p>Continued production of mutants and hybrids by disease organisms, sooner or later leads to the appearance of races which can infect the previously resistant host plant.</p> <ul style="list-style-type: none"> This can happen more readily if there are only one or a few genes controlling resistance in the host plant. 	
<p>Evolving and mutating disease fungi</p>	<p>The evolution of some fungi can contribute to 10-40% of crop losses. Such fungi evolve faster and more dramatically than previously thought and includes the most damaging pathogens on all major crops in Australia (<i>Crop Loss Discovery</i>. Countryman, Perth, 30 June 2011).</p> <ul style="list-style-type: none"> It was thought that these processes occurred over millions of years but new species of pathogens have evolved in the last 100 years. These pathogens overcome the new resistance genes and fungicides in 2-5 years and evolution can occur during a growing season lasting only a few months. Important diseases in this group include: <ul style="list-style-type: none"> Stagonospora (<i>Septoria nodorum</i>) tan (or yellow) spot of wheat. Apple scab (<i>Venturia inaequalis</i>). Black sigatoka (<i>Mycosphaerella fijiensis</i>) of bananas. Canola black leg (<i>Phaeosphaeria nodorum</i>). Many endophytes or saprobes growing on woody debris, decaying leaves or dung. 	
<p>Imported disease or pest race</p>	<p>Virulent races of the disease or pest organism existing overseas may have been brought into Australia since release of a resistant variety.</p> <ul style="list-style-type: none"> Widespread cultivation of a single previously resistant variety would prove an excellent substrate for the rapid development and spread of any new race of a disease or pest, possibly causing an epidemic. Planting several resistant varieties, therefore, is much preferred to just one. 	
<p>Undetected disease or pest race</p>	<p>Undetected races of the disease which could infect the resistant variety may have existed in the area in very small populations at the time the resistant variety was released.</p>	
<p>“Rust Never Sleeps” (Nobel Laureate Wheat Disease, Dr Borlaug)</p> <p>Ug99</p> <div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p>Rust epidemics result from the combined effects of a:</p> <ul style="list-style-type: none"> Susceptible host Virulent pathogen Favorable environment </div> <p>The aim is to develop Durable Rust Resistance in Wheat (DRRW)</p>	<p>Various programs in Australia and the world are working to tackle the threat to world wheat production from stem rust strain Ug99 (the name Ug99 was derived from its initial detection in Uganda in 1999 (Park 2010). Ug99 overcomes many of the resistance genes bred into modern wheat cultivars. Some resistance genes are already in use that are effective against Ug99.</p> <ul style="list-style-type: none"> Incursions of exotic rust isolates. Over the last 90 years 11 incursions have been documented. Just how and from where these exotic rusts reached Australia is mostly unknown. There is evidence that some of the stem rust pathotypes originated from central Africa, possibly reaching Australia by wind-borne transport of the spores across the Indian Ocean. History suggests that the probability of a local mutation to virulence is much higher than an incursion of Ug99. Wheat stripe rust has evolved through a series of newly emerging pathotypes since it became established in Australia about 30 years ago. Several of these pathotypes have specifically adapted to certain varieties of wheat and triticale and some have caused significant economic losses. New variations of pathotypes are mostly derived from new mutations in the existing pathogen population and more rarely from the introduction of new pathotypes from overseas. Although pathogen population mutations can be predicted to some extent based on current knowledge, pathogen incursions from overseas which could cause crop losses are unpredictable. 	



The US has given 40 million to fight world food threat from stem rust and the Bill & Melinda Gates Foundation have announced grants worth US\$49million over 5 years to support rust researchers worldwide (2011).


MANAGING PLANT RESISTANCE

Prolonging plant resistance

Cultivars have a limited life. Have a Resistance Management Plan.

If you don't have weed control, nutrition and time-of sowing right, if you don't check seed quality and carry out soil tests, the best varieties aren't going to save you!

<p>Before release Rotate varieties</p> 	<p><u>New varieties are grown and tested for resistance against many pathogens</u> in as many locations as possible (see minimum disease standards page 161).</p> <ul style="list-style-type: none"> • <u>IPM program must be in place</u> and followed after release of the resistant variety. Management must include cultural methods, eg crop rotation, sanitation, seed treatment or fungicide application, and other appropriate treatments to reduce exposure of the variety to large pathogen populations. • <u>For slowly dispersing pathogens</u>, eg soilborne pathogens, rotation of varieties with different sources of resistance reduces pathogen populations compatible with each variety, so each variety can last longer. • <u>For large area crops</u>, eg wheat and rice, varieties could last longer against airborne pathogens, eg stem rust, if each new resistant variety is grown in one of 3 or 4 regional zones of the epidemiological region. In this way even a new race attacking a variety in one region could not attack varieties in another region because there are different sets of genes for resistance in those regions.
<p>IPM</p> <div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p>The "holy grail" of combining plant resistance through an endophyte and biocontrol</p> </div>	<p><u>Plant resistance should be used in an IPM system.</u></p> <ul style="list-style-type: none"> • Cultural control. • Sanitation • Biocontrol agents • Biosecurity • Disease-tested planting material • Physical methods • Insecticides, fungicides
<p>Do not grow susceptible varieties over a large area</p>  <p>The green bridge</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-top: 20px;"> <p>Managing rust resistance is a community exercise</p> </div>	<p><u>Rust diseases of wheat and other crops recognize no property boundaries.</u></p> <ul style="list-style-type: none"> • <u>Control of cereal rust diseases is of necessity, a community exercise.</u> <ul style="list-style-type: none"> • <u>Initially unseen</u>, it can spread very rapidly and requires a community strategy to manage. • <u>All growers need to participate</u> in minimizing the level of rust both within crops during the season and in volunteers between seasons (the green bridge). • <u>Use Best Management Practices (BMP) for farm hygiene</u> to minimize the spread of pathogens on-farm, between farm and between regions is one of the most effective measures all growers can practice. Crop volunteers and weeds which act as hosts for the pathogens must be controlled. • <u>Arguably the most sustainable way of doing this</u> is to avoid growing rust-susceptible varieties. These varieties also become rust-resistant volunteers and thus provide a double advantage in controlling rust diseases. • <u>Wheat-breeding programs</u> around the country have agreed to abide by a set of Minimum Disease Resistance Standards (MDRS) for the release of new varieties. These standards need to be supported by growers, and varieties that are susceptible must be discarded as soon as possible. These standards aim to reduce or delay the development of epidemics in the short term and the likelihoods of more durable resistance in the long term. • <u>One of the characteristics of rusts is their ability to mutate into new strains</u> which can infect previously resistant varieties. Many years of work from finding new genes to introducing them into new varieties can be lost. • <u>The supply of new genes is not limitless</u>, so unless genetic engineering technologies can provide a permanent solution in the future, there will be a limited resource. <ul style="list-style-type: none"> • <u>This resource is best maintained</u> if we can reduce the rate at which new mutant strains develop by growing resistant varieties which ensures that the number of rust spores that can mutate are kept to an absolute minimum. • <u>Growers should replace</u> Susceptible (S) and Very Susceptible (VS) cultivars with more resistant, well adapted cultivars and encourage the adoption of effective management strategies when they are grown, eg <ul style="list-style-type: none"> • To reduce yield loss to growers. • To reduce threats to resistance breakdown. • To reduce pathogen survival over summer (green bridge reduction). • <u>Everyone in the area must play a part.</u> It is a community exercise.
<p>Cereal disease guide</p>	<p><u>Annual cereal disease guides</u> are available to help growers choose resistant varieties. Strategies to control wheat diseases in SE Australia include:</p> <ul style="list-style-type: none"> • Using resistant varieties. • Rotating crops. • Green bridge management, hygiene to remove overwintering volunteers, etc. • Application of fungicides (Hemphill 2011). • Seed and / or fertilizer treatments. • Active monitoring of crops with a view to fungicide applications if required.

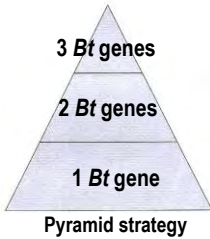
<p>Monitoring</p> <div style="border: 1px solid black; padding: 2px; display: inline-block;"> <p>1 2 3 4 5 6 7 8</p> </div>	<p>Surveillance for endemic and exotic virus diseases in Australian grain crops ensures early detection and best chance of eradication or control of spread.</p>
<p>Changes to the cropping system</p>	<p>Management changes in the cropping system may require modifications in Minimum Disease Resistance Standards (MDRS), eg</p> <ul style="list-style-type: none"> • Wheats may be sown early in the season in some areas and so favor the survival and buildup of inoculum early in the season hence a large area of winter wheats may require high MDRS. • Managing the environment, eg avoiding overhead irrigation which favors certain diseases.
<p>Industry associations</p>	<p>Growers can contact their specific industry associations for information on resistant cultivars, rootstocks and other propagation material for their particular crops. State / Territory websites may also provide such information. Genes that control pest and disease resistance have been identified in both wild and domesticated plants and are used extensively in breeding programs.</p> <ul style="list-style-type: none"> • There may also be difficulties in determining the precise level of resistance required in some crops, eg vegetables.
<p>SAR activation and IPM</p> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <p>BION Plant Activator Seed treatment</p> </div> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> <p>Always seek advice before reducing fungicide rates</p> </div>	<p>Overseas experience with acibenzolar-S-methyl (ASM) has shown that SAR activation on most crops is best used in combination with other methods of disease control, including genetic disease resistance and sound crop management that reduce disease pressure.</p> <ul style="list-style-type: none"> • Where less resistant cultivars are preferred for yield, quality, or agronomic reasons, resistance activators can stimulate the plants to better protect themselves against some pathogens. Where the level of genetic and activated resistance is not sufficient, biocontrol products (where available) or fungicides can help ensure healthy crops and quality food. • In some cases, mixtures of activators with reduced rates of appropriate fungicides have given excellent disease control, with the fungicide providing curative and short term protection and activated resistance providing long-term protection. • In other cases, activators can lower the fungicide load per season, thereby reducing the selection pressure for resistance against modern selective fungicides. Similarly, it could be shown that the use of ASM slows build-up of new races of bacterial pathogens that overcome the genetic resistance of cultivars.
<p>Herbicide resistant crops from biotechnology</p> <p>HRCB</p> <p>Check current guidelines</p>	<p>Weeds may develop resistance to the herbicides used on herbicide resistant crops. There are Guidelines for resistance-management for RoundupReady cropping systems, eg</p> <ul style="list-style-type: none"> • Growers not to make more than 2 applications of a glyphosate-based herbicide in a field during any 2 year period, • Rotate its use with herbicides having a different mode of action, • Growers should not plant RoundupReady crops in back-to-back years. • Growers should avoid tank-mixing.
<p>Blackleg of canola - risk</p> <p>rotate crops, rotate varieties of the same crop, rotate pesticides</p>  <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> <p>How are you going to fight black leg?</p> </div> <p>Lower Eyre Agricultural Development Association (LEADA) is an information gateway.</p>	<p>Blackleg (<i>Leptosphaeria maculans</i>) of canola severity varies depending on regional climate and intensity of canola production. Blackleg is favored by warm damp weather during flowering. By developing a rating system for risk factors the aim is to provide growers with the ability to quantify disease risk and to establish how this risk can be modified by changes in management. Blackleg is influenced by:</p> <ul style="list-style-type: none"> • Annual rainfall and how much of this falls in autumn (warm and damp during flowering). • Time of sowing (cultural). • The proportion of the farm sown to canola. • Variety resistance ratings. • The distance from canola stubble of a different or the same variety. • The use of fungicide on the seed or fertilizer. • How many years a variety has been sown on the farm. Each risk factor can be rated. <p>Currently blackleg recommendations to reduce risk focus on:</p> <ul style="list-style-type: none"> • Prevention (check potential risks) <ul style="list-style-type: none"> • Avoiding canola stubble, avoid planting beside last year's canola paddocks. • Destroy canola residues as soon after harvest as possible by raking/harrowing or burning. • Planting canola varieties with high level of genetic resistance. Choose varieties carefully. In high disease risk situations where a crop has to be planted beside previous year's stubble, plant varieties with the highest blackleg rating possible. Infection is increasing in some canola varieties. • Rotate canola varieties to avoid resistance. • Rotate crops. • Using seed dressing or fungicide-amended fertilizer. • Curative <ul style="list-style-type: none"> • Consider using fungicides where blackleg may cause significant yield losses. • Rotate fungicide modes of action to avoid resistance.

Multi-gene resistance
Super-rust resistant wheat

Plant breeders that are also working to provide multi-gene resistance that is capable of providing protection even when a disease mutates. Each year wheat diseases cause severe yield losses and reduce grain quality.

- **Rust** is the major disease of cereal crops in Australia and worldwide. "Avirulence" genes in flax rust have been identified that alert the plant to the rust's presence and trigger the plants's defenses. **DNA markers for 6 stem rust resistance genes** have been identified to help breed varieties with more robust resistance by adding **multiple resistance genes** to help breed super-rust resistant wheat.

Pyramid strategy
GM Cotton – Helicoverpa resistance



Refuge crops

When resistance has occurred, in all 3 cases researchers found there had been failures in using resistance management strategies

To thwart further evolution of pest resistance to **Bt crops**, growers have shifted to the "pyramid" strategy – each plant produces **two or more toxins** that kill the same pest.

Where insect-resistant **GM crops** are grown, insect resistant management strategies are employed to ensure the longevity of the products, eg

- **Plants need to produce enough Bt protein to kill pests** with low levels of resistance.
 - **Although Bt crops have helped to reduce insecticide sprays**, boost crop yields and increase profits, their benefits will be short-lived if pests adapt rapidly.
 - Several pests have already become resistant to plants that produce a single **Bt** toxin.
 - **To thwart further evolution of pest resistance to Bt crops**, growers have shifted to the "pyramid" strategy – each plant produces **two or more toxins** that kill the same pest. The one-toxin **Bt crops** are being **replaced** by the two-toxin **Bt cotton**. Cotton varieties with the Bollgard 11 genes (containing two insecticidal proteins to control *Helicoverpa*) has dramatically reduced the need to spray for *Helicoverpa* and other Lepidopteran pests.
 - **The pyramid strategy assumes that the crops provide redundant killing**. Plants producing two toxins that act in different ways to kill the same pest. So, if an individual pest has resistance to one toxin, the other toxin will kill it.
- **Refuge non-GM crops must be planted as a percentage of Bt crops** in order for the insects to develop without selection to the insect resistant varieties. This must be carried out in line with post-approval monitoring, where **GM crops** and their immediate environment, will be constantly evaluated for changes even after the crop has been released.
 - **These refuges are planted with conventional cultivars** (unaltered seed) so that pests living there can mate with resistant pests from the **Bt** fields diluting the pool of resistant gene. Insect-resistance management strategies are developed by **APVMA** in consultation with researchers and industry. www.gmo-safety www.grdc.com.au. Non-GM crop must **not** be treated with any pesticide.
 - **Problems with regulating the area and diversity of 'refuge' areas** containing mixed GM and unaltered crops.
- **Basic principles of IPM and Best Practice Management** must be followed. GM crops and GMO pest control agents should be integrated with other currently available control measures to reduce problems below economic injury. GM crops could lose their effectiveness unless farmers also use other proven weed and insect management practices such as herbicide rotations in the case of herbicide-tolerant crops.

Stacked genes
Multiple traits
SmartStax™ corn -

- Herbicide resistance **1**
 - Herbicide resistance **2**
 - Insect resistance **1**
 - Insect resistance **2**
 - Insect resistance **3**
 - Insect resistance **4**
 - Insect resistance **5**
 - Insect resistance **6**
- Stacked genes

If more than one gene from another organism has been transferred, the created GMO has **stacked genes** (or stacked traits). Gene stacked events are important in plant breeding.

Crops with stacked genes have multiple, synthetic genetic traits, eg

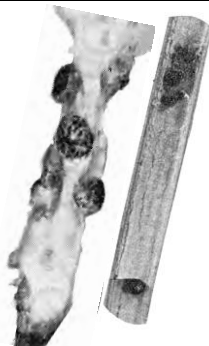
- **In North America farmers will be growing SmartStax™ corn** which will have **8 stacked traits** – two for herbicide tolerance and six for above and below ground **Bt** insect resistance.
- **Multi-stacked genes in cotton**, eg **Bt transgenic cotton** (INGARD™ cotton) with enhanced tolerance to **waterlogging**. Incorporation of the genes for the toxic substance in the bacterial insecticide, Dipel® (*Bacillus thuringiensis*) into plants, removes the need for spraying the surfaces of leaves with Dipel® to control leaf-eating caterpillars.
- **NemGenix a biotechnology company in WA's State Agricultural Biotechnology Centre (SABC)** primary focus is on developing genetic resistance to nematodes, eg root lesion nematodes and cyst nematodes in wheat.
- **Evogene, in partnerships with various companies**, develop plants with advantageous key traits, leading to sustainable agricultural production. <http://evogene.com>
 - **Improved yield** (allows better use of arable land).
 - **Abiotic stress tolerance**, eg drought, soil salinity and heat stress, resulting in increased yield and enables the use of semi-arable lands for agricultural production.
 - **Improved nitrogen use efficiency (NUE)** results in higher yields by enhancing the plant's utilization of N fertilizer, which reduces costs and land and water pollution.
 - **Biotic stress tolerance** reduces costs due to reduced use of pesticides as well as soil and water pollution.

Difficulties, The Tough Nuts

There are many examples of pests and diseases, both parasitic and abiotic (frost, drought) which are difficult to control. Climate change, market requirements, breakdown of resistance, etc mean that there is constant pressure to breed new lines to overcome the “tough nuts” of plant protection. Sometimes it is just not possible.

Narrow gene base <i>Genetic of disaster</i>	<p><u>The number of plant species used for crops has decreased</u>, so too has the genetic diversity within species. In one state in the US all the soybean cultivars were derived from about 6 introduced accessions.</p> <ul style="list-style-type: none"> • This narrow gene base has been described as the genetics of disaster. • The widespread use of particular cultivars as sources of resistance has often led to unwanted side effects, eg breakdown of resistance and previously unimportant pests suddenly becoming serious following the introduction of new cultivars.
Nematodes and vineyard soils	<p><u>The best vineyard soil, in terms of nematodes</u>, is one that testing shows is free of these pests. However this cannot always be the case.</p> <ul style="list-style-type: none"> • If testing shows nematodes are already present in the soil, or if there is potential for their establishment in the future (nematodes can be spread on grapevine planting material from region to region) resistant rootstocks can be used to help protect vines from some species of nematodes, particularly root knot nematode (see also page 314). • Avoid rootstocks which have a low tolerance to these nematodes. • When considering rootstocks the characteristics imparted to grafted vines by each rootstock variety should also be taken into account as the viticulture impacts may not be desirable for a given vineyard situation. For example, Ramsey has some resistance to nematodes and often imparts high vigor to vines, which could be undesirable or require additional management on high vigor sites. • Nematodes and need for IPM. There are many more published reports of resistance than of successful use of resistant cultivars for management of nematode populations (Cook 2004). It is considered that genetic resistance should be integrated with some other mechanisms that control nematodes in nature, eg <ul style="list-style-type: none"> • Using practices to encourage the development of suppressive soils (page 120). • Using rotations and gene mixtures to reduce exposure to resistance genes.
Soil borne fungal diseases <i>Difficult to control</i>	<p><u>Traditional breeding and genetic engineering</u> of crop plants with enhanced disease resistance has offered considerable promise but with varying degrees of success for some soilborne fungal diseases (Dickman 2006). Host resistance is often inadequate.</p> <ul style="list-style-type: none"> • <u>While the technology for gene manipulation</u> in virtually any crop plant has been available for several years, field success has not always followed. • <u>Sclerotinia rot</u> (<i>Sclerotinia sclerotiorum</i>) which has an extremely broad host range is an economically important necrotrophic fungal plant pathogen of economically important plants worldwide, causes considerable plant damage. <ul style="list-style-type: none"> • Sclerotinia has proven difficult to control (a new fungicide offers some hope). • Host resistance to this fungus has been inadequate. • The pathogenic success of this fungus is primarily due to its ability to form sclerotia (overwintering structure capable of surviving years in the soil). Sclerotia are an attractive target for intervention (Fig. 18 below). • <u>Rhizoctonia stem rot</u> (<i>Rhizoctonia solani</i>) has been described as “intractable” but researchers continue with novel strategies that are increasing resistance. • <u>Wheat crown rot</u> (<i>Fusarium</i> sp.) which is a chronic problem throughout the Australian wheat belt costs the industry about \$78 million a year in yield losses (Hemphill 2011). CSIRO in Brisbane is screening over 2400 wheat lines and 1000 barley lines from around the world to find the ones resistant the fungal disease. • <u>Disease suppressive soils</u> are described on page 120.

Aphanomyces
Chalara
Cylindrocladium
Fusarium
Macrophomina
Pythium
Gaeumannomyces
Phytophthora
Rhizoctonia
Sclerotinia
Sclerotium
Verticillium



Sclerotinia sclerotiorum. Sclerotia on carrots roots and inside sunflowers stems.



Sclerotium rolfsii on French bean. Photo©NSW Dept of Industry and Investment.




Phytophthora root rot on a 2-year old rough lemon. Photo©NSW Dept of Industry and Investment.



Rhizoctonia solani on French bean. Photo©NSW Dept of Industry and Investment.

Fig. 18. Some soil borne diseases. Few soilborne diseases have distinctive symptoms. Even those with distinctive symptoms may have many strains.

Age of the plant species	The age of the plant species can also play a role as certain species change their levels of disease resistance as they mature, a process known as ontogenic resistance .
Biodiversity	The Biodiversity Conservation Centre (BCC) at Kings Park and Botanic Garden in WA has a huge species base of floriferous, drought tolerant plants to explore for this market.
Carrot and celery viruses	<p>Conventional breeding for virus resistance with carrot and celery is difficult as sources of resistance are not known, ie for Celery Mosaic Virus (CeMV), Carrot Virus Y (CarVY).</p> <ul style="list-style-type: none"> • Celery growers will have to either grow tolerant varieties or instigate a break in production, whereas carrots suffer a reduction in yield which is cultivar dependent. • An alternative is to use gene technology which has been proven to be effective for introducing virus resistance into a range of species. • Genetic modification of carrot and celery can enhance virus resistance.
Resistance to insecticides	<p>Redlegged earth mite (RLEM) populations are resistant to two widely used pyrethroids chemicals.</p> <ul style="list-style-type: none"> • Bindoon and Rosabrook subclover varieties have been developed with increased seedling resistance to RLEM, offering an additional and more cost-effective strategy for reducing RLEM losses. • Use current IPM strategies, eg <ul style="list-style-type: none"> • The use of resistant subclover cultivars is recommended to reduce RLEM damage, • Plant certified seed. • Insecticides should still be considered at sowing to guarantee successful pasture establishment and at time of high RLEM densities. • A mite (<i>Anystis wallacei</i>) introduced from France preys on RLEM (page 111).
Need for novel strategies	Novel strategies are needed for creating crops with broad spectrum and durable resistance to various pests and diseases, particularly in view of climate change affecting both the crop and the pest or disease (Wolpert et al 2010).
People error	<p>Mistakes happen unfortunately and can cost dollars. Examples include</p> <ul style="list-style-type: none"> • Varieties with an incorrect label when sold. Mislabeling of deciduous nursery stock of stone fruit, both for production and ornamentals purposes occurs. • Rust resistant lines of wheat contaminated with susceptible varieties due to growers saving their own seed.
<p>Arabidopsis</p>  <p>Arabidopsis Photo©TAIR www.arabidopsis.org</p>	<p>Traditional breeding has been very successful in many cases but not so in other cases. GM crop plants with enhanced disease resistance have offered considerable promise with varying degrees of success (Dickman 2007).</p> <ul style="list-style-type: none"> • Arabidopsis thaliana, or mouse-ear cress, is small herbaceous annual flowering plants in the Brassicaceae, which also includes cabbage and broccoli, cauliflower, canola and mustard. • Arabidopsis thaliana is most widely used as a model organism in many aspects of plant biology, including plant pathology and plant stress physiology with many insights directly applicable to crop plants. • The genome of Arabidopsis has been sequenced, microarray chips are available, and a multitude of well characterized mutants, also reverse genetics will continue as a powerful tool to examine gene function in <i>Arabidopsis</i>.
<p>Brassicacae</p> <p>Genetic modification</p> <p>Clubroot Diamondback moth Shelf life</p>	<p>The fungal disease clubroot and the diamondback moth are both major problems worldwide with vegetable brassicas, resulting in reduced yield and produce quality.</p> <ul style="list-style-type: none"> • Management systems for both problems are being developed to reduce reliance on chemical control. • For crops such as broccoli, improved shelf life is also a desirable attribute. • Breeding for these traits is difficult as known sources of resistance are either not available or difficult to incorporate into cultivated lines using sexual hybridization. • A number of antimicrobial genes which might be effective against clubroot have been transferred to broccoli and cauliflower; a gene which might be effective against diamondback moth, has been transferred to cauliflower. A gene which could increase shelf-life by delaying senescence has been transferred to broccoli and Pak Choi (Chinese cabbage). All are still being assessed.
Phylloxera-resistant vine rootstock	<p>Select cultivars on the basis of their resistance to pests and diseases, eg in areas where phylloxera occurs the growing of grape varieties on resistant rootstock is compulsory.</p> <ul style="list-style-type: none"> • Remember phylloxera can live on the roots of resistant rootstocks. The resistant rootstock does not die as a result of phylloxera feeding but can serve as a source of inoculum for infesting nearby vineyards. This can be important especially if planting near established European self-rooted vineyards blocks.

PROS, CONS AND CHALLENGES

PROS

- It is compatible with other methods of control.
- Resistant, tolerant varieties can be the safest, least expensive and one of the most effective means of controlling some pests and diseases. It benefits the entire cropping industry, delaying the start of epidemics.
- Resistant varieties assist in reducing the need for insecticides and fungicides. GM *Bt* resistant crops reduce the need for insecticides.
- Herbicide-resistant crops reduce use of more hazardous herbicides but may increase use of low toxicity herbicides.
- Resistant varieties play a valuable role in IPM, eg even partial resistance may allow chemical sprays to be used less frequently or in smaller quantities. Natural or biological controls, which are normally inadequate, may be effective.
- Genetic engineering of crop plants has speeded up production of varieties tolerant to frost, etc.
- For certain problems, resistant plant varieties may be the only possible and / or practical way of obtaining control, eg public places, cereal rusts.
- Plants may have multiple resistance, eg tomato varieties which are resistant to *Fusarium* and *Verticillium* wilts and root knot nematodes.
- Usually there is no direct cost to the user, though this does not apply to GM resistant crops.
- Reduces maintenance time and therefore cost.
- Pre-emptive breeding of resistant varieties to counteract the arrival of an exotic pest or disease into Australia.
- More than 85% of the total agricultural acreage in the USA is planted with varieties resistant to one or more diseases.
- Current estimates suggest that at least 10% of animal species and > 20% plants hybridize in nature.

CONS

- Some breeding programs are costly, eg maintaining stem rust resistance in wheat cultivars. Some are also lengthy especially for woody plants. It can be eight or nine years before a plant starts to be sold in large numbers.
- Breeding varieties against some diseases has not been very successful, eg soilborne pathogens.
- Resistance may 'breakdown'. New resistant varieties of some plant species can sometimes be expected to be useful only for a limited number of years and so selective breeding for resistance must be on-going.
- Selecting for resistance to a single disease or pest may be linked to susceptibility to a different disease or pest organism.
- Resistance genes are sometimes linked to undesirable characters, eg plant may produce toxins, or only be resistant at certain temperatures.

- There may be a lack of financial incentive, eg a rose variety resistant to black spot may still have to be sprayed for other problems, so the new variety may reduce the spray bill for pesticides, but not the cost of labor to apply them.
- The grower has to be convinced that the new variety is better, or as good as, the older susceptible variety with respect to flowering, fruiting, yield, consumer attractiveness, etc.
- Difficulty in finding out the degree of resistance of many new cultivars being marketed.
- Some timber species are naturally resistant to termites - this should not be relied to protect a home from termite attack.
- Expensive GM seed may have to be repurchased each year.

SOME CHALLENGES

- **Plant genetics and products protected** by intellectual property agreements to overseas amenity markets are distributed overseas, especially in Europe and the USA. Global demand for novel products and the desire for drought tolerant plants have given impetus to this newer wave of breeding (Moody 2009).
- **Only a small number of Australian companies** have achieved major international sales of either native or exotic plants (Centre for Native Floriculture, Qld).
- There must be more emphasis **on growing the crop**.
- **Ensuring that a resistance management program** will be followed after the new resistant variety is released.
- **Educate the public** about the benefits of GM crops for reducing insecticide use, adapting to climate change and using crops with stacked genes and multi-trait resistance or tolerance.
- **The Tough Nuts** which cause considerable damage worldwide to economically important plants and are difficult to control culturally or chemically.
- **To develop crop varieties with tolerance to drought**, frost and heat stress to compensate for the negative effects of climate change and allow growers to produce higher yields by making **more effective use** of irrigation water and nutrients.
- **The next green revolution** must consider sustainability not just productivity.
- **The major need to reduce dependence** on synthetic insecticides.
- **Find multi-gene resistance** that is capable of providing protection even when a disease mutates.
- **Better ways to measure** disease and pest resistance in plants and identify disease resistance genes.
- **More knowledge about the interactions** between the types of resistance and plant nutrition, habitat management, chemical ecology, natural enemies, soil health, micro-organisms such as entophytic fungi and Wolbachia, etc.
- The need to assess plant traits **under field conditions**.

REVIEW QUESTIONS AND ACTIVITIES

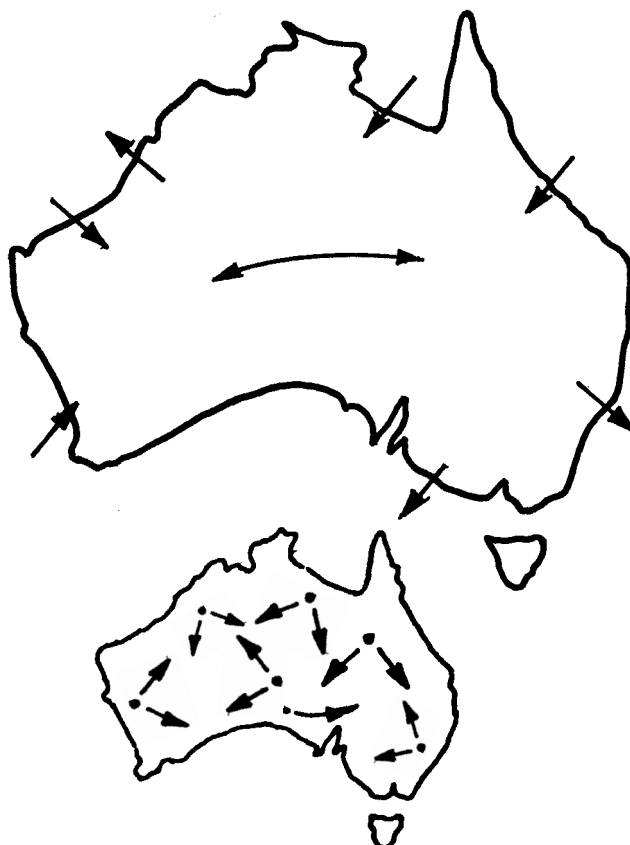
1. Name the group of **fungal diseases** that figure prominently in the development of resistant varieties.
2. Describe at least 4 ways by which a plant can **achieve resistance** to insect pests and fungal disease.
3. Describe how **genetic engineering** can contribute to the development of resistant varieties. Give 2 examples.
4. Describe ways by which resistance may '**breakdown**'.
5. **Describe how to prolong the resistance** of an existing cultivar.
6. Describe how resistant varieties can be used in **plant management, IPM** and **organic standards** programs.
7. Name plant varieties or species which have **some resistance** to:

Phytophthora root rot	Frost
Powdery mildew	Drought
Black spot (rose)	Your choice
Rust (geranium)	Your choice
8. List the **advantages and disadvantages** associated with using resistant varieties as a method of control.
9. Perform **practical exercises** in disease and pest control using resistant, tolerant varieties in an **IPM** program.

SELECTED RESOURCES

- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- Australian Centre for Necrotrophic Fungal Pathogens (ACNFP), Curtin University, Perth, WA. www.acnfp.curtin.edu.au/
- Australian Plant Study Group. The *Grow What* Series. Lothian Books, Port Melbourne.
- Babikova, Z., Gilbert, L., Bruce, T. J. A., Birkett, M., Caulfield, J. C., Woodcock, C., Piclett, J. A. and Johnson, D. 2013. *Underground Signals carried through Common Mycelial Networks warn Neighbouring Plants of Aphid Attack*. Article first published online: 9 MAY 2013 © 2013 John Wiley & Sons Ltd/CNRS Ecology Letters
- Ballantyne, B. and Gammie, R. L. 1995. *Minimum Disease Resistance Standards in New South Wales*. Aust. Plant Path. Vol 24 (1-8).
- Biosecurity 2011. *Local Varieties Destined for International Seed Vault*. Autumn.
- Braidotti, G. 2010. *Redesigning Wheat Roots to be Driven Deeper to Tap Late Season Water*. Ground Cover. Jul-Aug.
- Brown, J. F. and Ogle, H. J. (eds). 1997. *Plant Pathogens and Plant Diseases*. Rockvale Pubs., Armidale, NSW.
- Caradus, G. and Hume, D. 2011. "Phyting" the Good Fight. GRDC. July-Aug.
- Clare, R. 1997. *How Insects Storm Privet Defences*. New Scientist, 26 April.
- Cloyd, R. A. 2004. *Allelochemicals – Natural Instincts*. American Nurseryman July 15.
- Cook, R. 2004. *Genetic Resistance to Nematodes: Where is it Useful?* Aust. Plant Path. 33(2) 139-150.
- Cottee, J. 2004. *Plant Selection for Drought Tolerance*. CIT Canberra.
- Davidson, J. 2011. *Novel Fungicides on Trial*. Ground Cover Jul-Aug.
- Daw, B. D., Zhand, L. H. and Wang, Z. Z. 2008. *Salicylic Acid enhances Antifungal Resistance to Magnaporthe grisea in Rice Plants*. Aust. Plant Path. 37, 637-644.
- Dickman, M. 2007. *Approaches for Improving Crop Resistance to Soilborne Fungal Diseases through Biotechnology using Sclerotinia sclerotiorum as a Case Study*. Aust. Plant Path. 36(2) 116-123.
- Floyd, R. B. and Foley, W. J. 2001. *Identifying Pest Resistant Eucalypts using Near-infrared Spectroscopy*. RIRDC, Canberra.
- Gururani, M. A., Venkatesh, J., Upadhyaya, C. P., Nookaraju, A., Pandey, S. K. and Park, S. W. 2012. *Plant Disease Resistance Genes: Current Status and Future Directions*. Elsevier.
- Hemphill, D. *Push for Spray Use in Trials*. Weekly Times. 23/2/2011.
- Hubbes, M. 2004. *Induced Resistance for the Control of Dutch Elm Disease*. Invest Agrar: Sist Recur For (2004) 13 (1), 185-196.
- Iqbal, Z., Singh, Z., Khangura, R. and Ahmad, S. 2012. *Management of Citrus Blue and Green Moulds through Application of Organic Elicitors*. Aust. Plant Path. 41 (1): 69-77.
- International Conf. France, 2011. *Impact of Plant and Canopy Architecture on Disease Epidemiology and Pest Development*. French National Institute for Agricultural Research (INRA), Rennes, France.
- Johnson, P. 2011. *Waterwise Gardens Struggle*. Aust. Hort. March.
- Johnson, P. 2011. *Aussie Plants prove Adaptable Additions*. Aust. Hort. April.
- Jones, J. B., Momo, M. T., Obradovic, A., Balogh, B. and Olson S. M. 2005. *Bacterial Spot Management on Tomatoes*. ISHS Acta Horticulture 695: International Symposium on Tomato Diseases.
- Jung, C. S., Martinez-Medina, A., Lopez-Raez, J. A. and Pozo, M. J. 2002. *Mycorrhiza-Induced Resistance and Priming of Plant Defenses*. Jn. of Chemical Ecology June, Volume 38 (6) 651-664.
- Lee, N. 2011. *Wheat May become its own Weeds Defence*. Ground Cover. Sep-Oct.
- Linsell, K. 2011. *Characterization of Resistance to Pratylenchus thornei in Wheat*. Australasian Nem. Newsletter Vol22.No2, July.
- Lovelock, D., Donald, C. E., Conlan, X. A. and Cahill, D. M. 2013. *Salicylic acid Suppression of Clubroot in Broccoli (Brassicae oleracea var. italica) caused by the Obligate Biotroph Plasmodiophora brassicae*. Aust. Plant Path. 42:141-153.
- Marcroft, S. 2010. *Paddock-based Risk Assessment for Blackleg on Canola*. Ground Cover Sup. Mar-Apr.
- Mills, C. 2011. *Wheat Quality Changes Explained*. Ground Cover. Nov-Dec.
- Moody, H. 2009. *Ornamental Plant Breeding in Australia*. Nursery Papers April 2009 (3).
- Mulawarman. 2010. *Use of Natural Products based on Renewable Raw Material to Stimulate Soil Health and Control Meloidogyne incognita*. Aust. Nem. Newsletter Vol 21.No.1 Jan 2010.
- Neylan, J. 2013. *Bentgrass Trial Holes Out*. Australian Turfgrass Management. Vol 15. Jul-Aug.
- Nickson, D. 2011. *Turfgrass Flood Tolerance Tested*. Sportsturf. Mar-April.
- Norwood, C. 2012. *Legume Nitrogen Fixing may be Clue to Drought Tolerance*. Ground Cover. Jan-Feb.
- Norwood, C. 2012. *Genetic Maps to Fast-Track breeding for a Drier Climate*. Ground Cover. Jan-Feb.
- Papadakis, M. 2011. *Seeds for the Future*. Sunday Herald. 16/1/2011.
- Park, R. 2010. *Ug99 Closer but Defences Building*. Ground Cover. Sept-Oct.
- Park, R., Wellings, C. and Bariana, H. 2010. *Minimum Disease Resistance Standards (MRDS) for Cultivar Response to Rusts*. Ground Cover. Nov-Dec.
- Roossinck, M. J. 2013. *Plant Virus Ecology*. PLoS Pathog 9(5).
- Shabala, S. 2011. *What Goes Around Comes Around*. Ground Cover. July-Aug. (salinity).
- Shaw, K. 2013. *Myrtle Rust Research Update*. HMA News Sept.
- Smith, A. H., Pinkard, E. A., Hunter G. C., Wingfield, M. J. and Mohamed, C. L. 2006. *Anatomical Variation and Defence Responses of Juvenile Eucalyptus nitens Leaves to Mycosphaerella Leaf Disease*. Aust. Plant Path. 35(6) 725-731.
- Snapp, S. S. and Shennan, C. 1994. *Salinity Effects on Root Growth and Senescence in Tomato and the Consequences for Severity of Phytophthora root rot Infections*. Jn. for the Amer. Soc. of Hort. Science, 119(3):458-463.
- Spencer, J. 2008. *Modes of Action of Plant Protection Chemistries Part 3*. Golf and Sports Turf Australia. Sept-Oct.
- Tivoli, B., Andrivon, D., Baranger, A., Calonnet, A. and Jeger, M. 2013. *Foreword: Plant and Canopy Architecture Impact on Disease Epidemiology and Pest Development*. Eur. J. Plant Pathol. 135:453-454. Avail online.
- Thyer, R. 2009. *Global Support for Nematode Resistance*. Ground Cover. Nov-Dec.
- Thyer, R and Penfold, K. 2010. *Field-testing Stepped up in the Search for Frost Protection*. Ground Cover. Mar-April.
- Wallwork, H. 2006. *The Role of Minimum Disease Resistance Standards for the Control of Cereal Diseases*. SARDI, SA. Australian Journal of Agricultural Research 58(6) 588-592.
- Wang, F., Zhang, P., Qiang, S., Zhu, Y and Xu, L. 2008. *Effects of Epicuticular wax from Digitaria sanguinalis and Festuca on infection by Curvularia eragrostidis*. Aust. Plant Path. 37(1) 43-52.
- Wolpert, T., Shiraishi, T., Collimer, A., Akimitsu, K and Glazebrook, J. 2010. *Genome-Enabled Analysis of Plant-Pathogen Interactions*. APS Press.

BIOSECURITY



INTRODUCTION	172
Shared responsibility	174
Legislation and trade	176
BIOSECURITY – COMMONWEALTH	177
Offshore Activities	178
Getting import approval	179
Import risk analysis and trade	179
Border Activities	182
Onshore Activities	186
PLANTPLAN	186
Training	188
Diagnostic networks and resources	189
Surveillance and monitoring	190
Emergency response	192
Exports, trade and surveillance	194
High Priority Pests in Australia	195
BIOSECURITY – STATE, TERRITORY, REGIONAL	196
Quarantine Domestic	196
Individual States and Territories	198
BIOSECURITY – ON-FARM, ORCHARD, NURSERY	200
Entry and exit – Traceback and spread	200
Biosecurity Reminders, Tips and Examples	201
PROS, CONS AND CHALLENGES	203
REVIEW QUESTIONS AND ACTIVITIES	204
SELECTED RESOURCES	204

INTRODUCTION

Biosecurity is more than just preventing incursions of exotic pests, diseases and weeds. It is about ***maintaining market access, protecting the natural environment and securing the future of Australia's industries***. This makes biosecurity an essential part of every agricultural, horticultural and forestry business. Industry, government and the community must work together to maintain and improve the country's national plant health system.

What is Biosecurity?

- Biosecurity is the protection*** of the economy, environment and human health from the negative impacts associated with entry, establishment or spread of exotic pests (including weeds) and diseases (Beale et al 2008).
- ***Emerging biosecurity risks factors***, eg increase in the international movement of people and goods, intensification of agriculture, climate change including increasing numbers of viable natural pathways for exotic pests and diseases to enter Australia, have emphasized the need for effective and relevant biosecurity.
 - ***Risk management***. Biosecurity has become considerably more complex and there has been a shift from zero risk to managed risk.
 - ***Adopting a multi-layered biosecurity system*** means that detecting an exotic pest or disease within Australia need not be a failure of the system if it is detected quickly and dealt with at low cost.
 - ***It includes trying to prevent new pests, diseases and weeds*** from entering our country and becoming established. Preventing pest and disease incursions in the first place remains a national priority.
 - ***Managing established pests, diseases and weeds of national significance***, to eradicate them wherever feasible or lessen their impact with appropriate preparedness, a response capacity that is internationally recognized and that meets our trading partners' obligations and international treaties.
 - ***Shared responsibility*** and understanding between the governments (Australian / States / Territories), business and the community at large, of their respective roles and responsibilities, is essential (pages 174, 175).

Australian Government

www.agriculture.gov.au/
(under construction,
previously www.daff.gov.au/)

- The Australian Government, acting through the Department of Agriculture (DA)***, safeguards Australia's plant health status for the purpose of maintaining overseas markets and protecting the economy and environment from the impact of exotic pests, diseases and weeds. It does this through risk assessment, inspection and certification, and implementing emergency response arrangements for the Australian agricultural and horticultural industries. Activities and programs include:
- ***Risk assessment and policy advice***
 - ***Undertakes scientific-based assessment risk assessments*** and provides quarantine policy advice to protect Australia's plant (an animal) health status and natural environment
 - ***It provides*** scientific and technical advice and support to help Australia maintain and gain entry to international markets.
 - ***Specialists are active*** in the development of international biosecurity standards and help develop biosecurity expertise in our region.
 - ***International framework*** – As a World Trade Organization (WTO) member, Australia is obliged under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) to consider all import requests from other countries concerning agricultural products, just as other member countries are obliged to consider our requests.
 - ***Decisions to permit or reject an import application*** can be made only on sound scientific grounds. The Australian Government also works with international agencies that set standards for plant health, eg the International Plant Protection Convention (IPPC).
 - ***Inspection and certification***
 - ***Manages biosecurity controls*** at our borders to minimize the risk of exotic pests, diseases and weeds entering the country and provides export controls and assistance regarding exporting goods from Australia (formerly performed by AQIS).
 - ***Provides import and export inspections*** and certification to retain Australia's favourable plant and animal and human status and access to export markets.
 - ***Travel information***, international mail to Australia, exporting from Australia.
 - ***What can I bring into Australia?*** What Can't I bring into Australia?
 - ***Quick links to other information***, eg compliments and complaints, import conditions, Manual of importing Country Requirements (MiCOR Plants), Import Conditions (ICON) and Export Documentation (EXDOC).
 - ***Emergency management***
 - Implementation of emergency response arrangement for Australian agricultural and horticultural industries.
 - ***Reform and capability building***
 - Inspection based on risk assessments.
 - Working with other governments.
 - Early warning and preparedness through enhanced surveillance and diagnostic capacity and capability.

**Plant Health
Australia
(PHA)**



A snapshot of Australia's plant health status

PHA is the national coordinator of the government / industry partnership for plant biosecurity in Australia www.planthealthaustralia.com.au/. Its members include representatives from:

- **Industry**, eg Apple & Pear Australia, Avocado, Banana, Cherries, Citrus, Cotton, Grains, Honey Bees, Mango, Nursery & Garden, Nuts, Onion, Olive, Pineapple, Plantation Timber, Potato, Rice, Strawberry, Summer fruit, Sugar, Tropical, Vegetables, Viticulture.
- **Governments**, eg Commonwealth, State and Territory governments.
- **Associate members**, eg Australasian Plant Pathology Society, Plant Biosecurity CRC, CSIRO, Cotton Research and Development Corporation, Grains Research and Development Corporation (GRDC), Horticulture Australia Ltd (HAL).

PHA, in collaboration with members and associate members, minimizes impacts of plant pests on industry and the environment and assists trade of Australia's produce through:

- The development of national strategies, eg National Fruit Fly strategy.
- Identifying priority plant diseases, pests and weeds threatening plant industries.
- Enhancing preparedness, response capability and capacity for plant pest incursions.
- Contributing to management approaches for endemic pests, diseases and weeds and contaminants of national concern.
- Negotiating management and funding of agreed national projects.
- Advising government and industry on plant health priorities, resources.
- Promoting biosecurity awareness.
- The Annual Report is available online.

The National Plant Biosecurity Status Report (NPBSR) is published by PHA which is a snapshot of Australia's plant health status. The NPBSR lists **High Priority Pests (HPPs)** that are exotic or are of significant biosecurity concern to Australia.



A FEW DEFINITIONS

Pest. Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products - covers all insects, mites, snails, nematodes, pathogens (diseases) and weeds that are injurious to plants or plant products or bees.

Exotic pests are those pests, diseases and weeds which are not native to a particular country, ecosystem or eco-area (applied to organisms intentionally or accidentally introduced as a result of human activities).

Endemic pests are those pests, diseases and weeds which are established in a particular country.

High Priority Pests (HPPs) or key pests are the most significant and important pest threats to a **particular industry**. They are identified in **Industry Biosecurity Plans** (page 187).

Emergency Plant Pest s(EPPs) are defined in Australia's **Emergency Plant Pest Response Deed (EPPRD)** as a pest that meets one or more of the following criteria:

- **Known exotic plant pest**, the economic consequences of an incident of which would be economically or otherwise harmful for Australia, and for which it is considered to be in the regional or national interest to be free of the plant pest.
- **Variant form of an established plant pest** which can be distinguished by appropriate investigative and diagnostic methods, and which if established in Australia, would have a regional or national impact.
- **Serious plant pest of unknown or uncertain origin** which may, on the evidence available at the time, be an entirely new plant pest, and which if established in Australia would have an adverse economic impact regionally and or nationally.
- **Plant pest of potential economic importance** to the area endangered thereby and not yet present there or widely distributed and being officially controlled, but is occurring in such a severe and sudden form, that an emergency response is required to ensure that there is not either a large scale epidemic of regional or national significance or serious loss of market access.

Emergency Plant Pest Response Deed (EPPRD). This is a formal legally binding agreement between PHA, the Australian Government, all State and Territory governments and national plant industry body **signatories**. It covers the management and funding of responses to **Emergency Plant Pest (EPP)** incidents, including the potential for **owner reimbursement costs** for growers. It also formalizes the role of plant industries' participation in decision making, as well as their contribution towards the costs related to approved responses.

Quarantine pest A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled.

Non-quarantine pest A pest that is not a quarantine pest for a particular area.

Pest Free Area (PFA). An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained.

Exclusion zones are established by a sanctioning body to prohibit specific activities in a specific geographic area, eg It is illegal to take fresh fruit into a Fruit Fly **Exclusion Zone** without a permit. Host fruit or vegetables without a certificate or permit including host fruit and vegetables for household or personal consumption must be disposed of in quarantine bins before entering a Fruit Fly Exclusion Zone (FFEZ).

Phytosanitary certificates are issued in accordance with internationally accepted templates and are used to certify that the plants or plant products have been inspected according to appropriate procedures, and they are considered to be free from quarantine pests, practically free from other injurious pests, and conform to the current phytosanitary regulations of the importing country.

Quality assurance (QA). Continual assessment of performance of the plant biosecurity system results in recommending measures to address gaps and other identified weaknesses in the integrity of the plant biosecurity system.

Shared responsibility

Government, Industry and Community

Government and industry stakeholders and the community must be clear about their roles and responsibilities. Trained personnel and other services must be available to effectively respond to pest incursions. For example, **Australian Customs and Border Protection Services (ACBPS)** cover the main ports of entry. Plant quarantine officers can then be called in to deal with only those cases directly relating to plants. **Australia Post** cooperates by keeping a watch on all mail coming into the country and the **Australian Defense Force** may assist if there is a serious outbreak of a disease or pest.



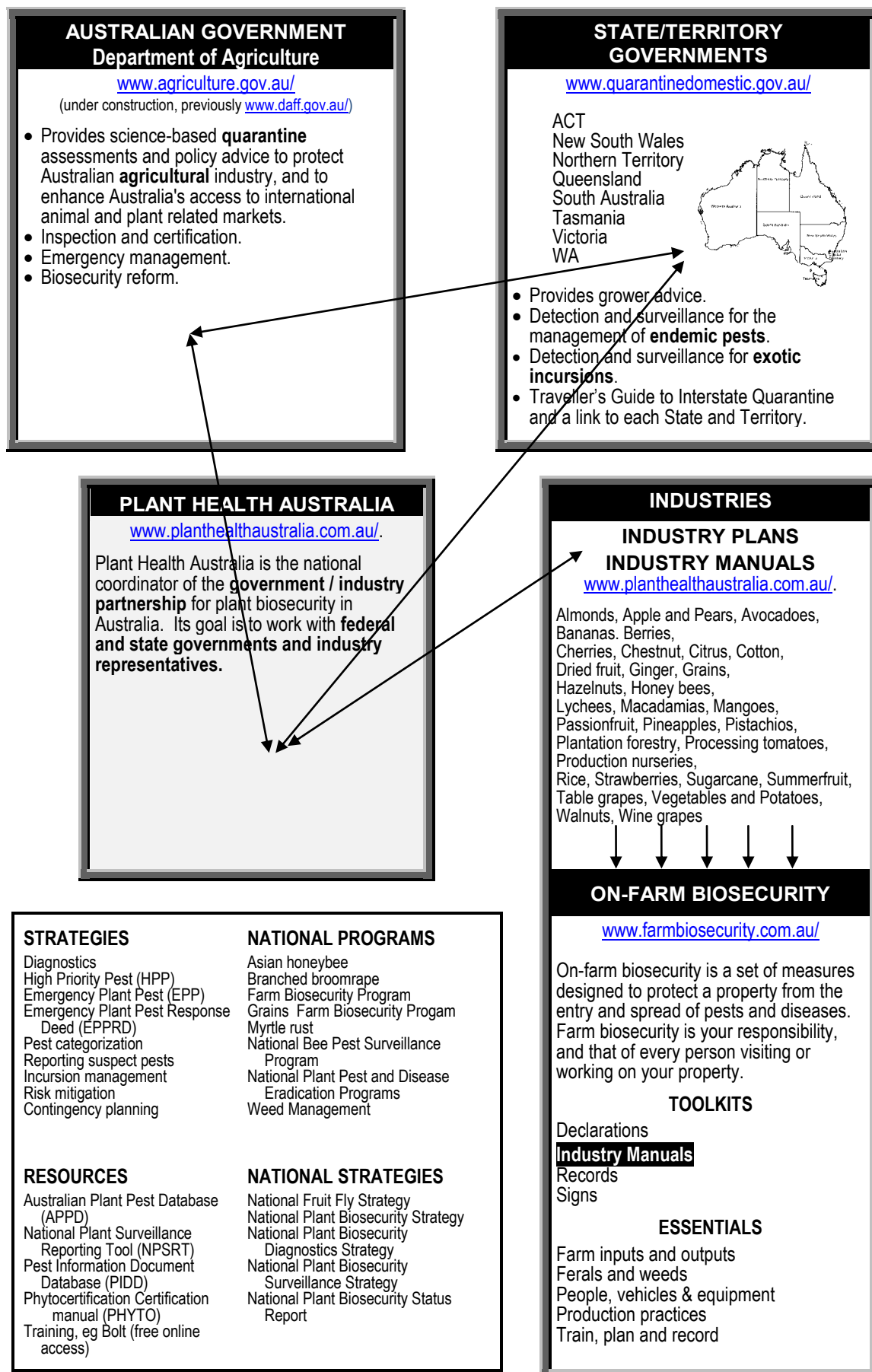
Protecting Australia from unwanted pests, diseases and weeds requires a joint effort. IT is playing an increasing role.

Stakeholder register

The stakeholder register involves consultative decision-making and includes:

- **A stakeholder register of people and organizations** with an interest in specific quarantine issues helps ensure wide consultation with stakeholders under the Import Risk Assessment (**IRA**) strategy.
- The **Department of Agriculture's various Risk Assessment Panels** have appointed many independent scientists to provide expertise.
- **Establishing an integrated national approach to plant biosecurity education and awareness.** An improved understanding of plant biosecurity among industries, industry service groups and the wider community with more active involvement from all in activities which prevent the establishment and spread of pests. A system of education, training and research funding that addresses skill gaps in the plant biosecurity sector into the future.


Table 9. Biosecurity is a shared responsibility.



Legislation and Trade

The plant biosecurity system works under the control of both **Commonwealth and State legislation**. This legislation is administered through a range of agricultural and environmental departments in the respective jurisdictions. The scope of the legislation covers the movement of plants and plant products into and around the country and many of the day to day activities of quarantine inspectors and the authority to deal with biosecurity emergencies and reporting requirements. Harmonized laws assist domestic trade and help Australia comply with its rights and obligations in international trade.

Biosecurity regulations may change, always check current requirements

Quarantine Act 1908 (Cwlth) 	<p>The Commonwealth Quarantine Act, 1908 is the current legal basis managing the risks of animal and plant pests and diseases entering, establishing, spreading in Australia and potentially causing harm to people, the environment and the economy.</p> <p>The proposed Biosecurity Bill 2012 seeks to replace the Quarantine Act 1908 and will provide a modern regulatory framework aimed at better managing risks in current and future trading environments. It seeks to promote effective cooperation between governments, trading partners, industry participants and the community. It contains a number of reforms including:</p> <ul style="list-style-type: none"> • Enhanced co-regulation arrangements with industry partners. • Partnerships between the Commonwealth, States, industry, trading partners and the community so a truly national biosecurity system is achieved. • Building the capability and capacity to proactively anticipate, detect and respond to emerging pests and disease threats.
Other legislation	<p>Other relevant legislation includes:</p> <ul style="list-style-type: none"> • Imported Food Control Act 1992 which is the legal basis for the inspection and / or analysis of imported food into Australia to meet the Food Standard Code. • The Export Control Act, 1982 (Cwlth) controls the export of primary produce to ensure that export foods are certified to meet importing country requirements. • The Grain Plants and Plant Product Orders of 1985 to cover Product Standards, etc. • Export Control Fruit and Vegetable Orders to apply to regulated and partially deregulated fruits and vegetables. • Export Control (Organic Produce) Orders to regulate the export of organic produce. • Environment Protection Biodiversity Conservation Act (EPBC Act) 1999 and its amendments, provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places.
Standards, Codes of Practice <div style="background-color: yellow; padding: 2px; text-align: center; font-weight: bold;">AS/NZ ISO STANDARDS</div>	<p>Examples include:</p> <p>AS/NZS ISO 31000:2009. Risk management - Principles and guidelines. AS/NZS 294: 2006. National Post-Border Weed Risk Management Protocol. ISO/IEC 17025:2005. General requirements for the competence of testing and calibration in laboratories.</p>
Penalties	<p>Responses to bringing in illegal weeds and other items range from education and / or warnings, to deterrent sanctions such as exclusion from programs, suspensions or cancellation of permits or approvals, seizure of good, infringement notices (on-the-spot fines) and criminal prosecution. DA has a compliance strategy.</p>
International obligations	<p>Australia's international rights and obligations derive principally from the:</p> <ul style="list-style-type: none"> • World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement) which requires among other things that: <ul style="list-style-type: none"> • Countries ensure their phytosanitary measures are based on scientific principles and not applied in a way to disguise a restriction on international trade. • Decision-making is transparent and based on pest risk analysis. Specific international guidelines on risk analysis have been developed. • International Standards for Phytosanitary Measures (ISPMs) are followed. • International Plant Protection Convention (IPPC) aims to protect cultivated and wild plants by preventing the introduction and spread of agricultural pests through the movement of plants and plant products by inspecting and issuing phytosanitary certificates when required by an importing country https://www.ippc.int/ • Australia's International Plant Protection Convention Secretariat ensures the country meets its international phytosanitary obligations. • Asia and Pacific Plant Protection Commission (APPC) aims to prevent the introduction and spread of plant pests and diseases in the region. • Pacific Plant Protection Organization (PPPO) is a regional plant protection organization for the islands of the Pacific including Australia and NZ. • The Convention on International Trade in Hazardous Chemicals and Pesticides 1998 requires exporting countries to inform importing countries about exports of chemicals banned or severely restricted in the exporting country.

BIOSECURITY – COMMONWEALTH

No country can stop everything: Incursions are a fact of life for any biosecurity system.

The Australian Government, acting through the **Department of Agriculture (DA)**, takes an integrated approach towards biosecurity involving *offshore*, at the *border* and *onshore* activities.

Offshore	<u>Primary responsibility</u> – Australian Department of Agriculture
Border	<u>Primary responsibility</u> – Australian Department of Agriculture
Onshore	<u>Primary responsibility</u> – Australian Department of Agriculture, State and Territory Departments, Plant Health Australia, plant industries and producers.

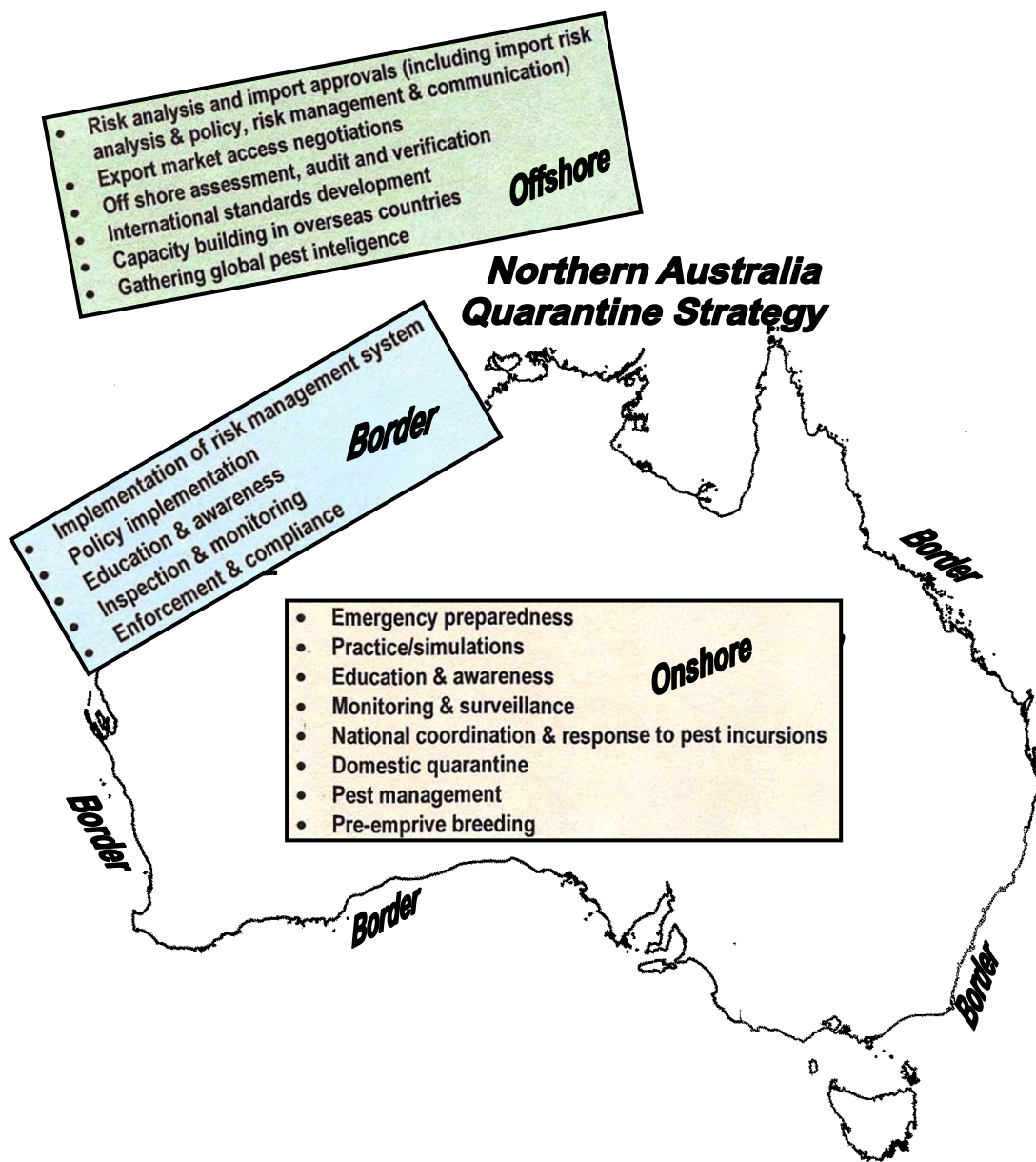


Fig. 19. Key components of Australia's plant biosecurity continuum.
 Photo©The National Plant Biosecurity Status Report published by PHA, 2013.
 The Northern Australia Quarantine Strategy (**NAQS**) protects northern Australia, from Broome to Cairns including the Torres Strait, from the entry of exotic pests.

Offshore activities

Australian Department of Agriculture

Managing biosecurity risks offshore



Offshore activities consider the risk and treat material **PRIOR** to the plant material reaching the border (point-of-entry) and include:

- **Identifying** exotic pest threats from overseas.
- **Undertaking research** and development offshore where pests are endemic.
- **Having protocols in place**, eg phytosanitary certificates, off shore treatments of imports (fumigation), area-freedom.
- **Pre-emptive breeding crops resistant to known threats**, eg wheat resistant to the Russian wheat aphid by looking internationally and within Australia for varieties resistant to the pest or diseases under investigation.
- **Surveillance of exotic pests overseas** for possible incursions into Australia, eg
 - **Biosecurity staff travel to PNG** to undertake plant health surveys.
 - **Saibai Island in the Torres Strait is just 5 km from the PNG coast** and is a potential route of entry to mainland Australia for many serious pests which are present in countries to our north. Some risks occur naturally such as insects and fungal spores being carried by wind and migrating birds. People and their goods also pose a biosecurity risk as food, plants and artifacts could carry exotic pests.
- **Have contingency plans** for high priority pest incursions should they enter from overseas.
- **Provide training and capacity building** in PNG, Indonesia, Samoa, Thailand, East Timor and other close neighbors.
 - **Engagement with neighbors** to counter spread of pests.
 - **Offshore fumigation**. The DA relies on effective offshore and onshore fumigation treatments to address quarantine risks associated with plant product imports. Australian Fumigation Accreditation Scheme (**AFAS**) helps train countries to DA fumigation standards.
- **Import Risk Analyses and import approvals** including estimating the probability of the pest becoming established.
- **Export market access negotiations**.
- **Offshore assessment**, audit, quality assurance (QA), quarantine arrangements.
- **International standards development**, gathering global pest intelligence.
- **Provides training for Australian diagnosticians** to help them identify high-priority pests (**HHP**), as well as ongoing support and access to diagnostic tools to help build the skills and surveillance training programs.

Target lists

Target lists of new plant pests are recorded in Australia each year. Complete lists are available on the DA website. **Target lists** are classified in different ways, eg by host, pest, diseases, weeds, and by host.

- **Target pests**, eg
 - **Asian gypsy moth**, Asian longhorned beetle, exotic fruit flies, khapra beetle, Asian tiger mosquito, Formosan termite, Russian wheat aphid, giant African snail, giant honeybee, black spined toad, varroa mite (a threat to pollination services). Citrus fruit borer, mango pulp weevil, sugarcane stem borer. Vectors of virus diseases.
 - **Exotic leaf miners**, eg serpentine leafminer, South African leafminer, pea leafminer.
 - **Social hitchhikers**, eg little fire ant, red imported fire ant, glassy-winged sharp shooter, Asian citrus psyllid, coconut whitefly, cloudy winged whitefly, and giant whitefly, giant African snail, the Asian gypsy moth.
- 
- Giant African snail (14-20 cm long). Photo© Australian Dept. of Agriculture.
- **Target diseases**, eg
 - **Karnal bunt**, black sigatoka, citrus canker, citrus greening disease, Eucalypts pine pitch canker, Pierce's disease, fire blight, Dutch elm disease, sudden oak death, Moko disease.
 - **Virus diseases**, eg plum pox, insect transmitted virus diseases.
 - **Root rots**, eg *Fusarium*, *Rhizoctia solani*, *Sclerotium rolfsii*, *Cylindrocladium* spp.
 - **Rusts**, eg grain rusts, orchid rusts, Western gall rust of pines, leaf rust of *Heliconia* in PNG. Rust species can be transported by monsoon winds over very long distances.
 - **Target weeds**, eg
 - **Branched broomrape**, Eurasian water milfoil, fringed spider flower, horsetail, Karoo thorn, King devil, koster's curse, lagarosiphon, Mexican feather grass, miconia, mouse-ear hawkweed, orange hawkweed, Siam weed, spiked pepper, witchweed.

Getting import approval (offshore)

Illegal importations of plant material in recent years are believed to be responsible for many hard-to-control diseases. In North America, the majority of forest tree diseases that have had the largest impacts resulted from **accidental importation, propagation, shipment and planting of infested nursery stock**. The arrival, establishment and spread of exotic forest pests have had a profound effect on forest ecosystems and continue to have significant economic effects long after their arrival because of the long life of trees.

Import conditions (ICON)

Import regulations change all the time



What are you bringing into Australia?

- ? Vegetable imports from China
- ? Potatoes from NZ, zebra chip disease could be a problem
- ? Has there been any change in the import conditions from India

A range of plant material can be imported with the approval of DA, eg seed, nursery stock or vegetatively propagated material (bulbs, woody plants, cuttings, scions) and plant tissue cultures of a range of plants. Importing plants is not that hard.

- **Check the botanical identification** of the plant, it may already be in Australia,
- **Plant Lists**. DA regularly reviews list of plant species that can be **legally imported** into Australia including a revised permitted seeds list. www.ngia.com.au
- **Check the laws or protocols** such as the Convention for International Trade in Endangered Species (**CITIES**) in the country you are exporting from. If the country of origin says it's alright to do so, and then go to the next step.
- **Import conditions may change** as new information and more advanced treatments become available, so check current import conditions.
- **Check the ICON database**, if the plant material is not there then an assessment will be required. If it is permitted for entry then fill out the appropriate import permits from the **ICON** database.
 - **Permits**. Import permit applications are on the Department of Agriculture's website. A link to the permit application can be found at the bottom of each ICON case however import permit applications are not directly located on ICON. Permits list the conditions of importation which must be met before the consignment will be cleared for importation. Conditions may include **inspection** and / or **treatment, etc.**
- **DA's role in importing genetically manipulated (GM) plants imports:**
 - **It is illegal** under the legislation to import to Australia GM seeds and plants without a valid import permit.
 - **Importers** are required to declare whether seeds or plants are genetically modified.
 - **DA checks with the Office of Gene Technology Regulator (OGTR)** to ensure that importers of GM seeds and plants are appropriately licensed before issuing an import permit.
 - **GM seeds and plants** are generally subject to the same biosecurity requirements as non-GM seeds and plants.
 - **GM seeds and plants** are only released from quarantine under licences granted by the Office of the Gene Technology Regulator (OGTR).
- **Phytosanitary certification** (phytocertification) is required for most live plant consignments including tissue cultures imported into Australia. Phytosanitary certificates must declare that:
 - **Overseas sources may be accredited** to facilitate trade, where a **DA** standard of pest and disease screening is carried out by competent authorities.
 - **DA endorses the concept of area freedom** where an entire country or part of a country is recognized to be free of a particular pest or disease.
 - **Tissue cultures**. An example of phytosanitary certificates.
 - **For tissue cultures with media**, Phytosanitary certificates must be endorsed with the following additional declaration: "*Tissue cultures in this consignment were visually inspected immediately prior to export and found to be free from any symptoms of disease or microbial infections*".
 - **For tissue cultures free of media**, Phytosanitary certificates must be endorsed with the following additional declaration: "*Prior to the removal of the plant tissue from the media, the tissue cultures were inspected and found to be free of contamination. The plant tissue was aseptically transferred under supervision to sterile containers which were then sealed and not subsequently re-opened*".
 - **There are a range of different declarations** depending on the plant form, species and country of origin. The exact words will be on the relevant ICON case / import permit.
- **Importing biological control agents** for the control of weeds and plant pests and diseases is a lengthy process (see also page 87). Guidelines for their importation are available on the **DA** website. www.daff.gov.au www.agriculture.gov.au
- **DA maintains a register of plant and plant product requests** and as resources become available the highest priority requests are commenced.

Import analysis and trade (offshore)

Biosecurity management in Australia, as in other leading economies, has moved to science and risk-based assessment, planning and action for pest and weed threats (Keogh 2012).

Plant Biosecurity CRC (PBCRC)

Plant Biosecurity CRC supports research and activities that extend from outside our borders to within the paddock, eg

- Identify and prioritize biosecurity threats to the Australian industry.
- Identify and prioritize gaps in knowledge, preparedness and response capability for the identified threats. Preparedness includes surveillance capacity, diagnostic capacity, pre-emptive breeding, etc.

A Centre of Excellence for Biosecurity Risk Analysis will commence operations in July 2013 replacing the Australian Centre of Excellence for Risk Analysis (**ACERA**) and continue to further Australia's capabilities to analyze and manage potential risks to Australia's biosecurity (Jay 2012).

Sound biological grounds, trade



In a period of global change when governments are trying to liberalize trade, quarantine regulations must have sound biological grounds.

- **Risks from exotic diseases, pests and weeds** must be assessed accurately and kept in perspective. Impacts on markets due to pests already present are crucial aspects of our biosecurity management (Rainbow 2011).
- **The increase in rapid air travel**, tourist numbers, imports and exports, mail and changing transport procedures, eg refrigeration and containerization of produce, as well as the potential for pests to enter via natural routes to Australia, mean that relying mainly on border quarantine is not enough. So from this relatively inflexible border-interception approach we are moving to a **risk-based approach**.

Import risk analysis (IRA)

Com of Australia. 2011. Import Risk Analysis. Biosecurity

Biosecurity conducts IRAs for vegetables, herbs, apples, bananas, bulbs, citrus, table grapes, tomatoes mangoes, grapevine nursery stock, olive plants, avocados, truss tomatoes, walnut plants, clonal grasses and sugarcane, etc

The process of developing a new quarantine policy where none exists is called an Import Risk Analysis (**IRA**).

- **Biosecurity Australia undertakes risk analyses** to identify any quarantine risks associated with requests to import plants and plant products into Australia.
 - Australia's biosecurity lies at the heart of our position as a trading nation and is based on good science and data collection.
 - This includes refocusing border protection effort on **keeping risks offshore**.
 - Conducted in a consultative framework.
 - A scientific process and therefore politically independent.
 - A transparent and open process. Stakeholders are fully informed.
 - Accountable for international standards, guidelines and obligations.
 - Subject to appeal on the process.
 - May be reviewed with new knowledge.
- **The DA Import Risk Analysis** includes entry potential, legalities, contamination, wind and impact of pest establishment on all Australia's plant industries, trade, environment and public health.

Steps in Pest Risk Analysis (PRA)

A PRA evaluates:

- Risks of entry,
- Establishment,
- Spread of diseases, pests and weeds,
- Their potential impacts

PRA Questionnaire

PRA is the systematic assessment and management of risks associated with the importation, or proposed importation of animals, plants, or goods and if necessary, identification of risk management options to limit the level of biosecurity risk due to exotic pests and diseases. Typically **PRA has 4 stages**:

- **Risk identification** involves determining whether the organism in question is a quarantine pest.
- **Risk assessment** is the process of evaluating the biological and economic consequences of entry, establishment or spread of a pest or disease within the importing country, and involves evaluating:
 - **Invasiveness**, eg history as a pest, reproductive capacity, means of dispersal, habitat suitability, competitiveness, human use as factors in their naturalization and spread.
 - **Impacts**, eg economic, environmental and social effects of the pest.
 - **Possible distribution**. Comparing the plants present and potential distribution.
- **Risk management** is the process of identifying, selecting and implementing measures that can be applied to reduce the level of risk (Beale 2008).
- **Risk communication**. The risk must be adequately passed onto growers, etc.

PRA ends when a decision is made – is the proposed import permitted or not?

- **A degree of risk is unavoidable**. However, accepting some risk reflects the requirements that quarantine must be flexible in meeting changing demands, new technology, and changing levels of resources, to avoid establishing unjustified trade barriers. It must also provide a level of security against the entry of unwanted diseases that is considered cost effective and scientifically justifiable.
- **Predictions can be wrong**. Even identifying the target pests can be difficult. Some insects overseas, which are not pests in their present country of origin, could be serious pests in Australia. Of **48 species of insects** that entered Australia in recent years **less than one third were on the target list**.

Weed Risk Assessments (WRAs)

There are potential advantages and limitations in using trait-based methods for predicting high impact weeds



The Australian Standard for National Post-Border Weed Risk Management Protocol (AS/NZS 294: 2006).

- **The Standards Protocol aims** to help with the standardization, use and further development of post-border **weed risk management (WRM) systems** so that weed species can be **prioritized** for coordinated control programs. **WRAs** are carried out for several reasons including:
 - **To assess** whether plants being considered for importations may become weeds.
 - **To assist** in making decisions about which weed species need priority action in their area of concern and the best way to manage and control weeds.
 - **There are various ways of conducting a WRA.** Generally a **WRA** assesses existing information on the new plant's weed history, reproductive capacity and biogeography to determine whether it is likely to behave as a weed in Australia. Predictions required include:
 - Invasiveness.
 - Impacts.
 - Possible distribution (spread and establishment).
 - Predicting weediness,
 - Prioritizing weeds for control.
- **The Weeds Network** provides evidence-based information for innovative ways of engaging with and managing weeds sustainably. <http://invasivespecies.org.au>

IRA reviews Examples

Apples from China and NZ



Apple and pear budwood

Kiwifruit from NZ

Flower bulbs



Mature orchids from Taiwan

Examples of IRA reviews include:

- **Apples imported from China and NZ and probably eventually the US.** The big concern from NZ is fire blight. Many consignments have been rejected because of the presence of leaf litter and live leaf curling midge. At one time up to 25% of consignments were rejected. The **IRA** was reviewed and the outcome was:
 - That the current import conditions for apple fruit from NZ be amended and that the importation of apples be permitted, subject to a range of quarantine conditions.
 - The risks associated with fire blight, European canker and apple leaf curling midge can be managed to achieve Australia's Appropriate Level of Protection (ALOP).
 - Apple scab (caused by *Venturia inaequalis*) is now considered to be present in Western Australia and is no longer a quarantine pest.
- **Import of apple and pear budwood (AFFA 2002).** **DA** has just completed a draft review of quarantine protocols for imports of apple and pear budwood. The review recommends revising post-entry quarantine conditions based on **pro-active in vitro testing for pathogens**. This allows introductions to be screened in a minimum of 15 months instead of the current 4 years.
- **Imported Kiwi fruit from NZ.** Imported Kiwifruit **pollen and nursery stock** are checked after the detection of **PSA** disease (*Pseudomonas syringae* pv *actinidiae*) in NZ. The import of nursery stock from NZ has been banned and earlier imports are being traced. The number of orchards in NZ with **PSA** has risen to 96 and NSW growers want a ban on the import of **fruit** from both NZ and Italy but **DA** says there is no scientific evidence that vine disease **PSA** is spread on fruit.
- **Flower bulbs import protocols are under review by DA** to minimize the risk of entry of exotic pests and diseases which may threaten our plant industries and the environment. Most of the flower bulb imports into Australia come from The Netherlands. However, other countries have also made import requests. The Australian Vegetable and Potato Growers Federation, the Australian Onion Industry and Environment Australia will form a working group to contribute their expertise to the development of the **IRA**.
- **Mature orchids from Taiwan** can now be sold directly into Australia markets providing all the year round option for growers and florists. Mature plants received by Australian growers will require only 5 months of cultivation to achieve the same high flowering *Phalaenopsis* orchid, prior to this it was 2 years of tissue culture in quarantine.

Be prepared Minimize risk

Effective national biosecurity is vital to **minimize the risk** of incursions of exotic pests, diseases and weeds into Australia.

- **Identify and prioritize biosecurity threats** to industry.
- **Identify and prioritize gaps in knowledge, preparedness and response capability** for the identified threats.
 - **Knowledge.** Implement Research and Development programs that deliver knowledge, tools and capability to lessen the risks of incursions and loss.
 - **Preparedness** includes:
 - **Surveillance capacity for endemic and exotic pests in crops** to ensure early detection and best chance of eradication or control of spread.
 - **Diagnostic capacity,** eg speedy and accurate identification.
 - **Pre-emptive breeding.** Having plant material commercialized or in the later stages of breeding provides immediate protection and risk minimization should there be an incursion. Resistant or tolerant varieties may already be available.
 - **Response capability,** eg
 - Investigation phase, eg identification, survey etc.
 - Alert, extent of the impact, etc, scope of response.
 - Operational, eg eradicate or contain and manage.
 - Stand down.
- **Best management Practices (BMP) for farm hygiene** to minimize the risk of on-farm, between farm and between regions spread of pests, diseases and weeds.

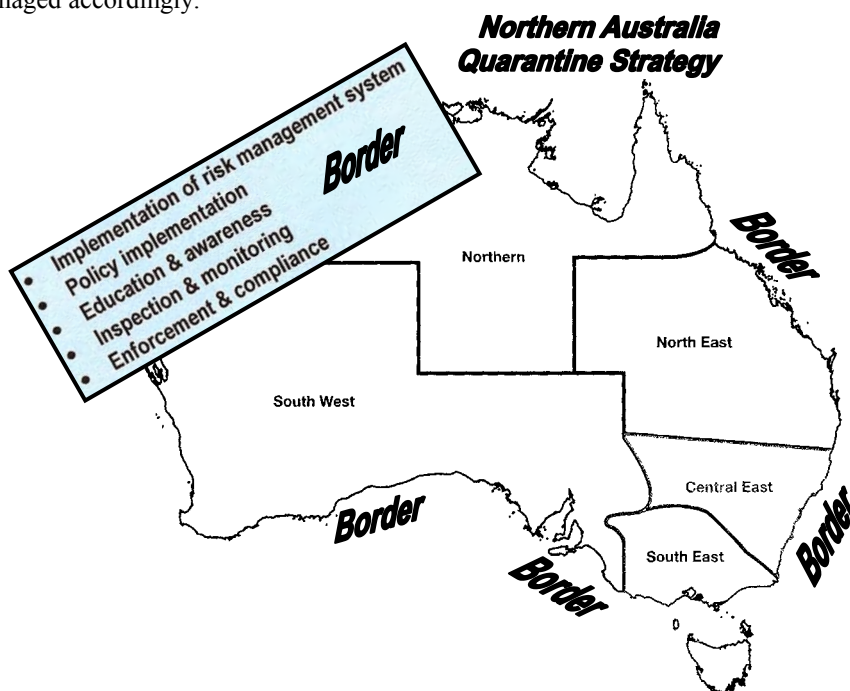
Border activities

Australian Department of Agriculture

The Australian Customs and Border Protection Services (ACBPS) and the Dept. of Immigration and Border Protection (DIBP) may be consolidated into the Australian Border Force in 2015.

At the Australian border, the **Department of Agriculture (DA)** minimizes the likelihood of pests and diseases entering the country. **Point-of-entry quarantine** is enforced at airports, shipping terminals and other points of entry. All food, plant and animal products must be declared. Threats at the border are mitigated by implementing:








- Policies involving imports and exports, education and awareness programs and risk management systems.
- Screening, inspection and monitoring.
- Compliance and enforcement arrangements.
- Post-entry quarantine stations.
- Northern Australian Quarantine Strategy (NAQS). **NAQS** is designed to protect northern Australia, from Broome to Cairns including the Torres Strait, from the entry of exotic pests (see also page 190).
- Ensuring that trapping and surveillance networks for pests that may bypass checkpoints are in place.
- **Remember, if it can move, it can carry diseases, pests and weeds.** The larger the quantity of material the greater the risk. For this reason, people, vehicles and equipment pose a high biosecurity risk and should be managed accordingly.



Biosecurity - Regional Boundaries. To minimize quarantine and market access risks, new regional boundaries were put in place with five (5) consolidated regions. Photo©The National Plant Biosecurity Status Report published by PHA, 2013.

<p>Imports, Exports Policy implementation</p>	<p>DA along with Food Standards Australia and New Zealand (FSANZ) administers the Imported Food Program, which ensures that food commercially imported into Australia meets Australia's Quarantine Standards and the Food Standards Code. DA also provides inspection and certification for a range of agricultural products exported from Australia, to ensure compliance with overseas countries importation requirements.</p>
<p>Memorandum of Understanding (MoU) Partnerships in Biosecurity strengthens border security</p>	<p>A MoU describes a bilateral or multilateral agreement between two or more parties.</p> <ul style="list-style-type: none"> • The MoU between the DA and the Australian Customs and Border Protection Service establishes the framework for how the two agencies work together. • A MoU between the DA and Defense provides understanding of biosecurity requirements for Defense property and personnel entering Australia from overseas operations. • A MoU between DA, Australian Post and Australian Custom and Border Protection Service reduces security risks from incoming international mail.
<p>AIMS & MAPS Import Management Systems</p>	<p>AIMS (AQIS Import Management System) manages risks and record actual biosecurity actions for individual consignments of imported cargo consignments that pose biosecurity or imported food risk.</p> <p>The MAPS (Mail and Passenger System) is used to manage the biosecurity risks associated with goods arriving with by mail or with a passenger. It can also be used to track certain imports and inspections.</p>

Table 10. How plant pests, diseases and weeds can enter and leave Australia.

MATERIAL	RISK
<p>Soil</p> 	<p>Soil is an ideal medium for transporting weed seeds, nematodes, insects, fungal diseases (and some animal diseases such as foot and mouth disease). This includes soil in plant pots, on shoes, vehicles, agricultural equipment, other machinery and implements. However, soil can be imported as a commodity, an import permit and appropriate controls are required.</p>
<p>Plants and plant products</p> <div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p>Pest and diseases that spread on hosts parts or on inert material such as packaging, containers, vehicles can be controlled by biosecurity.</p> </div>  <p>Infested fruit (Wendy Unger)</p> 	<p>Live plants (nursery stock, cuttings, rooted plants, etc) present the greatest risk of introducing plant diseases and pests., leafminers, leaf chewers, mites, sucking insects.</p> <p>Healthy-looking seeds may carry diseases and pests which can become established when the seeds are grown. Seeds may be contaminated with weed seeds.</p> <p>Bulbs, corms, tubers, rhizomes. Potato tubers have been responsible for the widespread distribution of potato cyst nematode and numerous virus diseases throughout the world.</p> <p>Plant tissue culture. Considered a relatively safe way of importing plant varieties into Australia since bacterial and fungal diseases can be readily excluded. Graft transmissible diseases such as virus diseases may be carried in this way.</p> <p>New genetic plant material is attractive to smuggle but there is very high risk of introducing diseases and pests.</p> <p>Fresh fruit and vegetables which appear healthy may carry fruit fly or other pests and diseases.</p> <p>Dried fruit spices and nuts may carry diseases and pests.</p> <p>Cut flowers, dried flowers may also carry diseases and pests.</p> <p>Straw, straw articles. Diseases and pests of major cereal crops can be transported in straw incorporated in straw articles or used as packing material.</p> <p>Wooden and bamboo articles may carry insects which can attack timber.</p> <p>Packaging materials. Timber and timber products, straw and straw products, rice hulls and other materials used as packing material can transport diseases and pests of many plants, eg timber, cereals and other crops.</p> <p>Shipping containers may be contaminated from previous cargo and thus introduce diseases and pests. Snails may hitch a lift!</p> <p>Boats may carry termites, timber borers, rats and other pests, also fruit and vegetables.</p> <p>Some plant products are prohibited on animal quarantine grounds, ie feed due to contamination.</p> <ul style="list-style-type: none"> • Accidental hitchhikers on host plants comprise 30% of total introductions, eg the giant African snail could enter Australia as eggs, or newly hatched snails, in empty containers or bags, in soil at the egg stage of its life, under packing cases, pallets in or on shipping containers, machinery, motor vehicles, bicycles, shell souvenirs or food carried by passengers. Defense equipment. • Quarantinable diseases and pests on host plant material, eg anther smut (<i>Ustilago violacea</i>) on tissue cultured carnations.
<p>People</p> 	<p>Clothing and footwear may carry rust and other fungal spores, or weed seeds which may remain viable for years. Soil may adhere to shoes introducing disease organisms, weed seeds.</p> <p>Smuggled birds, reptiles, fungal cultures, live insects. Some travelers bring these in and subsequently release them into the environment.</p> <p>Pets or display animals kept illegally (and legally) in Australia present one of the highest risks for new pests.</p> <p>Illegal imports of plant material, seed.</p>
<p>Aeroplanes, vehicles, etc</p> 	<p>Aeroplanes. Insects may travel in the cabin or cargo compartments of an aeroplane, eg vectors of human diseases.</p> <p>Stowaways. Hitch hiking snails cross Australian borders and escape into the environment.</p>
<p>Machinery, equipment</p> 	<p>Accidental hitchhikers on agricultural machinery and other equipment, defense equipment, recreational equipment, eg weed seeds or weed parts, Giant African snail, and fire ants.</p> <ul style="list-style-type: none"> • Machinery, equipment, etc may also carry soil. Increased use of contractors must add to the risk.
<p>Air</p>	<p>Birds can fly long distances. Few insects can fly the distances involved.</p> <p>Wind and air currents may carry insects, birds and pathogens.</p> <ul style="list-style-type: none"> • Sugarcane smut (<i>Ustilago scitaminea</i>) was probably carried into the Ord Irrigation Area in WA by windborne spores from Indonesia. • Wheat rust spores could be carried to Australia from overseas. • Pathogens carried on air currents, or by insects or birds are not amenable to control by quarantine • 46% of insect introductions were first detected in Qld and the Torres Strait coming in passively and naturally from the immediate north. <ul style="list-style-type: none"> • 40% of these insects belong to the Order Hemiptera (aphids, bugs, leafhoppers, lerp insects, mealybugs, scales, whiteflies). Generally males are not needed; a few females can start viable populations. Many plant pests are in this order. • 17% of the insects belong to the Order Coleoptera (beetles).
<p>Water</p> 	<p>Illegal fishing boats. Water supplies may carry mosquito larvae that could carry dengue fever.</p> <p>Ballast water may introduce marine pests, eg algae, bacteria and many other organisms.</p>

What can I bring into Australia?

What can't I take into Australia?

What can't be mailed to Australia?

Redline
1800 803 006
Breaches of Australian quarantine laws

If something is diseased at the border it is more than likely it wouldn't be allowed to go to a quarantine station (may be given options of re-export, being destroyed or treated).

Detection, screening



Screening of vessels, people and goods entering the country. Inspection and monitoring people, machinery, plants and goods

Products may be prohibited, require inspection, require treatment and / or post-entry quarantine.

- **Prohibited products.**
 - **Products may be prohibited** unless accompanied by a **valid Import Permit**.
 - **Prohibited products include live plants and animals, soil and sand**, bean, peas, cereal seeds, fresh and dried fruit and vegetables.
- **Inspection required.**
 - **Products will be inspected and treated** if necessary.
 - **Products inspected** include fresh and dried flowers, handicrafts, seeds, wood ware, bamboo, biscuits, dried fruit and vegetables, honey, tea, coffee, kava juice and other drinks, stuffed animals, bones, horn, feathers, rawhide, skins, hides, wool, animal hair, herbal medicines, holy water, therapeutic medicines, vitamins.
 - **Import Clearance Program.** Staff inspect and treat processed foods, agricultural products, containers, biological products, live plants and animals, machinery, timber, logs and moldings and other items.
 - **Tests applied to imported foods.** More than one test may be applied to food.
 - **Seaports program.** All vessels arriving in Australia require **biosecurity clearance**, either through documentation, physical inspection, surveillance or a combination of processes. Most breaches relate to waste, eg fruit cartons, plant material and garbage dumped on wharves, cargo, passengers, exotic pests and disease vectors, ballast water.
- **Treatment required.**
 - In some cases there may be a treatment cost.
 - Fumigation.
 - Pesticide treatments, eg systemic fungicides, dipping, insecticide spraying before passengers disembark to kill any airborne insects.
 - Commercial irradiation facilities in Brisbane, Melbourne and Sydney provide on-arrival treatments for various insects and allied pests.
 - Cleaning defense equipment on return to Australia.
- **Post-entry Quarantine (PEQ)** in quarantine-approved premises onshore **hold, inspect, test and / or grow high risk plant material** for varying periods of time, eg
 - **Approved post-entry plant quarantine stations onshore** include:
 - **Commonwealth PEQ facilities**, currently spread across Australia, will be consolidated into one site at Mickleham, Victoria.
 - **The post-entry quarantine facility for Darwin** was licensed by **DA** to receive imports of ornamental plants, fruit trees, orchids and seed.
 - **Quarantine approved premises outside the Perth Metropolitan area.** The Burrup purpose built facility in the Pilbara region of WA, was located at the Pluto LNG Park to speed up the quarantine clearance process of mining and gas field equipment.
 - **Test plants in Post-entry Quarantine**, eg:
 - Growing plants under observation before they are released to the importer.
 - Indexing plants for virus and virus-like diseases.
 - Repeated serological tests of seed lots (mostly through **ELISA**).
 - Nucleic acid tests involving **DNA** probes.
 - Polymerase chain reaction (**PCR**) amplification of specific pathogen **DNA** sequences.
 - **Trend is generic multi-taxa tests**, eg one test that detects more than one virus of interest.

DA provides biosecurity inspections for the arrival of international passengers, cargo, mail, animals and plants and animal and plant products. **DA officers** use X-ray machines, sniffer dogs, visual inspections and other methods in airports, seaports and international mail centers to search for quarantine risk material, eg

- **DA officers** screen all incoming mail and can intercept up to 80,000 high risk items each year (AQIS Bulletin Feb Mar 2009).
- **Sniffer dogs of various breeds** work at international mail centres, airports and international centres. Their extraordinary sense of smell is reported to be up to 100 times greater than humans and they can detect target odors of goods concealed in luggage, parcels, cargo containers, vessels, vehicles, aircraft and people. They are also trained to detect narcotics, firearms and explosives.
- **X-ray technology** for screening passenger luggage, trucks.
- **IONSCAN** detects and identifies trace explosives and narcotics from one sample.
- **Body scan imaging** is used to detect prohibited items concealed on a person's body or in their clothing and provides a technical alternative to removal of clothing.
- **Waterfront closed television**, container examination facilities, etc.
- **Remote diagnostic technology** allows some interceptions to be identified within minutes, eg an interception of Asian honeybees.
- **By targeting efforts and resources DA** can more efficiently find items of quarantine concern while allowing people and mail that are not carrying items to avoid unnecessary quarantine processes.

GET PERMISSION TO IMPORT PLANT MATERIAL

Interceptions

Lists of new plant pests are recorded in Australia each year since 1996 on the **DA** website. Similar lists can be found on State / Territory websites.

Pests, diseases and weeds that have been intercepted, eg

• **Pests**, include:

- **Giant African snail**, also other snails and slugs.
- **West Indian drywood termite** (*Cryptotermes brevis*) found in boat timbers.
- **Dead rats** and spiders have been found in luggage, post parcels.
- **Bulbs, soil and wooden pots** in express mail from Europe.
- **Asian gypsy moth** (*Lymantria dispar*) is a destructive pest of forest, horticultural and urban trees and if it were introduced into Australia it could cause extensive environmental and economic damage to our native bush, forests, crops and gardens. **Egg masses** are commonly found on ship hulls and rigging, cargo containers and vehicles.



Hairy larvae of the Asian gypsy moth showing **distinctive blue and red spots**. Photo©Australian Department of Agriculture. Yevgeny Aulos, Russian Research Institute of Plant Quarantine, Bugwood.org

• **Diseases**, include:

- Over the past 2 years alone the following diseases have all been identified on plant material either imported into post-entry quarantine facilities or seized at international airports.
 - Chestnut blight, citrus canker, quince rust, peanut stripe virus, coffee rust, brown rot and corky bar of grapevine.
 - Plums and cuttings infected with plum pox virus and pose the most serious threat Australia's stone fruit industry (sharka disease).
 - Food, vegetable meals, etc.

• **Weeds**, include:

- Siam weeds
- Cacti
- Bulbs
- Fruit
- Vegetables and flower seeds

Recent incursions

www.agriculture.gov.au/

Updates on incursions, eg grapevine leaf rust, South African citrus thrips, and red banded mango caterpillar can be found on the **DA Biosecurity** website. Similar lists can be found on State / Territory websites.

Pests, diseases and weeds that have established in Australia in the last few years include:

• **Insect pests**, eg

- Fire ants
- Electric ants
- Ash whitefly
- Western flower thrips

• **Diseases**, eg

- Myrtle rust.
- Sugarcane smut (*Silago scitaminea*) in Qld: arrival and emergency response.
- Daylily rust (*Puccinia hemerocallidis*) 28/1/2011. Be on the lookout! It affects these previously easy-care plants.
- Olive knot (*Pseudomonas syringae* pv. *savastanoi*), a bacterium.

• **Weeds**, eg

- African lovegrass, Chilean needlegrass and Mexican feather grass.
- Hudson pear (*Cylindropuntia rosea*) discovered in Qld. Early detection of harmful plants such as Hudson pear is the key to controlling and eradicating pests in Qld. If left uncontrolled the plant can destroy grazing land, kill native wildlife and prevent most forms of outdoor recreation such as bushwalking and camping.
 - This is the 4th known occurrence in Qld.
 - All of these detections are being managed by Biosecurity Qld in cooperation with local councils and landholders.
 - It has previously been found in other parts of Australia including WA, NT, and SA and in a major infestation at lightning Ridge in NSW (Aust. Hort. March 2012).

These grass weeds are almost impossible to manage

Compliance and enforcement

Redline
1800 803 006
Breaches of Australian quarantine laws

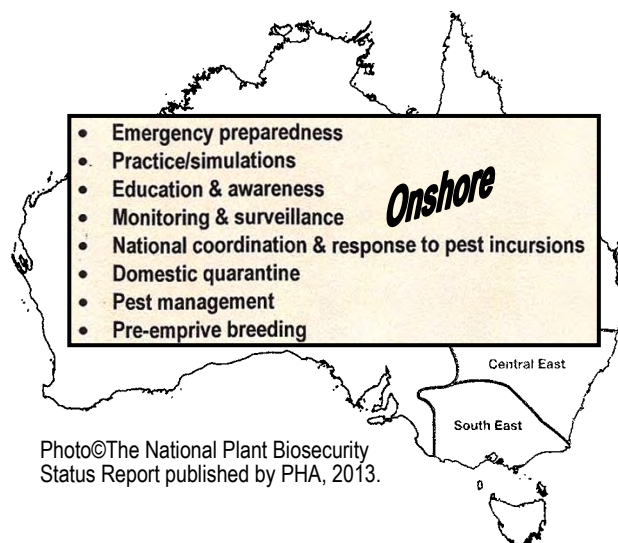
DA Redline is a confidential free call service (1800 803 006) for members of the public to report **suspected breaches** of Australian biosecurity laws.

National awareness campaigns advertise, eg

- **On-the-spot fines** for travelers arriving in Australia without declaring quarantinable items. Fines are not an issue if passengers declare the food they are carrying.
- **Prescribed penalties** for illegally importing plant material.
- **Seizures** of undeclared prohibited items.
- **CRAM (Compliance Risk Assessment Monitoring)** tests the performance of **DA** systems and compliance by industry.
- **Failure of point-of-entry inspections** is difficult to quantify.

Onshore activities

Australian Department of Agriculture,
States / Territories, Plant Health Australia, Industries and Producers



Photo©The National Plant Biosecurity
Status Report published by PHA, 2013.

PLANTPLAN (onshore)

PLANTPLAN provides nationally consistent guidelines for response to an **Emergency Plant Pest (EPP)** incursion as well as the key roles of government and industry during each phase.

Incursion management according to PLANTPLAN

PREVENT A PEST INCURSION EXCLUDE IF POSSIBLE

- Risk reductions measures
- Quarantine inspections
- Phytosanitary certificates
- Surveillance
- Post-entry quarantine stations
- Travelers and incursions
- Exotic Plant Pest Hotline
- Diagnostics

PREPARE FOR AN INCURSION IF IT OCCURS DESPITE PRECAUTIONS (Table 11)

- Plans** • **Industry Biosecurity Plans** outline **key threats to a specific industry**, including risk mitigation, identification of the categorized exotic pests and contingency plans for that particular industry.
- Manuals** • **Industry Biosecurity Manuals for growers** are prepared by industry and **PHA** to provide practical information that producers can use to implement on-farm to reduce the likelihood of exotic pests and diseases. Producers are encouraged to help minimize the biosecurity risks to their industry by adopting the biosecurity practices recommended in Manuals into their everyday business operations. They are available on the **PHA** website. www.planthealthaustralia.com.au/
- High Priority Pests (HPPs)** • **High Priority Pest (HPP) contingency plans** The information within these plans enables the quick development of an effective **Response Plan** in the event of an incursion.

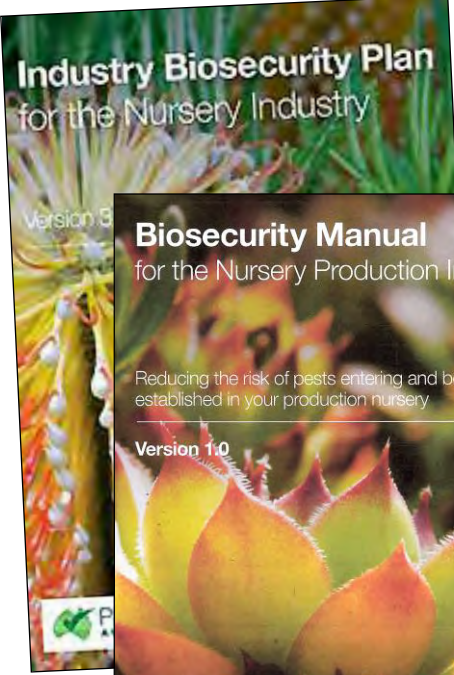
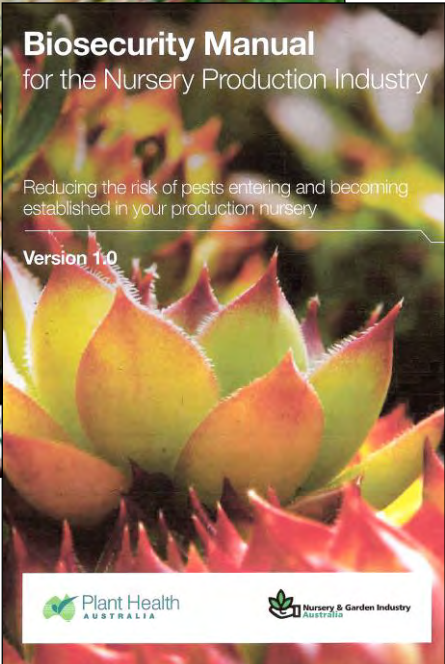
RESPOND TO AN INCURSION.

- **Investigation and alert phase**, eg initial report of pest incident, identification, surveys to indicate extent of the incursion, scope of response required, etc.
- **Operational**, eg defined response mechanism implemented to target the problem supported by legislation, funding and administration.
 - **Eradicate THEN IF UNSUCCESSFUL**
 - **Manage and Contain PEST MANAGEMENT, ETC.**
 - **Stand down**

RECOVER

- What has been learnt?

Table 11. Industry Biosecurity Plans and Manuals for specific industries

<p style="text-align: center;">INDUSTRY BIOSECURITY PLANS</p> <p style="text-align: center;">Key threats, responses etc</p>	<p style="text-align: center;">INDUSTRY BIOSECURITY MANUALS</p> <p style="text-align: center;">Practical information for GROWERS</p>
<p>Almond, Apple & pear, Avocado, Banana industry, Berries, Cherries, Citrus, Cotton, Grains, Honey bees, Lychees, Mango, Nursery Industry, Nut industry, Onion, Olives, Organic grains industry, Passionfruit, Pineapple, Plantation forestry, Potato, Rice, Strawberry, Summer fruit, Sugarcane, Vegetables, Viticulture Check for new industries www.planthealthaustralia.com.au</p> <p style="text-align: center;">Being prepared</p> <p><u>Industry Biosecurity Plans outline:</u></p> <p>Key threats to a specific industry. How to reduce the risks for that industry.</p> <p>High Priority Pests (HPPs) eg Dutch elm disease (<i>Ceratocystis ulmi</i>) European house borer (<i>Hylotrupes bajulus</i>) Exotic pests and diseases of trees, timber Five-spined bark beetle (<i>Ips grandicollis</i>) Giant African snail (<i>Achatina fulica</i>) Russian wheat aphid (<i>Diuraphis noxia</i>) Western Indian drywood termite (<i>Cryptotermes brevis</i>).</p>  	<p>Almond, Apple & pear, Avocado, Banana, Bundaberg Horticultural Farms (induction manual), Cherry, Citrus, Cotton, Honeybee industry, Mango, Northern Adelaide Plains Vegetable Growers Nursery production, Summer fruit, Vegetable industry, Viticulture Check for new industries www.planthealthaustralia.com.au</p> <p style="text-align: center;">Being prepared</p> <p><u>Biosecurity overview</u></p> <p><u>Industry Best Practice and Biosecurity Pests</u></p> <ol style="list-style-type: none"> 1. High priority exotic pest threats of your industry. 2. Pest surveillance. 3. Report suspect pests. <p><u>Product management</u></p> <ol style="list-style-type: none"> 4. Production inputs. 5. Product outputs. 6. Water management. 7. Waste. <p><u>People and biosecurity</u></p> <ol style="list-style-type: none"> 8. Biosecurity signs. 9. Managing people movement, contractors, consultants and utility providers and overseas travellers. <p><u>Equipment and vehicles</u>, eg</p> <ol style="list-style-type: none"> 10. Movement of vehicles and machinery, wash-down facilities, designated parking areas. <p><u>Records keeping</u>, eg</p> <ol style="list-style-type: none"> 11. Visitor record, materials import inspection record, vehicle inspection record, crop monitoring records. <p><u>Fact sheets</u>, pest photos, checklists, etc</p> <p style="text-align: center;">Six easy ways to start</p> <ol style="list-style-type: none"> 1. Be aware of current biosecurity threats, new and invasive threats. 2. Ensure seed and other propagation material is pest-free and preferably certified. Ensure all seed and other farm inputs are fully tested, pest-free and preferably certified. Keep records of inputs. 3. Keep it clean, good sanitation. Workers, visitor vehicles and equipment can spread pests, so make sure they are decontaminated before they enter and leave your farm. 4. Check your crops, monitor your crops. Knowing the usual appearance of your crop will help you recognize anything new or unusual. Keep photographic and written records of unusual observations. Constant vigilance is vital for early detection of any exotic plant pest threat. 5. Abide by the law. Support and be aware of laws and regulations established to protect your industry. 6. Report anything unusual. If you suspect anew pest or see anything unusual, report it immediately to the EXOTIC PEST HOTLINE 1800 084 881. <p style="text-align: center; background-color: red; color: white; padding: 5px;">Exotic Plant Pest Hotline 1800 084 881</p>

Training (onshore)

Training programs Preparedness and prevention



Optimize the selection and training of technical staff who work in biosecurity and / or surveillance related areas, to ensure effective and rigorous delivery of surveillance activities, both proactively and during an emergency response

Programs include:

- **Biosecurity Online Training (BOLT)** focuses on the biosecurity system (particularly the Emergency Plant Pest Response Deed (**EPPRD**) requirements) and what stakeholders can do to prepare.
- **A Graduate Diploma in Plant Biosecurity** (12 months) is available from Murdoch University in Perth, WA.
- **Industry Training** in the identification and reporting of exotic pests is provided.
- **Training overseas staff** and field extension officers from Indonesia, China, Thailand, Lombok, Bali, Java and Samoa.
- **ChemCert or similar training.** Availability and application of chemicals is an important part of responding to a pest incursion. Emergency use permits can be provided and approved by **APVMA** for chemicals which are effective and safe for use (pages 273-280).
- **Workshops**, eg
 - **Diagnostics.** Need to continually update diagnostics skills, diagnostic standards and diagnostic networks.
 - **Emergency Plant Pest (EPP)** workshops assist with identification of the most important pest and disease risks in different industries, eg nursery, fruit, vegetable, wheat. The Viticulture National **EPP** Training program and Plant Biosecurity Program are such programs. A shortlist of **75 EPPs** has been agreed to by all States.
 - **Specific industry workshops** to raise awareness of any new plant pest incursion arrangements in place the **EPPRD**, **PLANTPLAN**, Industry Biosecurity Plans.
 - **National Pest Risk Analysis (PRA).** **PRAs** assist land managers to develop risk assessment tools, how to control pests, diseases and weeds efficiently and **effectively respond** to emergency plant pest incursions through better understanding of their biology and epidemiology.
 - **National Weed** problems.
 - **Specific pests, diseases and weed**, eg Karnal bunt is the most serious exotic threats to the Australian wheat industry. Soilborne root plant disease workshops which cover ways to sample soils, best practices in interpreting test results and options for managing diseases. Accompanied by a comprehensive manual.
- **Accessing resources**, eg
 - **PaDIL**, fact sheets.
 - **Preparing contingency plans**, eg, prevention and response.
 - **Biosecurity Risk Management**, crop monitoring, inspection procedures (IPM).
 - **National Fruit Fly Implementation Plan.** The Australian Handbook for the Identification of Fruit Flies assists Australian diagnosticians to accurately identify fruit flies using **DNA** techniques.
 - **Inspection of plants and plant products exported from Australia** (The Plant Export Operations Manual on the **DA** website).
- **National stock takes** of Plant Quarantine Premises and Containment Facilities.
- **Cost sharing arrangements** are in place. The training includes how these are implemented.
- **National plant health awareness campaigns.**



Banana Freckle (*Phyllosticta cavendishii*)

The **Australian Banana Growers Council (ABGC)** is currently supporting action in the Northern Territory to eradicate, the first case in Australia of Cavendish banana plants being infected by the fungal disease, banana freckle.

- Banana freckle has previously been found on other banana varieties in Australia, including Bluggoe and Lady Finger, however, this is the first time it has been detected on Cavendish plants. The disease has not been found in Australia's commercial banana producing areas.
- Banana freckle reduces banana plant yield by damaging plant leaves which yellow and die. Visible signs are small spots or streaks which have a sandpaper feel and appear on the leaves as well as on the skins of the fruit.
- Overseas, it has been found in Papua New Guinea and south-east Asia, with reports of the disease also in India, the Caribbean and central Africa. There are no registered products to control the disease. Some products used to control other diseases in bananas also work on Banana Freckle (Source: Australian Banana Growers Council, 2013).

Diagnostic networks and resources (onshore)

Effective diagnosis is dependent upon reliable and reproducible methods.

<p>National Plant Biosecurity Diagnostic Network (NPBDN)</p> <p style="background-color: red; color: white; text-align: center; padding: 2px;">Outbreaks</p> <p style="font-size: small;">Weeds, insects, diseases</p>	<p>The National Plant Biosecurity Diagnostic Network (NPBDN) is a nationally integrated network for plant diagnosticians in Australia and includes:</p> <ul style="list-style-type: none"> • Contacts, information and resources to assist diagnosticians working in the field of plant biosecurity. • Remote Microscope Diagnostics (RMD) is a tool used to support activities off shore, at the border and onshore; it facilitates pest identification by connecting microscopes with computers over the internet. Quarantine officers and others in the frontline of biosecurity protection and experts in other cities, state or territories see what's under a remotely located microscope (Thompson 2010). Users can share live images with experts <i>in real time</i> around the world. www.padil.gov.au/rmd • The remote microscope network can deal with an information request immediately or direct it to a national expert. To bolster Australia's pre-border surveillance activities for exotic pests, microscopes have been set up in Thailand, Vietnam, Laos, Singapore, Malaysia, Indonesia, East Timor, PNG and NZ. • When Australian biosecurity officers find a suspicious insect or other invasive pest, they can now quickly identify it, drawing upon experts around the world using microscopes linked via the internet.
<p>Diagnostic Protocols</p> <div style="border: 1px solid black; padding: 2px; font-size: small;"> <p>International Standards for Phytosanitary Measures (ISPM)</p> <p>See also pages 1-14, 212</p> </div>	<p>Diagnostic protocols are documents that contain detailed information about a specific plant pest, or related group of pests, relevant to its diagnosis. Such information is crucial for the management of established and exotic pests, including:</p> <ul style="list-style-type: none"> • General surveillance for pest status. • Testing of material for compliance with certification procedures. • Surveillance as part of an official control or eradication program. • Pest diagnostic operations associated with phytosanitary certification. • Routine diagnosis for pests found in imported consignments. • Detection of a pest in an area where it is not known to occur. <p>National Diagnostic Protocols (NDPs) are diagnostic protocols for the unambiguous taxonomic identification of a pest in a manner consistent with ISPM No. 27 – Diagnostic Protocols for Regulated Pests. NDPs include diagnostic procedures and data on the pest, its hosts, taxonomic information, detection and identification. NDPs will:</p> <ul style="list-style-type: none"> • Allow the rapid and accurate diagnosis of specific plant pests. • Ensure Australia meets its international plant protection obligations.
<p>Resources</p> <p style="font-size: small;">Access the website; much material is available</p>	<p>Resources include:</p> <ul style="list-style-type: none"> • Australian Plant Pest Database (APPD) is a national online database of recorded pests of Australia's economically important plants and crops. The database helps demonstrate area-freedom from pests, negotiate market access, determine responses to suspected exotic pest incursions, develop quarantine policy and justify measures to exclude potentially harmful, exotic pests. www.planthealthaustralia.com.au/appd • Pests and Diseases Image Library (PaDIL) delivers high quality diagnostic images and fact sheets on pests and diseases that pose a potential plant health threat to Australia. PaDIL assists diagnosticians with rapid identification of exotic plant pests and diseases in the event of an incursion. http://www.padil.gov.au. • Atlas of Living Australia (ALA) shares biodiversity knowledge and contains information on all the known species in Australia aggregated from a wide range of data providers: museums, herbaria, community groups, government departments, individuals and universities. www.ala.org.au/ • BowerBird answers the need in Biosecurity and Biodiversity for access for a shared socially networked workspace. www.padil.gov.au/Bowerbird • Pest Information Document Database (PIDD) which contains the biology and taxonomy of pests developed as part of Industry Biosecurity Plans (IBPs), including Fact Sheets and Contingency Plans to minimize the threat of exotic incursions entering Australia. • Global databanks are available to assist with verification. • The Farm Biosecurity website. www.farmbiosecurity.com/ • Various e-newsletters, eg Biosecurity Bulletin, Tendrils (Plant Health Australia), Leaflets (Plant Biosecurity CRC). <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="border: 1px solid black; background-color: #f08080; padding: 5px; text-align: center;"> <p style="margin: 0;">Biosecurity Bulletin</p> </div> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div>

Surveillance and monitoring (onshore)

Early and confident identification means immediate steps can be taken to minimize impact of incursions.

Reporting, early detection

**Exotic Plant Pest Hotline
1800 084 881**

Outbreaks

Report an unusual pest, disease or weed

To inform Australian and trading partners

National, State, regional and on-farm surveillance. Each State / Territory has an obligation to report any new plant pest detection and new host records whether exotic to Australia or to the State or Territory of concern to the Australian Chief Plant Protection Office.

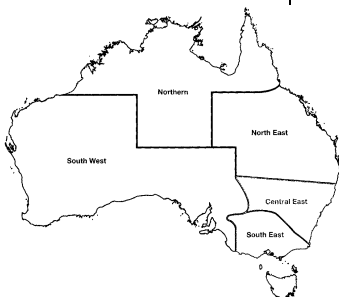
- **The detection of a High Plant Pest (HPP)** can have a very significant impact on market access for Australian agricultural exports. Enhanced interstate and international market access is achieved through improved ability to detect new pests and demonstrate freedom from designated pests. Some pests have not been detected until they have been in Australia many years.
- **Early detection** (from surveillance) is the key to mounting effective responses that have the best chance of eradicating or minimizing the impact of exotic pests.
- **The Exotic Plant Pest Hotline** is a free call telephone service to report if you have found an unusual pest or disease.
- **The Outbreak** website was created to keep Australian and trading partners better informed in the event of a future pest and disease outbreak. www.outbreak.gov.au
- **The online National Plant Surveillance Reporting Tool (NPSRT)** allows State and Territory surveillance coordinators across Australia to enter plant pest survey data into a web-enabled database. The database is password protected and only accessible by the relevant administrators, coordinators and reporters. The data can support "**proof of absence**" for all international markets.

Northern Australian Quarantine Strategy (NAQS)

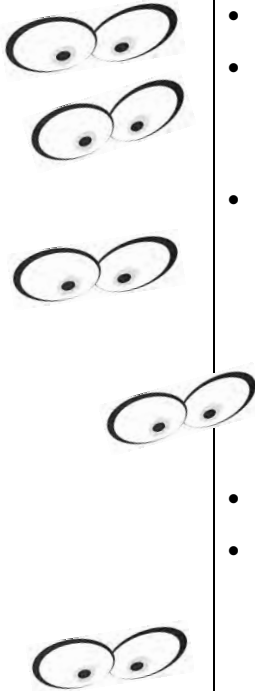
There would have to be a considerable probability of entry into northern Australia, followed by establishment and spread, with the potential to cause significant adverse impact to agriculture, horticulture, environment or the Australian public. Surveillance activities are carried out in this region for that reason. **NAQS** is designed to protect northern Australia, from Broome to Cairns including the Torres Strait, from the entry of exotic pests.

- **Quarantine Top Watch!** is the national public awareness campaign of **NAQS** and emphasises the importance of biosecurity in northern Australia and encourages residents in those regions to **keep a look out** for exotic pests that could harm Australia's animal and plant life and report sightings of unusual pests, weeds and diseases to **DA**.
 - **NAQS** implements measures for the early detection of targeted exotic pests and manages biosecurity risks associated with the southwards movement of goods through the Torres Strait.
 - **NAQS** conducts regular surveillance activities on the spread of pests, plant pathogens and weeds into PNG, and manages their potential movement towards northern Australia. **DA** continues to build stronger links with PNG, Timor-Leste and Indonesia.
- **Coen Information and Inspection Centre, Cape York Peninsula (Qld DAFF)** screens vehicles travelling south for potentially infected material. Cape York is a high risk area for the entry of exotic pests, diseases and weeds. The Far Northern Pest Quarantine Area covers Cape York and north of the Coen Information and Inspection Centre acting as a buffer against plant and animal pests and diseases which originate from countries to the north.
- **NAQS maintains and periodically review,** lists of exotic plant pests, diseases and weeds which could enter Australia's northern border and are serious threats to Australia's productivity, export markets and the environment. These may all be targets for surveillance, but this will be a mix of traps and other activities.
 - **Pests,** eg exotic fruit flies, cabbage and pea leafminers, *Asian gypsy moth (Lymantria dispar)*, redbanded mango caterpillar (*Deanolis sublimbalis*) a serious pests of mangoes in Southeast Asia and PNG. Also, mango pulp weevil (*Sternochaetus frigidus*) and banana stem weevil prevalent in Malaysia, Philippines, and parts of Indonesia. Rubber termite (*Coptotermes elisae*), cotton or citrus locust (*Chondracris rosea*), red spider mite (*Tetranychus piercei*).
 - **Weeds,** eg giant sensitive plant (*Mimosa diplotricha*) is a serious weed in Philippines southeast Asia, Pacific islands, east Timor, New Guinea and is already a pest in North Queensland and could invade Kimberley and NT. First Australian detection in Kununnurra of the tree mopane (*Colophospermum mopane*) in 2004 and then again in 2005. Pond apple (*Annona glabra*) collected from the grounds of Charles Darwin University is a **WONS**.
 - **Diseases** Fusarium wilt or Panama disease of bananas (world's worst disease of bananas) is under containment in some areas near Darwin. Black sigatoka is widespread in countries to Australia's north; citrus canker common in Indonesia and PNG has been eradicated from Australia. Citrus greening (Huanglongbing) occurs in Southeast Asia and northern Irian Jaya in Indonesia, the first detection on citrus in Australia occurred in Kununnurra in 2005. The fungus *Macrophomina phaseolina* was found on grapefruit tree in WA 2004-2005. First detection of *Nattractia mangiferae* in WA was associated with dieback, blossom blight and soft brown rot (postharvest disease) of mangoes.

Northern Australia Quarantine Strategy



Nationally coordinated plant pest surveillance



Post-entry measures such as trapping for monitoring and targeted surveillance of certain pests, diseases and weeds in crops, ensure early detection of exotic incursions which can provide the best chance of eradication or containment. Research is carried out to:

- **Enhance surveillance** capability for exotic fruit fly. The high risk of exotic species of quarantine fruit flies that are non-responsive to currently developed lures, entering Australia horticultural production zones at present free from these species.
- **Enhance preparedness** of Australia’s grain industry for incursions of Emergency Plant Pests (**EPPs**), the development of contingency and national surveillance.
- **Work towards** a national system for rapid and secure biosecurity surveillance data collected for States and Territories and systems to evaluate surveillance and optimization for Emergency Plant Pests (**EPPs**). This should facilitate the development of systems that automatically collect and synchronize data with server applications to provide live updates of detections.
- **Provide ongoing surveillance by trained researchers, growers, staff, consultants and contractors** in the field, to observe the presence of any new or unusual pest or disease or weed during their normal activities. GRDC and PBCRC are developing a surveillance plan to look specifically at the role of **routine crop monitoring by growers, agronomists and consultants**.
 - **Claims for area-freedom**. Constantly scanning crops for anything out of the ordinary, farmers and agronomists together provide an **extensive national passive surveillance network for exotic pests and diseases**. This surveillance is part of a national biosecurity effort. In the case of karnal bunt in WA the network provided a more than 90% level of confidence that the state was free of karnal bunt. Samples are sent to CropSafe® filter agronomists for examination – this provides valuable data and “known not to occur” evidence for claims of area freedom (Norwood 2010).
- **Co-ordinate on-farm and other necessary surveillance activity** as an important aspect for grains biosecurity strategy (McIntyre 2010).
- **Victoria’s CropSafe program** is an active, self-help ‘eyes in the field’ surveillance system looking out for new pests and diseases over the Victorian grains belt. The Dept. of the Environment and Primary Industries (DEPI) delivers the CropSafe® program in collaboration with a number of major agribusiness companies and a network of private consultants. CropSafe® has a network of over 150 experienced agronomists continually looking for new pests and diseases. This means Victorian farmers can be far more confident that their grain crops are free of exotic pests.
 - **CropSafe® has streamlined sample receipt**, analysis, reporting and record-keeping. Individual agronomists are emailed results and the network receives a monthly update on disease occurrence and trends.
 - **Managing the spread** of established viruses and weeds and will also help minimize the spread of any potential new pests.
 - **For growers**, the most effective way to minimize risk of on-farm, between-farm and between region spread of pests, include:
 - Weed control.
 - Use of clean seed.
 - Use of resistant or tolerant varieties where available.

Pest-free areas for exports overseas and interstate

Proof of absence for market access



Having an effective surveillance program is increasingly important to **maintain market access** for some export markets. Exporting countries must provide a certificate to declare that certain pests have **never been found** (not known to occur) and scientific “**evidence of absence**” based on recorded surveillance that the pests is known not to occur.

- **Information on that status of plant pathogens or pests** of concern is important because under the World Trade Organization’s Agreement on the Application of Sanitary and Phytosanitary Measures, countries can no longer restrict plant product imports for non-scientifically justifiable reasons.
- **An increasing number of countries** when buying Australian grain require “**proof of absence**” of high-priority grain.
- **Pest-free area for dodder weed in Niger seed** which is used in caged bird seed mixes in the USA market. US regulations insist that Niger seed be steam cooked to kill any weeds seeds present specially those of *Cuscuta* spp. However, the **Ord River Irrigation Area (ORIA)** in the north of WA was shown to be free of weed pests belonging to the Genus *Cuscuta* (dodder weeds) which supported negotiations for access to the USA market without steam cooking.

What to look for High Priority Pests




Each industry has a High Priority Pest (HPP) list which is constantly being updated, eg

- **Nursery industry**. The vegetable leafminer (*Liriomyza sativae*) has been detected in the Torres Strait on Warraber Island during routine surveillance carried out by Northern Australian Quarantine Strategy (NAQS). This pest which has not previously been detected in Australia is a threat to fruit, vegetable and ornamental plants but is known to favor bean and pumpkin plants as hosts. Routine surveillance around Cape York and Darwin has not found the pest (2008).

Emergency response (onshore)

Managing biosecurity incursions - Early detection

<p>Emergency Plant Pest Response Deed (EPPRD)</p> <p style="background-color: red; color: white; text-align: center; padding: 2px;">Outbreaks</p> <p style="font-size: small;">To inform Australian and trading partners</p>	<p>The EPPRD is a formal legally binding agreement between PHA, the Australian government, State and Territory governments and national plant industry bodies on how we respond to minimize the impact of incursions and improve our chances of achieving eradication.</p> <ul style="list-style-type: none"> • It covers the management and funding of responses to Emergency Plant Pest (EPP) incidents of national significance. • The EPPRD is enacted when outbreaks of serious exotic pests occur and this leads into an emergency response. • An Emergency Plant Pest Response Plan (EPPRP) provides policy and guidelines for the consistent management of exotic plant pest emergencies by appropriately trained personnel in each State / Territory. This is reviewed regularly and workshops held.
<p>PLANTPLAN Response</p>	<p>PLANTPLAN provides nationally consistent guidelines for response procedures under the EPPRD, outlining the three phase response to an Emergency Plant Pest (EPP) incursion as well as the key roles of industry and government during each phase. It is updated regularly and incorporates best practice.</p> <ol style="list-style-type: none"> 1. Investigation and alert. Initial report of a pest is detected. The process of identification is initiated and the relevant people and organizations notified. Identification of the pest is confirmed and the outbreak declared. The Consultative Committee on Emergency Plant Pests (CCEPP) will determine scope of the response, eg feasibility of eradication and make a recommendation. 2. Operational. Implementation, management and reporting on progress of the incursion. If relevant, a Scientific Advisory Panel (SAP) will evaluate the effectiveness of the response and its implementation. 3. Stand Down. After the coordinated response is completed or if a review determines that eradication is not feasible, each State and Territory's share of the cost is calculated. If eradication is not possible, then the approach is reconsidered.
<p>Eradication programs currently in place</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px; transform: rotate(-2deg); display: inline-block;"> <p style="background-color: red; color: white; text-align: center; padding: 2px;">Don't spread electric ants</p> </div>	<p>Eradication is the process of removing all insect, infected plant material or weeds after the outbreak of either a new disease in an area, or an old disease in a new area. Attempts to eradicate a disease or pest after it has entered Australia are highly dependent on identifying the incursion early. Eradication procedures may include:</p> <ul style="list-style-type: none"> • Eliminating or reducing the amount of inoculum present. • Removing diseased plants which act as sources of inoculum (rogueing). • Occasionally by voluntary or compulsory eradication of certain host plants. • Banning the growing of certain species. • Fruit stripping. • Using a decoy or trap crops. • Destroying insect and other vectors. • Male annihilation. • Cover sprays, bait spraying and fumigation. <div style="text-align: right; margin-top: 10px;">  <p style="font-size: x-small;">Electric ants on flower buds Photo ©The State of Queensland (through the Department of Agriculture, Fisheries and Forestry) [2014]</p> </div> <p>National plant pest and disease eradication programs past and present, include:</p> <ul style="list-style-type: none"> • Electric ants (Cairns Post 7. June.2011). Qld already has a wide range of measures in place to find and eradicate electric ants including their newest recruit sniffer dog. • Fire ants (<i>Solenopsis invicta</i>) were first detected in 2001. Qld has warned they might not be able to stop the species invading other States (2011). • Cocoa podborer (<i>Conopomorpha cramerella</i>) a mosquito-sized moth with damaging larvae, was first detected in a cocoa plantation in Far North Queensland in April 2011. Biosecurity Queensland undertook an eradication program under the terms of the Emergency Plant Pest Response Deed (EPPRD), and in less than three years, Australia has been declared free of the pest. In cocoa plants, the caterpillar infects the pod but not the rest of the plant. The response succeeded in breaking the month-long life cycle of the pest, by spraying and stripping pods from the trees. <ul style="list-style-type: none"> • Monitoring of crops for the pest continued for more than two years after the initial detection. Biosecurity authorities are now satisfied that the area is free from the pest, and it has been declared eradicated from Australia. • Chestnut blight which affects chestnuts and oak trees was first detected in Sept 2011 in north east Victoria, where more than 80% of Australia's chestnuts are produced. Authorities are confident the diseases can be eradicated. • Freckle (<i>Phyllosticta cavendishii</i>) disease of banana in the NT is the subject of an eradication program. <p>National weed eradication programs include:</p> <ul style="list-style-type: none"> • Siam weed is high on the hit list for eradication. Qld is working hard to eradicate Siam weed (Townsville Bulletin 29/Mar/2011). • Witchweed (<i>Striga asiatica</i>). Currently under eradication in Qld.
<div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p style="font-size: small;">COCOA PODBORER</p> <p>Eradication by:</p> <ul style="list-style-type: none"> • Spraying and stripping pods from trees <li style="padding-left: 20px;">then • Monitoring for at least 2 years </div>	

Successful eradication programs

Monitoring needs to continue for a long time to ensure the exotic pest has not reappeared

Some exotic pests recently found in Australia which have been eradicated

- Mile-a-minute (*Mikania micranthra*) has been eradicated from the Ingham area in Qld.
- Citrus canker (*Xanthomonas campestris* pv. *citri*).
- Fire blight (*Erwinia amylovora*).
- Strawberry angular leaf spot (*Xanthomonas fragariae*).
- Papaya fruit fly (*Bactrocera papayae*) and Philippines fruit fly (*B. philippinensis*) in NT.
- Giant African snail (*Achatina fulica*).
- Grapevine leaf rust.
- Onion smut; ongoing surveillance will be maintained to demonstrate that SA continues to be free of onion smut and has a pest free status.
- African crazy ants in Qld.

Conversion to containment



Branched broomrape (*Orobanche ramosa*), several branches grow from ground level. Photo© Australian Dept. of Agriculture.

Many attempts to eradicate a disease once it has become established have been unsuccessful, ie it was not technically or economically feasible to eradicate it.

- The **Myrtle Rust Transition to Management Program** is aimed at limiting the impact of myrtle rust on regeneration of Myrtaceae species (McRae 2013).
- The **National Banana Bunchy Top eradication** project in Qld and NSW is urging backyard growers to get a permit and get plants checked (2010). The biggest hurdle to eradication is illegal backyard plantings, passing suckers and material over the back fence and giving material away.
- **Rice blast** (*Magnaporthe oryzae*) detected in the Ord River Irrigation Area (ORIA) in WA has been deemed to be not eradicable. All production areas outside of the Ord are free from the disease.
- **Sugarcane smut** (*Ustilago scitaminea*) in Qld was soon widespread and well established. The disease can be successfully managed with resistant cultivars.
- **Asian Honeybee** (*Apis cerana*). The transition to management program has been completed already.
- The **green snail** (*Helix aperta*) is established in WA. Incursion in SA was initially considered under the **EPPRD**, but eradication was not attempted.
- **The National Branched Broomrape Eradication Program** has been reviewed and deemed not eradicable.
- **European house borer** which was eradicated from Sydney and Melbourne during the 1960's returned to WA in 2004. Transition to management program.

Status of some exotic pests, diseases and weeds

Target lists for

Insects
Diseases
Weeds

Watch lists crops

Banana, Citrus, Cotton, Forestry, Grains, Nursery and garden, Nuts, Pome (apple and pear), Qld fruit and Vegetable, Rice, Strawberry, Sugar, Summer fruit (stone fruit), Vegetables, Viticulture, etc



White rust of chrysanthemum. Photo© Ministry of Agriculture New Zealand.

Some pest, diseases and weeds NOT YET in Australia but which would pose serious threats if introduced and became established.

- Dutch elm disease (*Ophiostoma ulmi*), sunflower downy mildew (*Plasmopara halstedii*), western gall rust (*Peridermium harknessii*), sudden oak death (*Phytophthora ramorum*).
- Cadang-cadang and lethal yellowing of palms, citrus greening, plum pox virus.
- Citrus burrowing nematode (*Radopholus citrophilus*), pine wood nematode (*Bursaphelenchus xylophilus*), soybean cyst nematode (*Heterodera glycines*).
- Asian longicorn beetle (*Anoplophora glabripennis*), Colorado potato beetle (*Leptinotarsa decemlineata*), Japanese beetle (*Popilla japonica*), New Zealand grass grub (*Costelytra zealandica*).
- Varroa mite and various diseases affecting honeybees.

Some diseases, pests and weeds RECENTLY FOUND in Australia, which are of limited distribution, difficult to control and which are still **quarantinable**:

- Isolated outbreaks of Panama wilt (*Fusarium oxysporum* f.sp. *cubense* Tropical Race 4) of banana have occurred in the NT. Resistant varieties are not currently available. Field trials of GM resistant bananas have begun in Kenya.
- Anthracnose (*Colletotrichum gloeosporoides*) – a lupin strain in WA.
- Southern red mite (*Oligonychus ilicis*) occurs in NSW. Tasmania and WA have imposed quarantine restrictions on azaleas and camellias.

Some diseases and pests in Australia that are NO LONGER QUARANTINABLE:

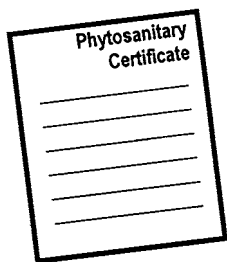
- Brown rot of stone fruits (*Monilinia laxa*).
- Chrysanthemum white rust (*Puccinia horiana*). Industry responded by developing resistant varieties which now comprise about 90% of field plantings.
- Western flower thrips (*Frankliniella occidentalis*), melon thrips (*Thrips palmi*).
- Hibiscus erineum mite (*Eriophyes hibisci*).

EXOTIC WEEDS WATCH LIST Weeds that you have not seen before could be exotic to Australia. Some of the more serious, exotic weeds to watch out for are listed on the **DA Biosecurity website**. Where available, links to fact sheets with images are provided to help with the identification of the weeds listed.

Exports, trade and surveillance (onshore)

Consignments of Australian produce may be **destroyed at the port of arrival** if found to contravene quarantine regulations. Overseas countries don't want our pests, just as much as we don't want their pests! The Department of Agriculture provides export controls and assistance regarding exporting goods from Australia, eg a simple brief and user-friendly guide for people interested in nursery exports (**A beginner's Guide to Nursery Export**).

Biosecurity pests in Australia which do not occur in some other countries	<p><u>Some diseases, pests and weeds in Australia are not known to occur</u> in some of the countries to which Australia exports produce:</p> <ul style="list-style-type: none"> • Potato cyst nematode (<i>Globodera rostochiensis</i>). • Mediterranean fruit fly (<i>Ceratitidis capitata</i>), Qld fruit fly (<i>Bactrocera tryoni</i>). • San Jose scale (<i>Quadraspidiotus perniciosus</i>). • Parthenium weed (<i>Parthenium hysterophorus</i>). • There is a zero tolerance of live insects in shipments of export grain.
Manual of the importing country requirements (MICoR)	<p><u>MICoR Plants is DA's Export Conditions Database</u> for plant and plant products including fruit, vegetables, seeds, grains, cut flowers and timber. It sets out the requirements that exporters and DA must meet for products and commodities to be accepted for import into specific overseas countries.</p> <ul style="list-style-type: none"> • Exporters must also comply with the requirements of the Export Control Act and associated orders when exporting commodities from Australia.
EXport DOCumentation (EXDOC)	<p><u>EXDOC has been designed to electronically process</u> notices of intention to export and where required, provide certification for horticulture, grain, meat, dairy, fish, skins and hides, wool and inedible meat products.</p>
Export Certification Reform Package) (ECRP)	<p><u>ECRPs have been developed with various countries.</u> Electronic certification quickly and securely provides assurances to our trading partners, that our produce meets their import requirements.</p> <ul style="list-style-type: none"> • Regulatory arrangements focus on company audits rather than item by item inspection; off-site audits are carried out remotely and company data accessed. • Examples include dried Australian flowers and foliage for export to Malaysia, glasshouse tomatoes to USA, tomato, and capsicum to NZ, acacia seeds to Brazil.
PHYTOsanitary Certification Manual (PHYTO)	<p><u>PHYTO is a Phytosanitary Certification Manual</u> - a plant and plant product export conditions database. PHYTO contains information about the conditions to export plants and plant products, including fruit, vegetables, seeds, grains, cut flowers and timber from Australia.</p> <ul style="list-style-type: none"> • PHYTO is a guide only and should not be taken as definitive as it may be subject to change without notice. Exporters should make their own enquiries to ensure compliance with the requirements of the Plant Protection Authority of the importing country or other regulatory and advisory bodies prior to and after the export. • A Phytosanitary Certificate may be issued for exported produce if the importing country requests it. A phytosanitary certificate is a government-to-government document certification, based on inspection and freedom from quarantine pests, indicating that the importing country's quarantine regulations have been met. • DA inspection is required for the export of prescribed goods, eg fresh fruit and vegetable and some non-prescribed goods, eg honey, confectionary. • Quality Assurance (QA) based systems mean that exporters have to be responsible for product safety, quality and meeting overseas government requirements, including Approved Quality Assurance (AQA) Agreements and Certification Assurance (CA) Arrangements. • Accredited third party providers of quarantine services are subject to rigorous auditing by DA Biosecurity.
Examples of protocols	<p><u>Examples</u> include:</p> <ul style="list-style-type: none"> • Non-host status. Avocadoes are not infested on trees by Medfly in WA but quarantine authorities require testing to prove "non-host" status to access overseas and inter-state markets. • Maximum residue limits (MRLs). Recently Egypt has eased its tolerance of ergot (a fungal disease of wheat) from zero to 0.01 per cent. This is well below the international level of 0.05%, a level considered safe for human consumption. Exported food must not contain more pesticides than the receiving countries permit. • Pre-shipment testing. WA obtained area freedom from potato cyst nematode in 2010. A substantial consignment of WA seed potatoes has been cleared for export to Indonesia, following pre-shipment pest and disease-testing (see page 218). • GlobalGap protocols. Guidelines are available to help Australian growers implement these protocols for exporting fresh fruit and vegetables to the European Union. • Export Control (Organic Certification) Orders make it illegal to export organic produce without a certificate that verifies the nature of the product (certification).



High Priority Pests in Australia (onshore)

Governments, Plant Health Australia and industries aim to minimize impacts, limit spread into new areas and make best use of available resources nationally, to manage **High Priority Pests (HPPs)** in Australia, eg

- Primary industry **pests** such as *Helicoverpa* spp., grain weevil.
- Developing **IPM and BMP packages** for key agricultural industries, eg grains, cotton and horticulture.
- Minimize risk or **regional risk, property entry and establishment**.
- Preparing for timely **detection, minimize spread and rapid response to emergency pests**.
- **Vertebrate pests** such as rabbits and carp.
- **Weeds** such as bridal creeper, prickly acacia, African lovegrass, Chilean needle grass.

National Fruit Fly Strategy (NFFS) 2011

Outbreaks

To inform Australians and trading partners, eg Fruit Fly Outbreaks

PHA in collaboration with Australian, State and Territory governments and industry partners has been facilitating the development and implementation of the draft of the **NFFS** which aims to develop a **viable, cost effective and sustainable national approach to fruit fly** management with all stakeholders committed to the national policy that underpins this approach.

- **The NFFS Action Plan (NFFSAP)** can be downloaded and there is a website for Fruit Fly Outbreaks. A new management approach is being put in place (page 197).
- **Plant Health Australia** has created a website to help home gardeners in Australia make informed decisions about control and prevention of fruit flies.

Weed programs

Australia is one of the very few countries in the world trying to manage invasive plant species, eg the top 5 weeds in Australia are alligator weed, serrated tussock, mesquite, parthenium and bone seed. Combating weed problems is a shared responsibility that requires all levels of government **in partnership** with industry, land and water managers and the community to understand their role. www.weeds.org.au

- **The Australian Weeds Strategy** is the overarching Australian Government's policy for weed management in Australia. It outlines goals and actions required to keep Australia's economic, environmental and social assets secure from the impact of weeds. www.gov.au/government/policies It has the following 3 goals:
 - Prevent new weed problems,
 - Reduce the impact of existing priority weed problems and
 - Enhance Australia's capacity and commitment to solve weed problems.
- **Weed management** is also addressed in a number of international agreements or national strategies and programs such as Convention on Biological Diversity, Ramsar Convention on Wetland, The World Heritage Convention, Australian Biodiversity Conservation Strategy, National Biosecurity and Climate Change Action Plan 2004-2007.
- **Programs in place to help tackle WONS** (now 32) include:
 - Caring for our country.
 - Natural Resources Management regions.
 - CERF (Commonwealth Environmental Research Facilities).
 - Weed Warriors is a national program for schools, administered and supported by National and State / Territory governments.
 - Managing Commonwealth land, eg defense establishments, national parks.
 - The National Landcare Program.
 - The Green Army.
 - Planting 20 million trees by 2020 (2014).
- **State and Territories** have a range of programs, policies and legislation to meet their responsibilities for weed management.
- **Local governments** have different land and weed management responsibilities dependent on which State /Territory they are in. In some States, local government is responsible for planning, coordinating and monitoring noxious weed control.

Managing established exotic weeds Difficulties

Difficulties in controlling exotic weeds in Australia.

- **African love grass (ALG)** (*Eragrostis curvula*) is a highly persistent, summer growing perennial grass weed that is invading rural properties, nature reserves, urban parkland, and roadsides. Management opinions differ. Some graziers have the view that **ALG** is here, cattle can use it. Others think that **ALG** is potentially one of the worst environmental and agricultural weed species.
- **Managing mimosa** isn't just about killing the plant off at the surface. Seeds may remain viable for anything **up to 20 years** so it's a matter of going back again and again until you are just dealing with the seedbed. Top end 1/12/2010.

Can invasive plants be eradicated?

Yes, especially when the outbreak is new, eg Koster's Curse in the NT; but once infestation reaches several hundred hectares they become increasing difficult to eradicate.

BIOSECURITY – STATE, TERRITORY AND REGIONAL

Quarantine Domestic

Quarantine Domestic

For more information, phone 1800 084 881

Interstate biosecurity is a serious issue and restrictions apply to the movement within Australia of various fruits, vegetables, plants and animals. www.quarantinedomestic.gov.au

- **Remember, pests, diseases and weeds can spread from one part of Australia to another** through the movement of plants or plant products, animals or animal products, soil, agricultural machinery and other equipment, recreational equipment (page 183).
- **The Quarantine Domestic website** gives you all the information you need for travelling within Australia to different States and Territories, eg the **Traveller's Guide to Interstate Quarantine** and a link to each State and Territory.
- **The States have an equivalent biosecurity** to the **Australian National Biosecurity System**, which is administered by the relevant State Departments of Agriculture, Primary Industry or their equivalents. State Biosecurity Acts set out special rules for protecting the State or Territory where you live. For examples, if you live in Tasmania then 2 sets of quarantine laws apply, ie the Commonwealth laws on Australian Biosecurity and the State laws that protect Tasmania.
- **Regional pest management** involves Domestic Quarantine, Quarantine zones, Pest-free areas, Exclusion zones, suppression and low pest prevalence, area-wide management and surveillance.
- **Emergency response management** is mitigated through **PLANTPLAN** which is for Emergency Plant Pests (EPPs) and will not be used for pests not present only in one state (page 192).

Travelling to:

- NSW/ACT
- Northern Territory
- Queensland
- South Australia
- Tasmania
- Victoria
- Western Australia



Check current regulations

Diseases and pests may occur in some States / Territories/regions within Australia but not in others. For this reason, hosts of certain diseases and pests:

- Are prohibited entry,
- Require certification, or
- Are subject to inspection.



Examples of diseases and pests not in some states include:

- **Not in WA.**
Codling moth (*Cydia pomonella*).
Dothistroma (*Dothistroma septospora*) which causes needle blight disease of pines.
European red mite (*Panonychus ulmi*).
Grape phylloxera (*Daktulosphaeria vitifolii*).
Qld fruit fly (*Bactrocera tryoni*)
- **Not in Tasmania**
Codling moth (*Cydia pomonella*).
Mediterranean fruit fly (*Ceratitis capitata*).
Qld fruit fly (*Bactrocera tryoni*).
Myrtle rust. Currently WA, SA and Tasmania are Myrtle rust free.
Lupin anthracnose (*Colletotrichum gloeosporioides*).
- **Not in Qld**
Mediterranean fruit fly (*Ceratitis capitata*).
- **Not in Victoria**
Mediterranean fruit fly (*Ceratitis capitata*).
- **Not in NSW**
Mediterranean fruit fly (*Ceratitis capitata*).
- **Not in SA**
Grape phylloxera (*Daktulosphaeria vitifolii*).
Mediterranean fruit fly (*Ceratitis capitata*).
Oriental fruit moth (*Grapholita molesta*).
Qld fruit fly (*Bactrocera tryoni*).
San Jose Scale (*Quadraspidiotus perniciosus*).

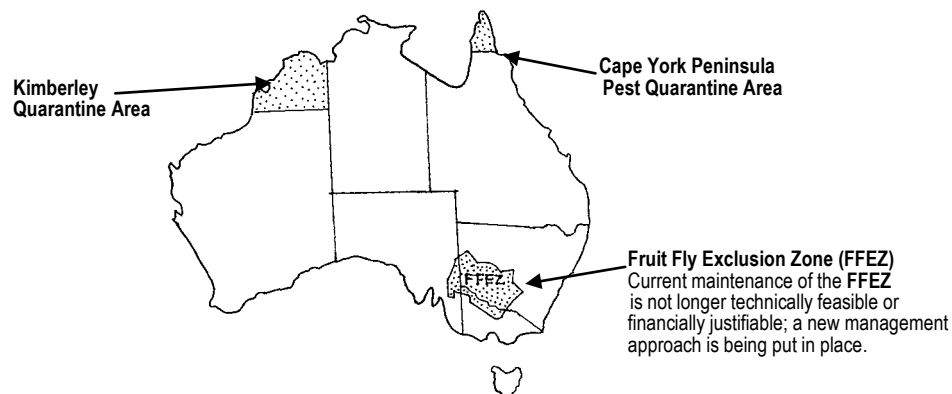


Fig. 20. State and quarantine borders

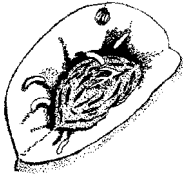



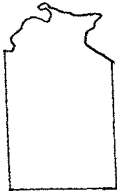

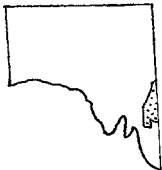
Interstate Certification Assurance (ICA)	<p>ICA is a national plant health certification scheme administered by <i>all</i> States and Territories. It is based on quality management principles.</p> <ul style="list-style-type: none"> • ICA provides an alternative to traditional plant health certification involving government inspectors and enables a business to be accredited by a State or Territory plant biosecurity authority and issue plant health assurance certificates for its produce. • There is mutual recognition of Plant Health Assurance Certificates accompanying consignments of produce moving interstate.
Nursery & Garden Industry Australia (NGIA)	<p>The NGI Quarantine and Biosecurity Policy Position document demonstrates how the Australian nursery and garden industry participates in the biosecurity continuum and outlines how governments and authorities can assist in this regard.</p>
Moving machinery	<p>Grape harvesters can spread phylloxera. All operators of mechanical grape harvesters are reminded to follow the regulations relating to movement between grape phylloxera quarantine zones and to maintain good cleaning procedures between vineyards. Growers need to make sure they have permits to move harvesters between zones. There are penalties for not following regulations (31/1/2011 Vic DPI).</p>
<p>Moving plants and plant products</p> <div style="border: 2px solid red; padding: 5px; margin: 10px 0;"> <p>Travellers' Guide to Interstate Quarantine</p> </div> <p>Biosecurity regulations may change, check</p>	<p>Quarantine areas may be set up within individual states to contain certain diseases and pests in one area. States/Territories and regions have established regulations restricting entry of certain plants and plant products, eg</p> <ul style="list-style-type: none"> • Plants which are not allowed into certain areas, eg <ul style="list-style-type: none"> • Banana bunchy top virus. No plants or seeds of banana or its relatives in the genus <i>Musa</i> are allowed into coastal shires of NSW north of Taree or into Qld because of the risk of introducing this potentially devastating disease. • Some plant materials may be allowed entry to certain areas if certified to be free from a particular disease or pest, eg <ul style="list-style-type: none"> • Spiraling whitefly (<i>Aleurodicus dispersa</i>). Areas of the northern parts of Cape York and in suburbs of Cairns have been quarantined. Host plants, flowers, foliage and fruits require a Plant Health Assurance certificate prior to movement into other areas of Qld. • They come from an approved breeding scheme. • They come from an area free from a particular disease (area freedom). • Interstate Produce (IP). WA allows property or area freedom for a number of actionable pests of ornamentals which occur in Qld, eg European red mite (<i>Panonychus ulmi</i>), hibiscus erinose mite (<i>Eriophyes hibisci</i>), palm leaf beetle (<i>Brontispa longissima</i>) and gladiolus rust (<i>Uromyces transversalis</i>). Inspections may also be required.
<p>Fruit Fly Exclusion Zone (FFEZ) Winter Windows Areas of Low Pest Prevalence Pest Free Places</p> 	<p>The distribution of Queensland fruit fly in eastern Australia has shifted significantly south to the point where the pest can be considered established in many parts of Victoria and most of NSW. Current maintenance of the FFEZ is no longer technically feasible or financially justifiable; a new management approach is being put in place (see also the National Fruit Fly Strategy (NFFS) on page 195). Changes will include:</p> <ul style="list-style-type: none"> • The deregulation of the movement of host fruit and vegetables across parts of Victoria and NSW. • Growers will take on a greater role in managing Queensland fruit fly on their land. • Trapping intensity will be reduced to a grid aimed primarily at demonstrating freedom from exotic fruit flies, including Mediterranean fruit fly. • Pursue negotiations with the US to recognize cold disinfestation as a stand-alone treatment and on other market access arrangements including: <ul style="list-style-type: none"> • Recognition of Winter Windows, • Areas of Low Pest Prevalence, and • Pest Free Places of Production. <div style="display: flex; justify-content: space-around; align-items: center;">   </div>




Table 12. Check the current Exclusion Zones in your State/Territory.

Exclusion zones in Victoria – 4 zones	Exclusion zones in your State/Territory?
<ul style="list-style-type: none"> • Queensland fruit fly and Mediterranean Fruit fly (fruit or fruiting vegetables). • Phylloxera (grapes, grapevine material, agricultural equipment and soil). • Potato cyst nematode (potatoes, potato plant material, agricultural equipment and soil). • Toolangi Plant Protection District (nursery plants, cut flowers, leafy vegetables, strawberry plants, <i>Rubus</i> plants and potato tubers). 	

States have adopted the continuum approach - **pre-border, border and post-border**. Each State and Territory has its own biosecurity legislation. As a grower it is imperative that you adhere to current State and Territory regulations, eg interstate certification protocols and export protocols. Import and export conditions change.

All States and Territories have their own Plant Quarantine Manuals and many Industries have Industry Biosecurity Plans, Industry Biosecurity Manuals (pages 186, 187). Ensure protocols are in place to monitor the movement of plants and nursery materials so movements can be traced to contain a potential outbreak. **State and Territory legislation is available.** www.quarantinedomestic.gov.au/

<p>New South Wales</p> 	<p>The proposed NSW Biosecurity Act will wholly or partly replace 14 pieces of existing legislation.</p> <ul style="list-style-type: none"> • NSW Biosecurity Strategy 2013-2021 establishes how NSW will manage biosecurity threats including plant and animal pests, diseases and weeds. • The NSW Invasive Species Plan, developed with extensive government, industry and community input, provides actions that aim to prevent and effectively manage the introduction and spread of invasive species which are a great threat to biodiversity and primary production. • Under the Non-Indigenous Animals Act 1987 and its Regulations there are offences for importing, moving or transporting certain non-indigenous animals without completing appropriate documentation, eg cane toads. • Quarantine road signs and fruit disposal bins. You are required to stop at a road block and declare any fruit. • Biosecurity programs include: <ul style="list-style-type: none"> • Emergency management. • Pests, diseases and disorders in field crops and pastures. • Pests, diseases and disorders in horticultural crops. • Pest and weeds management.
<p>Northern Territory</p> 	<p>The geographic location of the NT places it firmly in the frontline of Australian biosecurity. The role of the Biosecurity and Product Integrity Group (BPI) is to prevent, exclude, effectively manage and where possible eradicate risks to the economy, animal and plant industries, environment and human health posed by pests, diseases and chemical-residues and to ensure the continued access to domestic and international markets for Territory primary produce. Northern Territory Quarantine (NTQ) aims to:</p> <ul style="list-style-type: none"> • Protect the local fruit and vegetable industry including cut flower products and nurseries, from pests and diseases not established in the territory. • Regularly inspect fresh fruit and vegetables destined for interstate markets. • Plant Health Services maintains and improves market access capability for Northern Territory plant products. This includes facilitating domestic and international market access for plants and plant products, surveillance of post and effective responses to any incursions of plant pests and diseases and plant health policy and legislative compliance.
<p>Queensland</p> 	<p>The new Biosecurity Act 2014 will deliver a single cohesive legislative framework for an effective biosecurity system in Qld. It will provide proportionate powers and flexibility to respond to emergency events, evolving and ongoing biosecurity risks including emerging, endemic and exotic pests and diseases of animals and plants.</p> <ul style="list-style-type: none"> • The Bill would also regulate the safety and quality of animal feed, fertilizers and other agricultural inputs. • It would provide consistency, accountability and transparency in decision making, apply effective risk management measures to protect Qld's primary industries, natural environment, social amenity and human health and provide confidence that market access requirements of our customers are being met. • Post-entry facility plant quarantine at Eagle Farm near Brisbane's port and airport. • Currently Qld is carrying out a State-wide blitz on papaya ringspot virus to check if the disease has breached the quarantine area (2013). Bacterial crown rot is also another major disease for papaya. These diseases are spread by insects and plant material which is why quarantine zones are closely monitored. There is concern that the diseases could be present in backyard fruit trees and home owners may be unaware. Biosecurity is to monitor it and educate people on how to avoid them.
<p>South Australia</p> 	<p>Biosecurity SA provides for the protection of plants from pests and regulates the movement of plants into and within South Australia.</p> <ul style="list-style-type: none"> • Plant Health Legislation provides for the protection of plants from pests and regulation of the movement of plants into and within South Australia: The Plant Health Act 2009 and Plant Health Regulations 2009. • The Plant Quarantine Standard (PQS) for SA provides specific details about entry requirements for fruit, vegetables, plants, and plant related products into South Australia or where such requirements apply, the fruit, etc must be accompanied by a Plant Health Certificate or Plant Health Assurance Certificate (page 197). • Quarantine road signs and fruit disposal bins, Fruit Fly Exclusion zone (FFEZ) Quarantine roadblocks. You are required to stop at a road block and declare any fruit.

<p>Tasmania</p> 	<p><u>Tasmania has some of the world's most stringent quarantine arrangements.</u> One of the key goals of the <u>Tasmanian Biosecurity Policy</u> is to minimize the threat to Tasmania's primary industries, natural environment and public health from the negative impacts of pests, diseases and weeds associated with plants and plant products brought into the State from both overseas and the Australian mainland.</p> <ul style="list-style-type: none"> • <u>The Tasmanian Plant Quarantine Manual (PQMT)</u> has been developed to help importers, exporters and the broader public understand the current requirements for the <u>import and export</u> of plants, plant products, and other prescribed matter authorized by the <u>Plant Quarantine Act 1997 (Tasmania)</u>. <ul style="list-style-type: none"> • Search the <u>Tasmanian Biosecurity Import Requirements Database (TBIRD)</u> for requirements that must be met for the <u>import</u> of plants, plant products or agricultural machinery/equipment. • The <u>Kingston Quarantine Station</u> is fully accredited by <u>DA</u> for <u>post-entry quarantine</u> of plant material from allowable world sources. • There is a <u>new vehicle check-point</u> at the East Devonport ferry terminal in an effort to streamline discharge and loading of the Spirit of Tasmania vessels. • <u>Area Freedom for Fruit Fly status</u>, fruit fly trapping program and surveys of other pests and diseases. The <u>export program provides export inspection and certification</u> in accordance with the overseas importing country's requirements in order to facilitate exports of fresh fruit, dried fruit, vegetables and cut flower. It also inspects and carries out surveillance at seaports, airports, mail.
<p>Victoria</p> 	<p><u>The Plant Biosecurity Act 2010 and its regulations</u> protects the economy, the environment, social amenity or human health from negative impacts associated with the entry, establishment or spread of animal or plant pests and diseases or invasive plant and animal species.</p> <ul style="list-style-type: none"> • <u>Online links to South Australia</u> is managing the risks and potential harm to the economy, the environment and the community, of pests and disease, entering, emerging, establishing or spreading in SA. • <u>Plant Standards</u>. Victoria aims to minimize the impacts of plant pests and diseases on productivity, biodiversity and trade for the benefit of Victorian plant industries, communities and the environment. • <u>Green snail (Cantareus apertus)</u>, formerly <i>Helix aperta</i> is present in Victoria and. Restricted Areas have been declared in Victoria for its control. In Perth it has damaged pastures, vegetables, natural bush. Damage is similar to that caused by the common garden snail. Green snails are spread by <u>movement of infested plant material</u>, eg in hay bales, nursery stock or harvested vegetables, etc. • <u>An Asian black-spined toad (Duttaphrynus melanostictus)</u> was recently found in an outer Melbourne suburb (2014). Evidence of breeding won't be available until next summer.
<p>Western Australia</p>  <div style="border: 1px solid black; padding: 5px;"> <p>Lookout for the tropical fire ant. Nursery owners are being asked to lookout for the exotic tropical fire ant following the discovery of the potentially damaging pest at a wholesale nursery in Perth.</p> </div> <div style="border: 1px solid black; padding: 5px;"> <p>WA public has also been alerted to the cane toad.</p> </div> <div style="border: 1px solid black; padding: 5px;"> <p>The movement of all prickly pears (<i>Opuntia</i> sp.) and their seed is prohibited for all local authorities in areas north of the 26th parallel of latitude.</p> </div>	<p><u>Biosecurity and Agricultural Management Act 2007 (BAM Act)</u> has been developed in consultation with key industry groups, natural resource management and the community.</p> <ul style="list-style-type: none"> • <u>It replaces 17 existing Acts within the Agriculture Portfolio</u> and seeks to establish a modern biosecurity regulatory scheme to prevent serious animal and plant pests and diseases from entering the State and becoming established and minimize the spread and impact of any that are already present within the State. • <u>The Act also establishes controls in relation to agvet chemicals</u>, fertilizers and animal feeding stuffs and supports industry standards. • <u>Pre-border, border and post-border</u> biosecurity strategies include: <ul style="list-style-type: none"> • Identify key threats to productivity, sustainability and outlines preventative and response strategies. Involves development and implementing a biosecurity plan for each industry supplemented with farm biosecurity and regional biosecurity plans. • <u>Western Australia Quarantine and Inspection Service (WAQIS)</u>. Examples of breaches: <ul style="list-style-type: none"> • Many items of prohibited species weed seeds have been found during inspections. • Imported vegetables, pasture and crops seed rejected because of contamination. • <u>WAQIS</u> rejected a consignment of organic chicken feed found to contain sorghum seeds which require fumigation for sorghum midge prior to arrival. As the treatment had not been carried out the consignment was re-exported (2005). • A small survey of the potting mix taken from 15 consignments of nursery grown plants imported into WA and other states in Australia, found <i>Phytophthora</i> spp. were present in 25% of the samples. Plant pathogenic nematodes were isolated from 12 of 13 consignments (Davison et al 2006). • <u>Fruit fly exclusion zones</u> have been introduced to halt spread and damage to fruit crops. • WA is the latest State to issue a public warning about the <u>illegal sale of aquatic water weeds</u>. Salvinia was available for sale online incorrectly named giant duckweed. Salvinia is a declared <u>WONS</u>. Salvinia and water hyacinth weeds are prohibited in <u>WA</u>, prohibited from sale and must be destroyed when found. • <u>HortGuard</u> links to information on important pests, diseases and weeds.

BIOSECURITY - ON-FARM, ORCHARD, NURSERY

Entry and exit – Traceback and spread

If it can move, or be moved, it can carry diseases, pests and weeds. For this reason, people, animals, vehicles and equipment pose a high biosecurity risk and should be managed accordingly. Growers need to be able to list the inputs and outputs affecting the spread of pests, diseases and weeds relating to their crop or business. If a new pest becomes established in a production nursery, orchard, farm, it will affect business through increased costs (for monitoring, cultural practices, additional chemical use and labour to apply them), reduced productivity (yield and/or quality reductions) and / or loss of markets.

<p>Entry</p> <p>Farmers must be aware of the risk of weeds spreading through the use of stockfeed from outside their properties</p>	<p>Many pests, diseases and weeds are unwittingly <u>INTRODUCED</u> onto a property, eg</p> <ul style="list-style-type: none"> • Plants and plant materials, eg when purchasing plants and plant materials from wholesalers and retailers, eg seed may carry virus, bacterial and fungal diseases or insect pests or be contaminated with weed seeds. • Soil may contain weeds seeds, weed parts, soil borne diseases and pests, eg <i>Phytophthora</i>, black vine weevil. Soil may be spread in soil deliveries, pots and containers or adhere to boots, equipment, mowers, vehicle wheels and implements. Also in compost. • On-the job workers, visitors, contractors, itinerant and travelling farm workers, farm service providers, consultants etc. • Vehicles and equipment, eg mowers and harvesters may spread weed seeds, weed parts and pests carried on leaves, etc, eg phylloxera. • Livestock. Weed seeds may pass through animals. Feeding chaff to livestock. About 6% of viable ryegrass seed will pass through the gut of sheep and about 12% through cattle. Manure from animals fed nematode-infested potatoes may be infested.
<p>Exit</p>	<p>Many pests, diseases and weeds unwittingly <u>LEAVE</u> your property, eg</p> <ul style="list-style-type: none"> • Plants, nursery stock, cuttings, bulbs, corms and other vegetative plant material may carry all types of diseases and many insect pests. • Pests and diseases may leave your property in soil, water, on or in plants in containers, in or on produce. • Weeds may leave your property in soil or media in containers, on boots, tools, or adhere to vehicles, mowing and harvesting equipment, on plants, in fodder, by stock as weed seeds and weed parts. • Nurseries still sell some plants with a potential to become weeds in some regions.
<p>Traceback</p>	<p>Make sure protocols are in place to monitor the movement of plants and other nursery materials to track or contain a potential outbreak.</p>

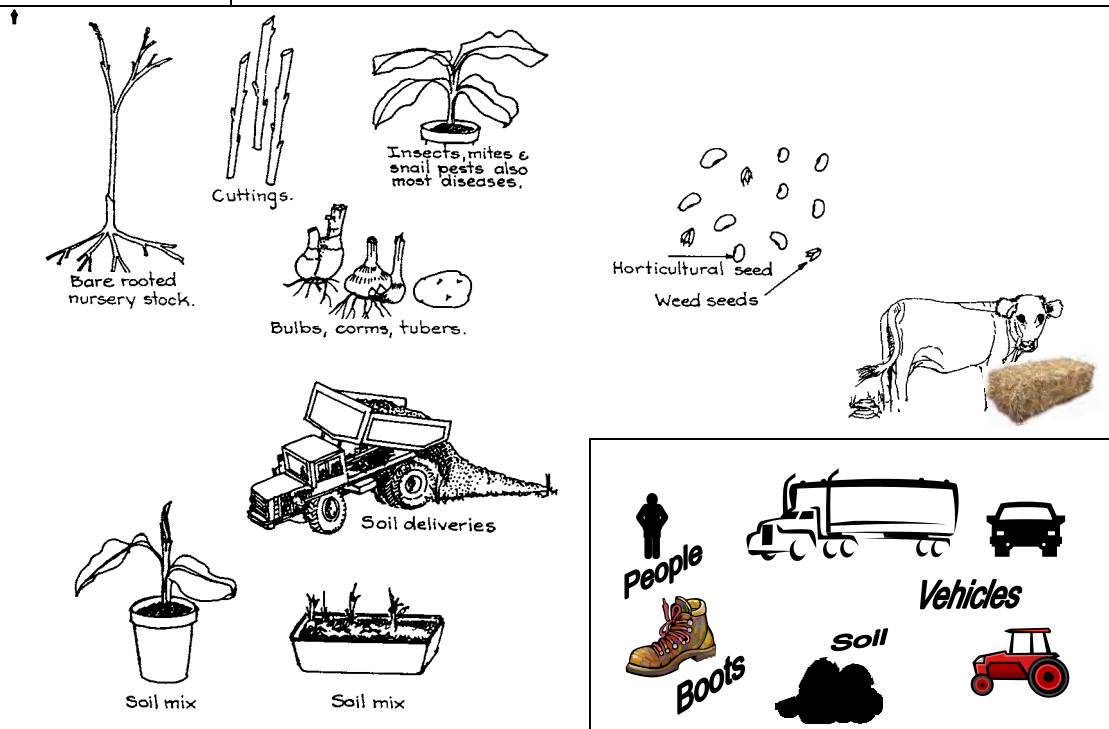


Fig. 21. Spread. A few examples of how pests, diseases and weeds may be enter or exit from your property (see also ages 223-225).

Biosecurity Reminders, Tips and Examples

Industry Biosecurity Best Practice is as much about managing the issues immediately surrounding the farm as it is about threats that may come in from interstate or overseas. Continual crop monitoring and good farm hygiene will help manage any new pests that do come onto a property (Norwood 2011). Set up everyday practices that reduce the risk to your property. Know the **pests, disease or weeds** you have to look out for in your **crop**.

Individual growers can benefit greatly by setting protocols for entry standards, eg request tests or certification for a specific disease or pest, or sighting of permits for harvesters, etc.

Industry Biosecurity Manuals



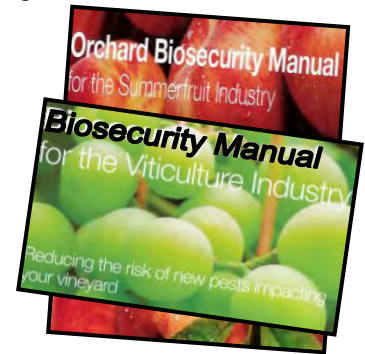
Wendy Unger

Information about on-farm biosecurity, including how to protect your plants from pests and diseases, and awareness materials, is available on the website.

www.planthealthaustralia.com.au/ www.farmbiosecurity.com.au/

Industry Biosecurity Manuals and related resources, including videos, etc relate to:

- Employing itinerant workers.
- Biosecurity for travelling farm workers.
- Biosecurity for on-farm service providers.
- Biosecurity measures for plants, animals, small farms and equipment.
- The nursery industry has developed **BioSecure HACCP** guidelines to assist production nurseries implement sound on-farm biosecurity measures. More information on **BioSecure HACCP** can be found at www.ngia.com.au
- Farm Biosecurity has produced **videos (online) and signs** to help producers take steps to reduce the risks posed by people, vehicles and equipment. The signs can be used to indicate to visitors the importance of following biosecurity procedures on your property.



Biosecurity on-farm

Exotic Plant Pest Hotline
1800 084 881

Report an unusual pest, disease or weed

Redline
1800 803 006

Breaches of Australian quarantine laws

6 routine practices for on-farm biosecurity reduce the threat of new pests impacting on your livelihood.


1. **Be aware of biosecurity threats** Make sure you and your workers are familiar with the most important exotic pest threats to you property. Conduct a biosecurity induction session to explain required hygiene practices for people, equipment and vehicles in your orchard.
2. **Use pest-tested propagation material.** Ensure all propagation material is from trusted sources and inputs are fully tested and preferably certified. Keep good records of your farm inputs.
3. **Keep it clean.** Practicing good **sanitation and hygiene** will help prevent the entry and movement of pests onto your property. Workers, visitors, vehicles and equipment can spread pests, so make sure they are decontaminated before entering and leaving your property. Have a designated visitor's area and provide vehicle and personnel wash-down facilities.
4. **Check your farm, crop, nursery, etc.** **Monitor** your plants frequently. Knowing their usual appearance will help you recognise new or unusual events and pests. Keep written and photographic records of all unusual observations. Constant vigilance is vital for early detection of any exotic plant pest threat.
5. **Abide by the law.** Respect and be aware of laws and regulations established to protect your industry, Australian agriculture and horticulture and your region.
6. **Report anything unusual.** If you suspect a new pest, report it immediately to the Exotic Plant Pest Hotline **1800 084 881**.

Visitors and workers



Sign©Plant Health Australia.

1. **Have a designated meeting or arrival area** on your property well away from your crop or plants. Consider holding an induction session for new workers that focuses on some simple biosecurity measures.
2. **Consider providing a wash-down area for cars** where the wash down water can be contained along with any dirt and seeds.
3. **Ask visitors or workers to check** that they are not carrying any seeds, grasses or other contaminants on their clothing or in their hair. Footwear is a major risk – make sure boots are free of soil, mud or seeds. A footbath with disinfectant is recommended.
4. Itinerant workers often have their own equipment. **Make sure their equipment is clean and free of any foreign matter** before using it on your plants. Wiping the equipment over with a farm-grade disinfectant is recommended.
5. **Consider placing signs or posters in appropriate areas** on you property that will remind people to carry out the above biosecurity measures.
6. **Keep a record of who is coming into your property**, eg date of arrival, and departure, where they came from before working on your property and where they intend going next. Contact details such as mobile phones numbers are crucial during a pest outbreak and can significantly improve the chances of containment and eradication.

<p>Surveillance, monitoring, recording</p> <p>Exotic Plant Pest Hotline 1800 084 881 Report an unusual pest, disease or weed</p> <p>Continual crop monitoring and good farm hygiene will help manage any new pests that come onto a property.</p>	<p>Inspecting crops and plants regularly for pest and disease symptoms is important.</p> <ul style="list-style-type: none"> The early detection and containment of a weed, pest or disease is essential to prevent its spread and assists in eradication efforts by agricultural authorities. What to do if you spot anything unusual: <ol style="list-style-type: none"> Report the suspect weed, pest or disease by phoning the Exotic Plant Pest Hotline 1800 084 881 or contact your local agricultural department. Take reasonable action to isolate the problem area and to minimize spreading the pests or disease do not touch or disturb the site. Describe the detection site in sufficient detail to allow a person to return to the exact location if necessary. You can tag or mark the site with a non-degradable ribbon or flag to assist relocation. Or mark the detection site on a map or sketch a map. Take note of the symptoms and the plant upon which you found the pest. Clean any boots, clothes and equipment that have been used on soil and plant material at the site. While waiting for confirmation of a pest, use the following precautionary measures: <ul style="list-style-type: none"> Restrict operations in the area by withdrawing people, vehicles and equipment from the area. Limit access to the area to agricultural department authorities only. Clean and disinfect your hand, clothing and any equipment that has been in contact with the affected area. Apply interim control and containment measures as advised by your agriculture authority.
<p>Piggy-backing on other programs</p>	<p>The Birdwood tropical and subtropical fruit production nursery produces more than 150,000 trees annually.</p> <ul style="list-style-type: none"> In 2006 it became one of the first nurseries to achieve EcoHort certification which is the national environmental management system for production nurseries, growing media manufacturers and greenlife markets. In 2011 it implemented BioSecure HACCP which aims to maintain the production site and nursery stock free of unwanted pest, disease and weed threats by prevention, early detection and planned managed responses which maintain the biosecurity integrity of the business (<i>Biosecurity Champions</i>. Aust. Hort. Oct 2011).
<p>Changes in biosecurity status</p>	<p>Growers are always modifying their enterprise mix, trying new crops, new practices and perhaps adding or removing livestock. These changes may affect a farm or district's biosecurity status.</p>
<p>Eucalypt rust Myrtle rust</p>	<p>Tasmania, SA and WA want to develop a pre-emptive approach in case the rust reaches them (Shaw 2013).</p> <ul style="list-style-type: none"> NGIA has requested a standardized disease rating system to be applied across Myrtaceae species to enable trade in disease-free species and provide advice, to councils, etc on the level of myrtle rust susceptibility or tolerance for a particular species and varieties. A resistance breeding program is part of the National Transition to Management Program. http://myrtlerust.net.au
<p>Papaya fruit fly NAQS case study</p>	<p>Papaya fruit fly (<i>Bactrocera papaya</i>) response to an incursion.</p> <ul style="list-style-type: none"> Impact: an estimated \$A100 million through increased production costs and losses, and reduced access to international markets for many horticultural products (2005). Pathway: Smuggled fruit. Detection: Late, by a grower after the pest had established (more than 1 year after entry). Surveillance: Extensive lure trapping. Diagnostics: The world authority is Australian. Quarantine: Strict controls on imported horticultural host commodities; strict internal controls on movement of product outside of the infested area. Eradication: Lure and insecticide treatments; \$A35 million over four years.
<p>Bunchy top disease of bananas</p>	<p>Protecting Qld's banana industry from the devastating bunchy top virus disease by implementing the following quarantine procedures where necessary, eg</p> <ul style="list-style-type: none"> Banning the growing of all species of ornamental bananas in Qld. Prohibiting the cultivation of all banana species except those being grown for fruit, including <i>Ensete ventricosum</i>, a closely related plant.
<p>Take time to update on control methods</p> <p></p>	<p>Control methods include:</p> <ul style="list-style-type: none"> Cultural Sanitation Biological control Resistant varieties Biosecurity Disease-tested plant material Physical methods Pesticides <p>Start with:</p> <ul style="list-style-type: none"> SANITATION followed by DISEASE-TESTED PLANTING MATERIAL, then RESISTANT VARIETIES, etc. <div style="border: 2px solid red; padding: 5px;"> <p style="text-align: center;">VISITORS</p> <p style="text-align: center;">PLEASE RESPECT FARM BIOSECURITY</p> <p style="text-align: center;">Please phone or visit the house before entering.</p> <p style="text-align: center;">Do not enter property without prior approval. Keep to roadways and laneways.</p> <p style="text-align: center;"><small>Plant Health</small></p> </div>

PROS, CONS AND CHALLENGES

PROS

- **Most countries** attempt to protect commercial crops and native flora from exotic economic pests.
- **Effective biosecurity** can reduce pesticide use.
- **Biosecurity reduces exotic pest incursions** which may reduce cost of production and impact on trade.
- The number of serious exotic pests **not known to occur in Australia** is estimated to be several hundred.
- **Biosecurity within Australia prevents spread** of quarantine pests within Australia.
- **Cost of eradicating or managing** a pest or disease once it is established is much greater than keeping it out of the country.
- **Phytosanitary certification** allows Australian produce into markets which would be otherwise closed to it for quarantine reasons. It also allows Australia to import plant material in a similar manner.
- It can be easier **to certify organic** produce if there are fewer pests to be managed.
- On entry of new pest, it may not be possible to grow some crops economically until **resistant varieties** have either been developed locally or imported from overseas.
- **Exporting** countries must inform **importing** countries about **exports of chemicals banned** or severely restricted in the exporting country.

CONS

- **Biosecurity does not guarantee** that exotic pests will not enter Australia, it reduces the risk.
- **Concept of free trade** can put undue pressure on biosecurity risk analysis.
- Some **overseas companies may fail** to meet Australia's standards for overseas treatments (they are suspended).
- If a large consignment of infected material is widely distributed in Australia, say via nurseries, it may be impossible to contain some disease outbreaks.
- **Quarantine treatments may damage products**, eg heat treatments.
- **After an accidental introduction**, biosecurity regulations can be **onerous and expensive**. A national survey to detect **fire blight** covered almost 6 million trees.
- **Certification procedures** necessary to prevent spread of pests can also be costly.
- **Established pests are difficult to eradicate**. Generally suppressing pests to economically acceptable levels is more practical than complete **eradication**.

CHALLENGES

- Unrealistic expectations by scientists, growers and the community. **No country can stop every thing**. Incursions are a fact of life for any biosecurity system.
- Explaining to the community, industry, and advisors the **way risks are calculated**.
- **Biosecurity is constantly changing** due to new pests, new knowledge, and new pathways into Australia, etc. It is difficult to keep ahead of pests, agronomic practices and human behaviour (McNee 2012).
- **Rust diseases which are spread by windborne spores** and with a **very wide host range** of cultivated and bush species **would likely not be amenable to eradication**, especially if it had been in the country some time before being detected.
- **Developing alternative strategies** for eradication other than crop removal and applying broad spectrum pesticide, especially in perennial crops.

- **Some cut flower growers want** the federal government to bring certification; fumigation and revitalization services back to Australia from the country of origin and allowed **DA** accredited treatment premises to undertake treatment before flowers enter Australia.
- **Biosecurity protocols** may not be properly carried out, eg cleaning and disinfecting boots or cleaning vehicles when entering to prevent spread or new pests, diseases and weeds. Records of visits which are important in trace back to properties are not always kept, indicating a need for further training and consideration of likely human factors.
- **A case for re-inventory of Australia's plant pathogens** has been made (validate any suspect identifications). This would be time consuming, involving specimens being re-collected, re-isolated and subjected to DNA analysis and living culture, but is necessary for some pathogens.
- **Mis-identification of an exotic pest species** poses as much of a threat to trade as the actual presence of the pest species. Much of the investment in biosecurity relates to improving the accuracy, reliability, accessibility and speed of **diagnostic tests**. These new tests can also demonstrate and potentially certify that product is free from a specific pest at the point of export (Rainbow 2011).
- **Forest insect and pathogen species** are expanding their geographical ranges through international trade at an alarming rate. Some exotic pests have had catastrophic impacts on ecosystem functions when they invade native communities in which they have no prior evolutionary history, eg chestnut blight in North America, Dutch elm disease in Europe and North America, jarrah dieback in WA and pine wood nematode in Asia (Britton and Liebhold 2013). What to do?
- **Predicting which insects or pathogens** will become most problematic and devising mitigation measures to reduce the risk of their arrival and establishment has become the **'holy grail'** of plant pathologists and entomologists.
- **Many consider that Australia needs a new approach** to tackling its growing and worsening environmental pest problems. The **Invasive Species Council** have proposed a national taskforce called **Environment Health Australia** to stem the rising tide of environmental pests. www.invasives.org.au Various publications including 2 senate committees have provided some answers (Selected Resources).
- **Australia is vulnerable** to emerging and changing pest threats due to climate change and other factors.
- **Inadequate funding for eradication programs** for nationally significant pests is a constant complaint.
- Some pests, eg some rusts are not amenable to eradication.
- **Control of a new exotic pest may be difficult** because of resistance to pesticides.
- **Senate Committee. 2004. Turning Back the Tide – the Invasive Species Challenge**, Commonwealth of Australia. Report on the Inquiry into the regulation, control and management of invasive species and the Environment Protection and Biodiversity Conservation Amendment (Invasive Species) Bill 2002 establishes beyond any doubt Australia's vulnerability to emerging pest threats. Providing an efficient and coordinated delivery of programs is a big challenge.
- **Biosecurity taking some responsibility** for managing some key pests within Australia seems a sensible step to prevent their spread.

REVIEW QUESTIONS AND ACTIVITIES

Australian Department of Agriculture

1. Name the governing biosecurity legislation.
2. Explain **offshore, border and onshore** biosecurity and describe the roles of each.
3. Explain the meaning of a **phytosanitary certificate**.
4. Name at least **2 serious exotic diseases, pests or weeds** which are **not known to occur in Australia**.
5. Advise a member of the public **how to legally import** seeds and other plant material into Australia.
6. Advise a traveler on what would happen to these items **on arrival in Australia** without a permit:
Fresh fruit Dried flowers Seed soil
7. **Explain the role** of prohibition, inspection, treatment and post-entry quarantine in **border biosecurity**. Give 1 example of each.
8. Name at least **2 pests, diseases and weeds present in Australia** subject to quarantine regulations of an **overseas country**.
9. Advise a member of the public **how to legally export** seeds and other plant material out of Australia.

States / Region Biosecurity (Quarantine Domestic)

10. Name 2 serious diseases or pests which **occur in your State** but not in some other States of Australia.
11. Advise a member of the public on how to **legally import plants** from another state into your state.
12. Advise a grower on how to **legally export plant material** from your state into another state.

On-farm, orchard, nursery biosecurity

13. Describe at least 4 ways by which you could **accidentally introduce** diseases, pests or weeds **into** your farm, nursery or orchard. Name the problem(s) likely to be introduced in each instance.
14. Describe at least 4 ways by which you could **accidentally** spread diseases, pests or weeds **from** your property to other areas of Australia or overseas. Name the problem(s) likely to be spread.
15. **Perform practical exercises** in biosecurity.

SELECTED RESOURCES

- AgGuide series. 2013. *Machinery Hygiene: Inspecting and Cleaning Machinery to Prevent the Spread of Weeds, Pests and Diseases*. NSW DPI.
- AS/NZS 294:2006. *National Post-Border Weed Risk Management Protocol*.
- AS/NZS ISO 31000:2009. *Risk Management - Principles and Guidelines*.
- Australian Biosecurity Group. 2005. *Invasive Weeds, Pests and Diseases: Solutions to Secure Australia*. Invasive Animals CRC; Weeds CRC; WWF Aust.
- Baxter, L. 2011. *Plant Pathology Research and Capacity Building in Developing Countries: Issues and Opportunities*. Aust. Plant Path. 40(4).
- Beale, R., Fairbrother, J., Inglis, A. and Trebeck, D. 2008. *One Biosecurity: A Working Partnership*. Commonwealth of Australia.
- Britton, K. and Liebholt, A. M. 2013. *One World, many Pathogens!* New Phytologist 197, 9–10.
- Carnegie, A. J. and Cooper, K. 2011. *Emergency Response to the Incursion of an Exotic Myrtaceous Rust in Australia*. Keynote Paper. Aust. Plant Path. 40:346-359.
- Carnegie, A. J. and Lidbetter, J. 2012. *Rapidly Expanding Host Range for Puccinia psidii sesu lovato in Australia*. Aust. Plant Path. 40(1).
- Casey, P. and Henderson, W. 2012. *Biosecurity Threats of Vertebrate Pests in Australia*. Ecos. 20 Feb.
- Davison, E.M., Drenth, A. Kumar, S., Mack, S., Mackiue, A. E. and McKirdy, S. 2006. *Pathogens Associated with Nursery Plants Imported into WA*. Aust. Plant Path. 35(4).
- Dobson, A., Barker, K. and Taylor, S. L. 2013. *Biosecurity: The Socio-Politics of Invasive Species and Infection Diseases*. Vol.1. Rutledge, Taylor & Francis Group. Series of books.
- Gordh, G. and McKirdy, S. 2014. *The Handbook of Plant Biosecurity: Principles and Practices for the Identification, Containment and Control of Organisms that Threaten Agriculture and the Environment Globally*. Springer.
- Jay, C. 2012. *Biosecurity Risk Analysis a Tough Task*. AFR. 25 May 2012.
- Keogh, R. C. 2012. *An Invasive Risk Assessment Framework for New Animal and Plant-based Production Nurseries*. RIRDC. Canberra.
- McNee, W. 2012. *No Country Can Stop Everything*. The Press, Christchurch. 20 Jul.
- McIntyre, K. 2010. *Surveillance Key to National Biosecurity*. Qld Country Life. 16/12/2010.
- McRae, M. 2013. *Whatever Happened to Myrtle Rust?* Ecos 21 June.
- Narayanasamy, P. 2001. *Plant Pathogen Detection and Disease Diagnosis*. 2nd ed. Marcel Dekker.
- Norwood, C. 2012. *Plant Biosecurity needs Neighborly Approval*. Ground Cover. Nov-Dec.
- Price, T. V. (ed.). 2006. *Pest and Disease Incursions: Risks, Threats and Management in New Guinea*. ACIAR.
- Rainbow, R. 2011. *Prevention is Better than Cure*. Ground Cover 90 - Biosecurity Supplement. Jan-Feb.
- Santini, A. et al. 2013. *Biogeographical Patterns and Determinants of Invasion by Forest Pathogens in Europe*. New Phytologist 197, 238–250.
- Secretariat of the IPPC. 2005. *Identification of Risks and Management of Invasive Alien Species using the IPPC Framework*. Proc. from a Workshop in Braunschweig, Germany Sept. 2003. FAO.
- Senate Committee. 2004. *Turning Back the Tide – the Invasive Species Challenge*. Com. of Australia.
- Senate Committee. 2007. *Government Response. Turning Back the Tide: The Invasive Species Challenge*. Com. of Australia.
- Shaw, K. 2013. *Myrtle Rust Research Update*. HMA News Sept.
- Thompson, M. 2010. *Remote Microscopy Web-based Microscopy brings Finer Focus to Biosecurity*. Ecos 25 Oct.
- More resources on DA Biosecurity website**, eg www.agriculture.gov.au/ www.farmbiosecurity.com.au/
Biosecurity in Practice: Making Decisions, Making Choices
Biosecurity: A Working Partnership 2008
Reform of Australia's Biosecurity System – An Update Since the Publication of One Biosecurity: A Working Partnership 2012
Plant Health Australia www.planthealthaustralia.com.au/
Industry Biosecurity Plans
Industry Biosecurity Grower Manuals
National Plant Biosecurity Diagnostic Network (NPBDN)
Import Risk Analysis Handbook
National Plant Biosecurity Strategy (2010)
National Plant Biosecurity Status Reports (annual)
Biosecurity Annual Report
Biosecurity Bulletin, Bowerbird, PaDIL, Atlas of Living Australia
Plant Protection News
Plant Protection Quarterly
Tendrils
The Australian Handbook for the Identification of Fruit Flies
Forests and Timber: A Field Guide to Exotic Pests and Diseases
International Plant Protection Convention (IPPC)
NGI Quarantine and Biosecurity Policy Position
Invasive Plant Risk Assessment Tool www.plantrisktool.com

DISEASE-TESTED PLANTING MATERIAL



INTRODUCTION	206
Disease-free or disease-tested?	207
CONTAMINATED PLANTING MATERIAL	208
Vegetative planting material	208
Seed	209
Testing planting material for diseases, pests and weeds	212
TREATMENTS TO ELIMINATE DISEASES AND PESTS	213
Disinfestation	213
What is disinfestation?	213
Mechanical means	213
Heat treatments	213
Non-systemic chemicals	213
Disinfection	214
Heat treatments	214
Systemic chemicals	215
Tissue propagation systems	216
How do they work?	216
Tip cuttings, grafting, seedlings	216
Meristem culture, tissue culture	217
Meristem culture <i>FOLLOWING</i> heat treatment	217
AREA FREEDOM	218
Evasion or avoidance	218
Exclusion zone	218
Area freedom	218
Toolangi Plant Protection District	218
National Fruit Fly Strategy (NFFS)	218
CERTIFICATION SCHEMES	219
Seed certification schemes	221
Vegetative propagation certification schemes	222
MANAGING DISEASE-TESTED PLANTING MATERIAL	223
Preventing re-infection or re-infestation	223
Industry testing services	223
Sources of re-infection and re-infestation	223
Preventing re-infection and re-infestation	224
Using certified plant material	226
PROS AND CONS AND CHALLENGES	227
REVIEW QUESTIONS AND ACTIVITIES	228
SELECTED RESOURCES	228

INTRODUCTION

Every plant and crop grows and yields better if the propagating material, the soil, water and air are **free of the key economic pests, diseases, weeds and other problems** affecting that plant or crop. Every effort should be made to obtain and use **tested seed and nursery stock**.

Legislation, standards, codes, improvement schemes



CODES OF PRACTICE

Various types of Commonwealth and State / Territory legislation regulate the production and sale of planting material to growers, eg

- **Horticultural Stock and Nurseries Acts and Regulation** in some States / Territories provide for the **registration** of nurserymen and resellers of some types of horticultural stock to ensure that as far as possible, propagating material is the best available with regard to **certification** (freedom from disease) and **trueness-to-type**.
- **Seeds Acts** prohibit the sale of noxious weed seeds, of agricultural seeds mixed with noxious weed seeds or containing more than a specified proportion of other weed seeds.
- **The Trade Practices (Horticulture Code of Conduct) Regulation 2006** aims to improve clarity and transparency of transactions between growers and wholesalers of fresh fruit and vegetables. The code is mandatory under the Competition and Consumer Act 2010 and enforced by the Australian Competition and Consumer Commission.
- **Horticulture Marketing and Research and Development Services (Repeals and Consequential Provisions) Act 2000**.

Codes of practice include:

- **National Code of Practice - Labelling and Marketing Seed for Sowing (The Code) 2010** requires that a person shall not sell seeds contained in a parcel unless there is clearly written or printed thereon, or on a label securely attached thereto, a statement setting out the particulars that ensure that consumers are provided with consistent and accurate information to enable them to make informed decisions about the suitability of seed for sowing, eg crop species, cultivar, pure seed (min%), etc. A seed testing analysis certificate is to be available upon request.
- **The National Code of Practice for the Use of Seed Treatments** aims to ensure that all treated seed for sowing sold under the **Australian Seed Federation (ASF)** logo has been treated safely, accurately and efficiently in accordance with current regulatory and industry best practice.

Plant improvement schemes, eg

- Vine Improvement Schemes and Associations.
- Ornamental Improvement Schemes.
- Nursery Accreditation Schemes.



These and similar Acts, their Regulations and Codes of Practice, include requirements for appropriate:

- **Seed of varieties accepted by OECD** authorities which is produced in accordance with their rules may be labeled with **OECD** certification labels providing immediate **international acceptance**.
- **Records** to be kept.
- **A range of Certification schemes** which specify different requirements (page 219).

Computing, communication, technology



Keeping accurate records of the history of planting material of all types, eg seeds, nursery stock, etc, is an essential part of successful crop production. Records include:

- **History and date of purchase** of certified planting material.
- **Documentation** of improvement schemes, certification schemes.
- **History and updating of testing procedures** to ensure continued disease, pest and weed freedom.
- **Computing has facilitated the development of fast and accurate diagnostic tests** to ensure planting material is free of specified pests and diseases.

Quality assurance (QA)

Growers must be supplied with QA "tested" planting material, ie material free of specified pests, diseases and weeds. Other contaminants are frequently tested for in **QA** schemes, eg

- **Presence of Genetically Modified Material** in non-GM crops (Best Practice Guidelines for Management of Adventitious Presence in Canola Varieties).
- **Pesticides** (Maximum Residue Limits (MRLs) and other contaminants).
- **Traceability of organic seed**.
- **Varietal correctness**, eg grafted varieties with wrong rootstock or wrong scion. Olive varieties can now be confirmed by DNA testing.
- **Mycorrhizal incompatibility**, eg truffles.
- **Penalties may apply** under certain conditions if growers have been sold contaminated guaranteed disease-tested planting material.

Disease-free or disease-tested?

Many **diseases, pests and weeds** are carried over between crops or to new areas in, on, or in association with, seeds, buds, bulbs, corms, cuttings, rhizomes, rootstocks, tubers, **in soil in container stock and on boots, equipment**, etc. All growers should be aware of how the key diseases and pests in their crops are **spread**.

Disease-free planting material

The term 'disease-free' could imply that seed or vegetative propagation material is free from **all** diseases or pests. However, this is usually not practical; also methods used to eradicate even known diseases from plant material are not always 100% successful!

Disease-tested planting material

Disease-tested planting material has undergone therapy or been grown in special areas to **free** it from **specified diseases** and then **tested** to see if the treatment has been successful.

HIGH HEALTH
VIRUS-TESTED
ELITE STOCK

Planting material found to be free from the diseases for which it has been **tested** is called:

- **Disease-tested.** This term is a **general term** used to include plant material of all types which has been **tested** and found to be **free** from **specified** diseases. However, it may carry other diseases and pests for which it has **not been tested**.
- **Pathogen-tested (PT).** This term has usually been applied to **ornamental plants** which have been tested and found to be free from specified diseases.
- **Virus-tested.** This term has usually been applied to **ornamentals, fruit and vegetable** crops which have been tested and found to be free from specified viruses. Nursery people and orchardists are increasingly aware of the value of using virus-tested rootstocks and scions to produce quality trees and improve productivity. Virus-tested plant material improves fruit quality and stock and scion compatibility.

The term DISEASE-TESTED includes plant material of all types which has been TESTED and found to be FREE from SPECIFIED DISEASES AND PESTS.

It may carry other diseases and pests for which it has NOT BEEN TESTED.



Keeping accurate records of the history of all types of planting material, eg seeds and nursery stock, is an essential part of successful crop production.

- When certified plant material was purchased.
- Information on improvement schemes, certification schemes.
- Fast and accurate diagnostic testing of plant material.

Other pests and diseases. Efforts are made to ensure that disease-tested plant material is as free from as many other diseases and pests and weed contamination as possible.

Improving the quality of planting material. eg

- Diagnostic tests are improving all the time.
- Techniques of testing and treating seed are improving.
- Nursery stock is better able to withstand transplanting.

Tolerance levels

No guarantee can be given that any **seed** sample is **absolutely free** of **specified diseases**.

- **There are prescribed maximum tolerances** for certain diseases at field inspections.
- **Zero tolerances** may only apply to certain diseases, which if detected on a property could result in severe quarantine restrictions.
- **Seed testing and treatment methods are not fool proof nor 100% effective** (page 211).
- **It can be difficult to obtain a representative sample** of seed for testing. This can be partially overcome by statistical analysis of a large number of samples.
- **Seek advice** regarding standard procedures for obtaining samples.

CONTAMINATED PLANT MATERIAL

Vegetative plant material

Vegetative propagation material such as bulbs, corms, , rhizomes, cuttings, nursery stock, rootstocks, budwood, grafting material, tissue cultures, can be expected to carry **internally** almost every virus, bacterial and fungal disease and nematodes present in the parent plant, this is in **addition** to diseases, nematodes, insects, mites and weed seeds that may be present **externally**. The more widely a particular variety has been grown, and the longer it has been in cultivation, the greater the chance that it will have accumulated an assortment of 'disease' organisms which can be passed on directly to new plants, so that all individuals in a crop may become diseased.

Diseases and pests



Stem and bulb nematode damage to a daffodil bulb. Bulb cut longitudinally to show browning of scales.



Root knot nematode damage to a potato tuber.

Examples include:

- **Daffodils bulbs** may carry:
 - Several virus diseases.
 - Fungal diseases, eg basal brown rot (*Fusarium oxysporum* f.sp. *narcissi*).
 - Stem and bulb nematodes (*Ditylenchus* spp.).
 - Insect and mite pests, eg bulb mite (*Rhizoglyphus echinopus*).
- **Chrysanthemum setts** may carry:
 - Several virus diseases.
 - Most of the fungal and bacterial diseases which attack chrysanthemum.
 - Foliar nematodes.
 - Several insect pests, eg cineraria leafminer (*Chromatomyia syngenesiae*).
- **Carnations cuttings** may carry:
 - Several virus diseases.
 - Most of the fungal and bacterial diseases which attack carnation including *Fusarium* wilt (*Fusarium oxysporum* f.sp. *dianthi*).
- **Rose cuttings** may carry:
 - Several virus diseases, especially *Prunus* necrotic ringspot.
 - Fungal diseases, eg black spot (*Marssonina rosae*).
 - Insect and mite pests, eg rose scale (*Aulacaspis rosae*).
- **Bare-rooted apple nursery stock** may carry:
 - Several virus diseases.
 - Fungal diseases, eg apple scab (*Venturia inaequalis*).
 - Insect pests, eg San Jose scale (*Quadraspidiotus perniciosus*), woolly aphid (*Eriosoma lanigerum*).
- **Strawberry runners** may carry:
 - Many virus diseases.
 - Fungal diseases, eg fungal leaf spots, *Phytophthora* root rot, various nematodes.
 - Mite pests, eg European red mite (*Panonychus ulmi*).
- **Seed potatoes tubers** may carry:
 - Many virus diseases, especially potato leaf roll virus (PLRV), some are spread by insects.
 - Some bacterial and fungal diseases are also spread by water, wind and other insects so that some re-infection occurs.
 - Diseases, eg root knot nematodes (*Meloidogyne* spp.).
 - Insect pests, eg potato moth (*Phthorimaea operculella*).

Disease-tested scion and a disease-tested rootstock

"Total Clean Concept"

Nursery people, orchardists and viticulturists are aware of the value of using disease-tested rootstocks and disease-tested-scions to produce quality trees and improve economic productivity, eg

- **It improves stock and scion compatibility**, reduces budding failures and improves uniformity in trees by reducing stunting and distorted growth.
- **Fruit quality is improved**, eg a number of virus infections produce symptoms such as pitting, russetting and cracking which reduce the marketability of the product and may reduce storage life.
- **Ideally, all peach seed used for rootstocks should come from a virus-tested source** and only virus-tested budwood should be budded onto those rootstocks.
- **There are a number of graft-transmissible disease agents** which are endemic to Australian viticulture and adversely affect yield and vigor, eg leafroll virus complex, and crown gall disease (*Agrobacterium tumefactions* biovar (AT3). Disease-tested scion / disease-tested rootstock combinations are compromised if:
 - **Diseased or graftwood of unknown disease origin** is used in graft combinations with clean material and if:
 - **Clean material is planted** directly into soils containing crown gall residue populations.
- **Note:** Prune dwarf virus and *Prunus* necrotic ringspot virus are also **transmitted through pollen and seed**.

Seed

Seeds may be contaminated with virus, bacterial and fungal diseases, nematodes, insects, mite pests and weed seeds and are therefore an ideal vehicle for the introduction and spread of new diseases, pests and weeds into 'clean' areas or for their re-establishment in already infested areas. **May be a problem for export markets.**

Disease contamination

Always check the disease status of seed before planting

With seed-transmitted and especially insect-borne viruses, seed must be free of pathogens, especially virus diseases, otherwise disease organisms will be present in the field at the beginning of the growing season, and **even a small proportion** of infected seed is sufficient to provide enough inoculum to spread and infect many plants early, causing **severe losses**.

- **Disease organisms can be carried** in dirt and trash around seed or on the outside of the seed coat. They can also be carried in the seed coat or deep inside the seed tissues. Sometimes contaminated seed is discolored but signs of most disease-causing organisms cannot be seen on seeds.
- **Examples** of seedborne diseases include:
 - Brassicas - At least 9 seedborne diseases
 - French bean - At least 12 seedborne diseases
 - Pea - At least 8 seedborne diseases
 - Snapdragon - At least 2 seedborne diseases
 - Tomato - At least 21 seedborne diseases
 - Wheat - Many seedborne diseases, eg smuts, bunts, etc

Insect contamination

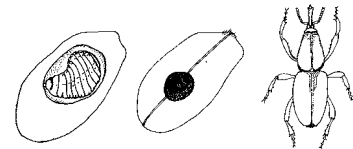
The Khapra beetle (*Trogoderma granarium*) - not yet in Australia - is one of the world's most destructive pests of grain products and seeds

Insect pests are commonly associated with seed, eg

- Argentine stem weevil (*Listronotus bonariensis*) in ryegrass seed.
- Parsnip seed wasp (*Systole* sp.).
- Mango seed weevil (*Sternochaetus mangiferae*).
- Pea weevil (*Bruchus pisorum*).

Stored grain pests:

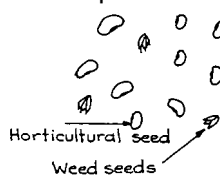
- **Primary pests** attack and destroy sound unbroken seeds, eg granary weevils (*Sitophilus* spp.), maize weevil (*S. zeamais*), rice weevil (*S. oryzae*).
- **Secondary pests** are mostly surface feeders in both adult and larval stages, eating damaged, moist and out-of-condition grain and stored food products, eg driedfruit beetle (*Carpophilus hemipterus*), warehouse beetle (*Trogoderma variabile*).
- **Locusts in crop seed.** Receival standards vary with crop type, eg
 - **Cereal crops** - the maximum allowed live or dead insects is **3 field insects** per half litre of grain or seed – one locust counts as one field insect.
 - **Canola limit** is 10 large field insects per half a litre of grain or seed including hoppers.
 - Check withholding periods if considering spraying for late-arriving locusts.



Rice weevil (*Sitophilus oryzae*)
Left to right: Larva, exit hole, adult.

Weed seed contamination

As a seed industry we need excellent hygiene – weed-free crops are essential



Some growers might unknowingly be harvesting herbicide-resistant weed seed and sowing it back into cropping paddocks (Baxter 2011). Other problems include:

- **Most growers use contractors to clean seed but 74% of cleaned samples checked were contaminated with weeds.** Seed cleaning does reduce weed seed numbers, but only seed from weed-free paddocks and cleaned effectively before sowing, should be retained to minimize weed seed carryover.
- **Australian lucerne seed sales to the USA can be jeopardized by seed contamination** from the weed *Setaria verticollata* (love grass). *Setaria* sp. is a prohibited weed in the US; so there is nil tolerance by US markets for contaminated pasture seed.
 - **A rejected shipment** must be returned to Australia or sold on to a country which will accept contamination by the weed.
 - **Current seed cleaning** procedures in Australia do not guarantee 100% *Setaria* freedom.
 - **The most effective strategy** to eliminate contamination has been found to be by **effective field control of the weed**. The lowest incidence of *Setaria* sp. seed in uncleaned seed samples was achieved with a combination of pre-emergent and post-emergent herbicides.

Variety contamination, saving seed

Undesirable variety, adventitious GM material

Growers need to ensure varietal purity and correct identification of seed used for sowing

Plant or crop seed may be contaminated with undesirable varieties, adventitious GM material or a variety may be just wrongly labeled.

- **Growers of conventional or organic canola** have problems with contamination with **GM canola** planted close by. Testing can be difficult and there is a tolerance level (page 415).
- **Wheat crops may not be the variety specified** or be contaminated with other varieties. A 2010 stripe rust outbreak scare in the wheat variety **Sunvale**, rated moderately resistant (MR) to all current races of the disease, triggered research that found widespread seed impurity in commercial crops. The investigation found that:
 - **Sunvale resistance had not broken down**, but that many so-called Sunvale crops were heavily contaminated with other varieties or were other varieties entirely. The stripe rust fungus was largely infecting **susceptible non-Sunvale plants**.
 - **Sunvale was commercially released in 1995**. Its 16 years of commercial production becomes an illustration of how contamination can build up at harvest, handling (often several times), storage, labeling, grading, delivery and sowing (Freebairn 2012).

Organic seeds and traceability	<p><u>This remains an issue for organic growers.</u> Has the seed been grown according to organic production methods, seed bred to organically accepted methods and / or seed varieties adapted to organic agriculture conditions with low-external inputs? Issues include:</p> <ul style="list-style-type: none"> • Organic seeds should be purchased when available. The reality is that the Australian standard with regards to seed, allows growers to access varieties they need. • It is critical though, that growers producing for export markets realize there are differences in operations relative to the sourcing of seed that must be considered. Registered Plant Variety Rights (PVR) for organic seeds used by growers to claim royalties and fund the developed plant with particular characteristics will also need volume to develop. • There is a breeder right on one species of Nemkat, a nematode resistant variety for cane sugar country but without high volume, the breeding program is expensive. • Organic seed currently relies on breeding that comes from public varieties.
Florabank Native seed	<p><u>Florabank is Australia's premier resource for native seed</u>, encouraging quality and choice for buyers of native Australian seed. It is an initiative of the Australian Government, Greening Australia and CSIRO (page 159).</p> <ul style="list-style-type: none"> • Florabank aims to improve availability and quality of native seed used for revegetation and conservation and to provide technical support to community groups that collect, handle and store seed for revegetation. Florabank also trains seed professionals. • Seed suppliers are available on the Florabank website. www.florabank.org.au
Doomsday vault	<p>The <u>Svalbard Global Seed Vault in a Norwegian island</u> is only one of the many 'vaults' of samples of the world's most important seeds to protect food crops from disease, climate change, natural disasters and war (page 151).</p>
Timing when to test seed for diseases and pests	<p><u>Germination % should be checked at harvest, during storage and before sowing.</u> Low germination seed should not be used.</p> <ul style="list-style-type: none"> • Seed testing should be done as soon as possible after harvest to identify the best seed for cleaning and testing, eg establishes true disease risk. • Buying the seed. Check the disease level of seed before purchase or bringing it into an uncontaminated area where the crop has not been grown before. Seed is the most likely source of a new disease. Once established, other hosts, volunteers or residues may harbor the pathogen helping the disease to flourish. • Highly susceptible host plants. Seed testing allows growers to minimize risks of disease from aggressive pathogens in susceptible varieties. Even when the initial inoculum levels are low, diseases such as bacterial blight of peas can decimate production under the right seasonal conditions. • High disease environments. Identifying seed with low inoculum levels minimizes the risk of a disease outbreak – even if weather conditions are favorable. • Saved seed following disease outbreaks. If saving you own seed then testing is particularly important following disease outbreaks in the previous season. Early testing is recommended in case you need to source alternative seed. • Interstate and international biosecurity. Seed for export to interstate or international markets may require a disease certification. • Testing seed before sowing is a vital link in <u>Integrated Disease Management (IDM)</u>. • Post sowing. Curative treatments may be required. Fungicides may be required. It may be necessary to harvest the crop early.
<div style="border: 1px solid black; padding: 5px; text-align: center; width: 40px; margin: 0 auto;">1</div> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> Identify threats, select paddocks, test and treat seed, use resistant varieties and crop rotations, adjust sowing rates, seed depth and carry out weed control </div>	
Seed testing services Risk management	<p><u>International Seed Testing Association (ISTA)</u> has internationally agreed rules for seed sampling and testing, accredits laboratories, provides international seed analysis certificates and training, and disseminates knowledge in seed science. This facilitates seed trading nationally and internationally and contributes to food security.</p> <ul style="list-style-type: none"> • <u>SARDI Diagnostic services</u> provide accredited laboratory seed tests for a range of crops and diseases. The test meets all international standards and arrangements of testing methods, including DNA-based tests. • <u>Risk management.</u> Laboratory seed testing offers seed buyers and sellers 3 key benefits: <ul style="list-style-type: none"> • Establishes the true disease risk associated with a seed lot. • Provides solid data for acceptance or rejection of a seed lot. • Highlights the need for specific disease management. • <u>The use of a range of testing methods</u> ensures that the results are appropriate to the field situation and cost effective. • <u>The sensitivity of each test method</u> is determined by the number of seeds tested. <u>DNA-based</u> tests allow a greater number of seeds to be tested quickly and accurately. Generally 400-1000 seeds are tested from a sample to achieve the correct sensitivity. • <u>Trade Seed testing</u> provides a quality benchmark on the disease status of a seed lot, allowing seed to be traded with confidence. • <u>Testing can be carried out</u> for the presence of genetically material (page 415).
<div style="border: 1px solid black; padding: 5px;"> Contact the seed testing service for instructions on how to collect seed samples </div>	

Types of seed tests available.

Diseases.
Rural solutions SA 2009.

The tetrazolium test differentiates between metabolically active and inactive tissue

1. **Purity analysis** infers the physical quality of an entire seed lot by defining the % composition by weight of the sample being tested, the identity and legislative status of any other seeds and the identity of inert particles such as stones, soil or de-coated seed, constituting the sample. Varietal purity.
2. **Germination analysis** determines the maximum germination potential of a seed lot as an estimate of its field planting value. Germination % should be checked at harvest, during storage and before seeding. Low germination seed should not be used. The germination of seeds is the ultimate measure of viability of any seed collection; therefore successful germination testing is critical to the function of any seed bank.
3. **A weed search** detects other species including specified weed species, number / kg can be determined, indicates presence of toxic or troublesome weeds, protection of stock and pastures.
4. **Seed identification** services provide an accurate identification of weeds and other species.
5. **Weight determination** – the results from 1000 seed weight determinations are used to calculate sowing rates.
6. **The biochemical tetrazolium test** is a rapid, reliable means of estimating seed quality, in particular, their ability to produce normal seedlings.
7. **Sprouting test** – is designed for species traded in the “fresh sprout” market, eg lucerne, mung bean, radish, peas. This test is distinct from a germination analysis as seedlings are assessed for their acceptability for the culinary market. This is not an ISTA accredited test and should not be used as a guide to sowing potential.
8. **Moisture content** – seed viability and vigor is very much influenced by storage conditions. Moisture content of seed must be accurately measured as this is the greatest single factor causing loss of viability in seed lots.
9. **Seed Vigor Index (SVI)** - a vigor test provides a more sensitive index of seed quality than the germination analysis and provides a ranking of the seed lot in terms of its potential field performance, eg **statement of seed analysis** will be produced for each batch, this includes Standard Germination tests, eg a **9-day test** which will tell you the ultimate germination potential of the seed; a **4-day test** will give an indication of the speed of germination, while the **7-day cool germination percentage** provides an indication of the seed’s ability to germinate under cool soil temperatures. The **SVI** combines the 4-day and 7-day cool germination percentages to give an indication of seed vigor.
10. **Quarantine inspection.** Australia’s seed testing laboratory is in a **Quarantine Approved Premise (QAP)**. Imported and exported seed consignments are checked for the presence of prohibited organisms, noxious weed seed, insects and soil.

Tips for gardeners

Seed is the most likely source of a new disease


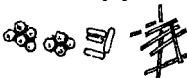




- By far the best way of controlling a pest, disease or weed is to avoid introducing it** in the first place. Use good quality, healthy seed or seedlings.
- Always use seed well within the ‘**use-by**’ date. Old seed may not produce as many strong seedlings as fresh seed. If you are storing seed, store it in cool, dry conditions.
 - Often bought seed has been treated with fungicide, treatment details are printed on the seed packet.
 - If you are determined to sow home grown realize they may be carrying some disease.
 - If planting seedlings rather than direct-seeding, use healthy vigorous-looking plants.
 - If seedlings were grown in contaminated soil, disease organisms may be carried on their roots at transplanting. Young plants may show symptoms of this infection.
 - Burn any seedlings with swollen or damaged roots.

Table 13. National Code of Practice - Labeling and Marketing Seed for Sowing. The Australian Seed Federation (ASF) is the peak industry body for the Australian seed industry at the local, state, national and international level. Member associations include the Australian Field Crop Association and the Western Australia Seed Growers Association.

ASF – Sowing seeds - <u>Minimum Details</u> Required on Label or Parcel	Sales of Seed <u>Not</u> Requiring Full Labelling	National Code of Practice - Labeling and Marketing Seed for Sowing
6.1 Species 6.2 Purse Seed 6.3 Germination 6.4 Hard Seeds 6.5 Other Seeds 6.6 Chemical / Additive Treatment 6.7 Biological Treatment 6.8 Mass of Parcel 6.9 Lot Designation 6.10 Seller 6.11 Analysis Certificate 6.12 Summary of Label Information 6.13 OECD Seed Labelling Standards	7.1 Seed Sold in Large Quantities 7.2 Unpacked Seed – Bulk Deliveries 7.3 Seed Sold in Small Parcels 7.4 Seeds of Flowers, Ornamentals, Trees and Shrubs 7.5 Sale of Seeds Drawn from a Larger Parcel 7.6 Sales of Seeds Mixtures	The Code requires that a person shall not sell sowing seed contained in a parcel unless there is clearly written or printed thereon, or on a label securely attached thereto, a statement setting out the following: <ul style="list-style-type: none"> • Lot number • Crop species • Cultivar • Pure seed (min %) • Germination (min %) • Hard seeds (max %) • Other seeds (max %) • Net weight • Packer • A statement ‘A seed testing analysis certificate is available upon request’. • Chemical / biological treatment details

Testing plant material for diseases, pests and weeds

The trend is generic multi-taxa tests, eg one test that detects more than one “disease” of interest

<p>Visual inspection</p> 	<p>Symptoms are the external and internal reactions or alterations of a plant as a result of disease or pest damage.</p> <ul style="list-style-type: none"> • Inspection can be carried out both in the laboratory and in the field. • Hand lens or ordinary microscopes are used for more detailed examination and identification of fungal agents and insect and mite pests. • Follow-up procedures may include: <ul style="list-style-type: none"> • Sorting procedures to separate healthy from infected or infested material by hand. • Sieving and fanning mills (sieves and a strong air current). • Immersion of seed samples in liquids to segregate infected seed by density. • Inspection of propagating material during growth, harvesting, storage, at market or before planting, eg current on-going inspections by relevant government department, of banana propagating stock while it is growing, to ensure freedom from Panama disease, burrowing nematodes, banana bunchy top virus and weevil borers. • Weed seeds in contaminated crop seed must be identified and quantified.
<p>Electron microscopy</p> 	<p>Electron microscopy is a highly specialized technique used to examine microscopic samples of crude sap and purified laboratory preparations to provide information about the size and shape and other components of virus particles and bacteria. This information can allow their speedy identification.</p>
<p>Isolation and identification</p> 	<p>Many fungal and bacterial disease organisms cannot be observed directly and consequently various diagnostic tests have been developed.</p> <ul style="list-style-type: none"> • In the laboratory fungal and bacterial organisms can often be identified by placing surface-sterilized seeds or other plant material on sterile agar or other media. Any disease agent that grows out from the seed or plant tissue can be identified.
<p>Indexing and indicator hosts</p>  <p>Right: New growth of indicator plant develops symptoms of infection</p>	<p>Indexing is the procedure used to determine whether any given plant is infected by any given virus. It involves the grafting of a bud, or other vegetative structure known to be or suspected of being infected with a virus, onto one or more kinds of indicator plants in which disease symptoms are easily observable.</p> <ul style="list-style-type: none"> • Indicator hosts can also be inoculated with expressed sap or via insect vectors. • The time required for symptoms to develop in herbaceous hosts is usually much less than for woody hosts. • Indexing of parent plants for viruses is used to certify some pome, stone and citrus fruits, as well as for grapes, strawberries, raspberries and several ornamentals, such as roses and chrysanthemums. • Today the term indexing may be used to describe any procedure that tests for the presence of known pathogens, especially viruses, in plants.
<p>Serology</p> 	<p>Virus protein (antigen) from a plant is injected into a mammal, eg a rabbit, which induces the animal to produce new proteins (antibodies).</p> <ul style="list-style-type: none"> • Serology uses the specificity of the antigen-antibody reaction to detect and identify antigenic substances and the organisms that carry them, eg bacteria, viruses. • ELISA (Enzyme Linked Immuno-Sorbent Assay) is a test in which one antibody carries with it an enzyme that releases a colored compound. Field kits are available to test for the presence of some virus diseases in some hosts.
<p>DNA</p> 	<p>Deoxyribonucleic acid (DNA) is the genetic code that contains all the information needed to build and maintain an organism.</p> <ul style="list-style-type: none"> • The DNA test to identify organisms whether plant or animal has revolutionized diagnostics. • Less than 1 cell may be necessary for detection and identification a disease organism. • Some tests based on a polymerase chain reaction (PCR) can detect pathogens in air, water and soil. • DNA testing is described in more detail on page 7.

National protocols are in place so everyone uses the same method to identify a particular problem.

Diagnostic protocols are described on page 189.

TREATMENTS TO ELIMINATE DISEASES AND PESTS

Before diseases and pests can be eliminated from seed, cuttings or other planting material, the **presence** of the disease or pest must be confirmed and identified by a competent diagnostic service.

Types of treatments developed to eliminate diseases, pests and weeds from seeds and vegetatively propagated planting material include:

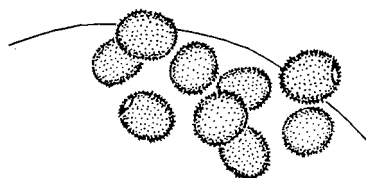
- Disinfestation.
- Disinfection.
- Tissue propagation schemes.

Disinfestation

What is disinfestation?

Disinfestation is the eradication of diseases (usually bacterial and fungal diseases) and pests, from the **outside** of seeds, bulbs, cuttings and other planting material **before** they can penetrate plant tissue, eg

- **Fungal rust spores** commonly adhere to the outside of snapdragon seed of varieties susceptible to rust. If the rust spores are not killed, seedlings developing from such seed will soon become diseased.



Rust spores on the outside of seed.
Diagrammatic.

- **Gladiolus thrips** (*Thrips simplex*) on stored gladiolus corms will quickly move to feed on emerging foliage if unchecked.
- **Disinfestation methods** include:
 - Mechanical means.
 - Heat treatments.
 - Non-systemic chemicals.

Mechanical means

Propagules, like hardened **sclerotia** of ergot-causing fungi (*Claviceps* spp.), **weed seeds** and **resting stages** of certain insect pests such as grain weevil eggs (*Sitophilus* spp.) may be of similar size to, and physically mixed with, **crop seed**.

- **Various mechanical** graders and liquid separators are used to **exclude, destroy or remove** specific seedborne pests.

Heat treatments

Always seek advice before attempting hot water treatments

- Heat treatments are sometimes** used to eradicate **external** diseases and pests, eg
- **The success of any heat treatment** applied to any propagating material depends on the host tissues being able to **withstand higher temperatures than the pathogen** during the treatment period.
 - **The SA standard treatment for surface sterilization** of vine cuttings and for certification for phylloxera (additional to the requirement for sourcing from an area free of phylloxera) for **HWT**, is **55°C for 5 minutes**. This treatment is effective against nematodes, root rotting fungi, bacteria as well as phylloxera.
 - **Seeds which have been treated with hot water** are frequently dusted with fungicides to protect them against further disease.

Non-systemic chemicals Protectants

Before using any of these materials on seed of a particular crop, check the label to ensure that they are registered for use on that crop

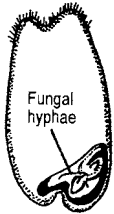
Fungicides and insecticides can be used to disinfest the outside of seeds, bulbs, cuttings and other planting material and protect them from infection by **soilborne** damping-off diseases and insect pests during germination and as young seedlings. However, they are more commonly treated with systemic fungicides which can also inactivate disease organisms within infected seeds (page 215).

Non-systemic chemicals used either as dusts or liquid dips to disinfest the **outside** of seeds or other planting material.

- **Fungicidal treatments** include:
 - Thiram is widely used on vegetable seed.
- **Other treatments** are used for special seeds and diseases.

Disinfection

What is disinfection?



Fungal hyphae of loose smut of barley inside the embryo of barley seed.

Disinfection is the eradication of diseases from the **inside** of seeds, cuttings, bulbs and similar plant material, including:

- **Virus diseases**, eg tobacco ringspot in soybean, bean common mosaic, lettuce mosaic, barley stripe mosaic, squash mosaic and *Prunus* necrotic ringspot.
- **Bacterial diseases**, eg those causing bacterial wilts, spots and blights.
- **Fungal diseases**, eg hyphae of anthracnoses and smuts.
- **Insect and allied pests**, eg bean weevil (*Acanthoscelides obtectus*).
- **Seeds** may carry **internally**, smut and other fungi, some bacterial wilts, various viruses, eg tobacco ringspot in soybean, bean common mosaic, lettuce mosaic, barley stripe mosaic, squash mosaic and *Prunus* necrotic ringspot. A range of insect pests such as larvae of the bean weevil may also be present inside seed.
- **Disinfection methods** include:
 - Heat treatments, eg hot water, aerated steam or dry heat.
 - Systemic chemicals.



Discolored scales in bulbs due to stem and bulb nematodes feeding.

Heat Treatments

How does heat work?

Heat appears to kill microbes by denaturing their enzymes

Heat treatments control some plant pathogens that are so deep in the planting materials that fungicides are unable to penetrate the host tissues.

- **The basic principle of heat treatments** is that **dormant host plant material** (eg bulbs, seed) must be able to withstand higher temperatures during the treatment period than the **disease or pest organisms inside**.

TEMPERATURES used and the DURATION OF TREATMENT vary with the different types of HOST and DISEASE / PEST COMBINATIONS

Precautions

Follow recommendations carefully and control the temperature accurately for the recommended period of time, otherwise

- **Temperatures higher** than those recommended will kill the plant material as well as the disease.
- **Temperatures lower** than those recommended will not kill the disease.
- **After treatment with hot water**, most plant material requires treatment with a fungicide.
- **Often a pre-treatment soak** minimises hot water damage to the plant material.

Hot water treatments (HWT)

Always seek advice before attempting hot water treatments

This is the commonest and most widely used form of heat treatment. Temperatures range from **35-56°C** and duration of treatments vary from a **few minutes to several hours**, eg


- **Seed**. Some seeds because of their fleshy nature cannot be treated with hot water or aerated steam, eg bean seeds.
 - **Leaf spot of broccoli** (*Alternaria spp.*) can be controlled by immersing infected seed in water at **50°C for 20 minutes** (Floyd 2005).
 - **Tomato seed** - **56°C for 25 minutes** (Persley et al 2010).
- **Vegetative propagating material**
 - **Dormant plant material**, such as budwood, dormant nursery trees and tubers, is usually treated with hot water at temperatures ranging from **35-54°C**, with treatment times lasting from a **few minutes to several hours**.
 - **Daffodil bulbs**. **HWT** has been used for many years to manage stem nematode and basal rot in daffodil bulbs, but the process also helps to control a number of other pest and disease issues. Bulbs are usually immersed in water containing disinfectant and fungicide and maintained at **44.4°C for 3 hours** to achieve the desired results.
 - **Some diseases and pests of vine propagation material** can be eliminated or their impact reduced by **HWT** of vine cuttings, eg treatment at **50°C for a period of 30 minutes** protects against *Agrobacterium*, *Phaeracremonium* as well as phytoplasma. Due to the potential for bud damage to propagation material at times and temperatures not much greater than this specification, critical attention to specifications is required.

Aerated steam Steam-air treatments of seed	<p>Steam-air treatment of seed to control seedborne diseases of vegetables, flowers and other plants has in the past, mainly been used by biosecurity for imported seed. However, the availability of new steam air machines may revolutionize seed treatment in the nursery industry.</p> <ul style="list-style-type: none"> • Aerated steam is produced by mixing steam with air. The ratio of the mixture largely determines the final temperature. • Advantages of aerated steam for seed treatment include: <ul style="list-style-type: none"> • Causes less seed damage than hot water. • Controls seedborne diseases while maintaining high levels of seed germination. • Temperatures and exposure can be precisely maintained. • Seed is left in a cool dry state, ready for sowing. • Seeds do not clump together.
Dry heat	<p>Actively growing plants under conditions of prolonged heat (usually at temperatures of 35-40°C for periods of 2 weeks to 8 months) may either become completely free from virus or produce meristematic tissue or buds that are virus-free (page 217).</p> <ul style="list-style-type: none"> • Exposing seed to dry heat reduces anthracnose (<i>Colletotrichum lupini</i>) infection of lupin seed. Moderate periods of exposure to dry heat are an effective way of reducing seed infection to extremely low or undetectable levels (Thomas and Adcock, 2004). • Disinfecting seeds and vegetative planting material. Heat is used to free plant material from viruses. Dry heat treatments inactivate some seedborne viruses, eg tomato mosaic virus (5 days at 70°C or 1 day at 80°C).
Solar heat	<p>Solar heating has been used in India for the treatment of wheat seed to control loose smut (<i>Ustilago tritici</i>).</p>

Systemic chemicals-

<p>Seed treatments</p> <p style="text-align: center;"><i>Always check for latest recommendations</i></p>	<p>Systemic fungicides and insecticides applied to the outside of seeds, cuttings and other planting material may protect them from attack by fungi and insects on or in the seed and from damping-off diseases and insect pests in the soil. They may also protect seedlings and growing plants from pathogens and insects which later attack emerging foliage reducing the need for further insecticide or fungicide applications.</p> <p>Systemic fungicides for seed treatments include:</p> <ul style="list-style-type: none"> • Bulbs and corms may be treated with Vorlon® (thiabendazole) to protect them from <i>Fusarium</i> basal rot and <i>Penicillium</i> blue mould in the field. • Vegetable seed in WA may be treated with Apron (metalaxyl) or a mixture of thiram and P-Pickel T (thiabendazole). • Wheat and barley seed may be treated with EverGol Prime Seed Treatment (penflufen) to protect them from <i>Rhizoctonia</i> root rot and smuts diseases. • Wheat seed is treated with Vitavax® (carboxin + thiram) to protect foliage of the developing plant against loose smut and other diseases for export. • Wheat, barley, oats and triticale seed may be treated with Vibrance (difenoconazole + metalaxyl + sedaxane) for seedling diseases. <p>Systemic insecticides for seed treatments include:</p> <ul style="list-style-type: none"> • Cruiser (thiamethoxam) to control early season and sucking insects in cotton, maize, sweetcorn, sorghum and sunflower. • Gaucho (imidacloprid) to manage a range of insects in various crops. <p>Mixed function seed treatments include:</p> <ul style="list-style-type: none"> • Baytan T Flowable Seed Dressing (triadimenol + triflumuron). • Poncho/VOTiVO⁴ (clothianidin + <i>Bacillus firmus</i>) for corn and soybean combines a seed-applied insecticide with nematode protection on the seed (not available in Australia).
---	---

READ SAFETY DIRECTIONS BEFORE OPENING OR USING



VORLON

500 SC FUNGICIDE

Apron XL 350ES

Fungicide Seed Treatment

Metalaxyl

Cruiser 350FS

Insecticide Seed Treatment

Thiamethoxam

Vibrance

Fungicide Seed Treatment

Difenoconazole
Metalaxyl-M
Sedaxane

CAUTION
KEEP OUT OF REACH OF CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING OR USING

Baytan® T

FLOWABLE SEED DRESSING

Active Constituents: 150 g/L TRIADIMENOL
4 g/L TRIFLUMURON

GROUP	C	FUNGICIDE
GROUP	15A	INSECTICIDE

Tissue propagation systems

Tissue propagation systems are usually used to eradicate **internal contaminants** that **cannot** be eradicated by simpler and cheaper means, eg heat or chemicals.

How do they work?

Growing tissue may be free from disease.

- **The basic principle involved in using tissue propagation** to produce disease-tested planting material, is that systemic disease organisms do **not** always invade **growing tissues**. It is, therefore, sometimes possible to propagate from such tissues while they are temporarily free of disease organisms.
- **Testing.** Such methods do **not** guarantee disease-freedom. Plants derived from tissue culture systems must still be tested for freedom from **specific** diseases.
- **Tissue propagation techniques used** to produce disease-tested planting material include:
 - Tip cuttings, grafting and seedlings.
 - Meristem culture, tissue culture.
 - Meristem culture **followed** by heat treatment.

Tip cuttings, grafting, seedlings

Short cuttings taken from the tips of rapidly growing shoots are usually free of *Fusarium* and *Verticillium* wilts and this technique has become common practice for controlling these diseases (Agrios 2005).

- **Verticillium enters chrysanthemums** through the roots and grows systemically but does not usually invade the tips of young actively growing shoots. Plants derived from such tips are usually *Verticillium*-free.
- **With some crops, eg carnation and chrysanthemum**, greenhouse growers need cuttings free of *Fusarium* and *Verticillium* vascular wilts each time they plant, as it is almost impossible to keep these fungi from production beds. This technique is also used occasionally to produce plants free from foliar nematodes.
- **Testing is essential.** Isolations are made from the bases of **all** tip cuttings. Those which yield *Verticillium* are discarded.

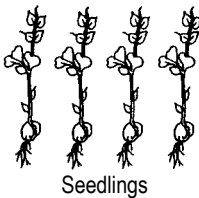
Shoot tip grafting is a micro-propagation technique developed to produce virus-free parent citrus trees of improved health status. Shoot tips are excised and grafted onto 2-week old rootstock seedlings to produce virus-free parent trees of local and imported varieties.

Seedlings.

- Some viruses are generally seedborne.
- It is important to know whether a disease **is** seedborne or **not**.
- If a virus **is** seedborne, it is important to know on **which hosts** this occurs.
- Virus diseases of apples are **not** seedborne so apple seedlings are **free** from virus and can be freely used as a source of rootstock.
- Seedlings of many plants are **virus-free**, eg seedlings of iris. Remember that if a virus is spread by insects or other vectors, then these virus-free seedlings may quickly become infected.

Examples.

- **Grapevines.** There are a number of **graft-transmissible disease agents** which are endemic to Australian viticulture and adversely affect yield and vigor.
 - **Two of the most economically important of these diseases** are **leafroll** (a complex disease probably caused by a mixture of virus and virus-like agents) and **crown gall diseases** caused by the *Agrobacterium tumefactions* biovar (AT3).
 - **The primary transmission of each disease** is through infected propagules, whether grafting or planting diseased cuttings.
 - **Tissue culture technology** can eliminate both diseases from grapevine material.
- **Sweet potato** production in Qld is adversely affected by virus and other diseases that persist in planting material from one generation to the next (Persley 2007. DPI&F Note)
 - **Sweetpotato little leaf disease** is a phytoplasma transmitted by leafhoppers into and within sweet potato crops.
 - **Sweetpotato feathery mottle virus** is easily spread by planting infected cuttings or roots and by aphids, eg cotton aphid (*Aphis gossypii*) and the green peach aphid (*Myzus persicae*).
 - **Qld Daff maintains a collection of virus-tested tissue culture** and a nursery of virus-tested sweet potato plant material. From this nursery seed roots are grown every year and are available for sale to sweet potato growers.
 - **Although it is impossible to guarantee 100% disease-free material**, the nursery varieties are held in a screened facility to exclude aphids. Nursery maintenance and field production of plant material are performed at Gatton Research Station in the Lockyer Valley where few sweet potatoes are grown commercially. Growers can purchase these and multiply their own cuttings as soon as climatic conditions allow.



<p>Meristem culture tissue culture</p>	<p>Meristem-tip culture is the most widely adopted technique to obtain virus-free plants. Virus-free plants can be obtained by tissue culture of the upper millimetre of so of the growing meristematic tip of the plant, which most viruses do not invade. This method ensures that organised 'plantlets' can be grown more quickly and that their genetic characteristics are less variable than with other tissue culture techniques. Examples include:</p> <ul style="list-style-type: none"> • Potatoes, usually 85-95% of potato plants obtained are virus-free. • Carnations, most viruses can be eliminated. • Chrysanthemums, only some viruses can be eliminated. <p>Testing. Not all plants resulting from meristem culture are virus-free. To ensure virus-freedom all resulting plants must be tested.</p> <p>Other culture systems have been used to free plant material from virus and other diseases, including callus cultures and living tissue taken from the non-chlorotic tissues of infected leaves to produce tobacco plants free from tobacco mosaic virus (TMV).</p>
<p>Meristem culture FOLLOWING heat treatment</p> <div style="border: 1px solid black; padding: 2px; margin-top: 10px;"> <p>Always seek advice before attempting these treatments</p> </div>	<p>The efficiency of meristem cultures in eliminating viruses seems to depend on excising a small tip of living tissue and some form of heat therapy applied to the parent stock prior to the tip culture. For most host-virus relationships, heat treatment at 36-40°C for 6-12 weeks is most effective (Brown and Ogle 1997). Current evidence suggests that heat therapy is most effective in eliminating certain types of viruses and phytoplasmas. Because the success of heat therapy is also related to the chances of survival of the host, some workers have suggested the use of antibiotics which inhibit virus replication as a substitute treatment during culture.</p> <ul style="list-style-type: none"> • Growing plants, under conditions of prolonged heat (usually temperatures of 36-40°C for periods of 2 weeks to 8 months), may either become completely free from virus or produce meristematic tissue or buds which are virus-free. • Reasons for this include the reduction in the rate of virus multiplication and in the rate of virus movement and an increase in rate of virus breakdown. • If only the meristem is free from virus, it must be removed and cultured using special techniques. This technique is used mainly for ornamental plants, eg <ul style="list-style-type: none"> Carnation Chrysanthemum Gladiolus Daphne • Heat therapy followed by working new buds onto seedling rootstocks for surveillance is used mainly for fruit crops, eg <ul style="list-style-type: none"> Deciduous fruit trees Citrus Grapevine

TESTING AFTER TREATMENT

All plant material APPARENTLY FREED FROM VIRUS AND OTHER DISEASES, by heat treatment and / or by meristem culture or by other methods, must be TESTED FOR FREEDOM FROM DISEASE AFTER TREATMENT

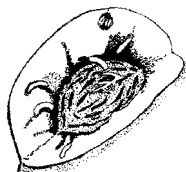
Only plants found to be FREE FROM THE SPECIFIED DISEASES ARE RETAINED to become a SOURCE of disease-tested material for CERTIFICATION SCHEMES.

AREA FREEDOM

The concept of evading or avoiding a disease or pest is not new. During much of the 20th century, **banana production** in Central America depended on evading *Fusarium* wilt or Panama disease (*Fusarium oxysporum* f.sp. *cubense*) of banana, by moving onto new, previously uncultivated fields as soon as older banana fields infected with *Fusarium*, became unprofitable. **Pest-free zones** have been established throughout Australia to prevent the spread of certain pests and diseases and provide **guaranteed pest freedom to facilitate trade**.

<p>Evasion or avoidance</p>	<p><u>Today, disease-tested planting material</u>, especially seed production, may be produced by growing the crop and producing the seed, runners, rootstocks, etc in areas that are:</p> <ul style="list-style-type: none"> • Free of the disease, pest or vector (in the case of vector-transmitted disease). • Not suitable to the disease or pest, or vector so that plants and seed are more likely to be free from the disease or pest, eg unfavorable weather such as low rainfall. The pest may not be present in winter. • Kept free from the target disease or pest by destroying or spraying diseased or infested plants in these areas when there are incursions. • Regularly monitored for disease and pest incursions, eg trapping for western flower thrips (<i>WFT</i>) (<i>Frankliniella occidentalis</i>) in the Toolangi area. • Phytosanitary Certificates are issued as a guarantee of disease or pest-freedom and there may be Compliance and Verification Agreements. • Isolated from the disease or pests, eg in many cases, a susceptible crop is planted at a great enough distance from other fields containing possibly diseased plants. The pathogen would be unlikely to infect the crop. This type of crop isolation is practiced mostly with perennial plants, such as peach orchards to protect them from virus and virus-like diseases.
<p>Exclusion zone</p>	<p><u>Grape phylloxera</u>. Protection Areas have been established in Victoria and other States to prevent the introduction of grape phylloxera (<i>Daktulosphaira vitifoliae</i>) into grapevine-producing districts (grapes, grapevine material, agricultural equipment and soil).</p>
<p>Area freedom from potato cyst nematode</p>	<p><u>WA obtained area freedom from potato cyst nematode</u>. A substantial consignment of WA seed potatoes has been cleared for export to Indonesia and other countries, following pre-shipment pest and disease-testing.</p> <ul style="list-style-type: none"> • The new system of testing in Australia rather than following arrival overseas ensures a better quality product for overseas customers. The new arrangement involving cooperation between Biosecurity, the Indonesian quarantine service, the WA government, testing laboratories and exporters has worked well. • Seed potatoes are especially grown potato crops and overseas markets are particular about pest and disease freedom, size, varieties and other specifications. Sending perishable goods overseas entails a large risk as you can't bring it back if it fails any tests in the receiving country. • A standardized system of testing before shipment would have huge advantages for both exporters and importers and we hope this may soon be possible.
<p>Toolangi Plant Protection District (PPD)</p>	<p><u>Toolangi PPD</u> is a protected area in which plant breeding programs are conducted. Crops include nursery plants, cut flowers, leafy vegetables, strawberry plants, <i>Rubus</i> plants (raspberry) and potato tubers. The Toolangi PPD helps to ensure the sustainability of the district as a producer of high health planting material by:</p> <ul style="list-style-type: none"> • Establishing protocols to prevent the introduction of certain pests and diseases which affect the major crops in the district. Specific prohibitions, restrictions and requirements operate to prevent the entry of pests or diseases into the control area or spread of pests and diseases within the Toolangi PPD. • All consignments entering the Toolangi PPD must be accompanied by certification and be verified by an accredited business. • This requires that commercial consignments of nursery plants, cut flowers and leafy vegetables, strawberry plants, <i>Rubus</i> plants and potato tubers be free from certain plant pests and diseases or treated to control certain pests. • Facilitating the export of plants out of the district and • Giving producers an additional marketing tool for their produce.
<p>National Fruit Fly Strategy (NFFS) Winter Windows Areas of Low Pest Prevalence Pest Free Places</p>	<p><u>The distribution of Queensland fruit fly in eastern Australia has shifted significantly south</u> to the point where the pest can be considered established in many parts of Victoria and most of NSW. The FFEZ as it was is no longer workable so a new management approach is being put in place (pages 195, 197). Changes will likely include:</p> <ul style="list-style-type: none"> • Trapping intensity will be reduced to a grid aimed primarily at demonstrating freedom from exotic fruit flies, including Mediterranean fruit fly. • Pursue negotiations with the US to recognize cold disinfection as a stand-alone treatment and on other market access arrangements including: <ul style="list-style-type: none"> • Recognition of Winter Windows, • Areas of Low Pest Prevalence, and • Pest Free Places of Production.

Targeted pests include western flower thrips (*WFT*)



CERTIFICATION SCHEMES

Certified plant material gives growers confidence that their purchase meets defined quality standards. Identifying and eliminating viruses is an expensive complicated procedure, viable only with high-volume crops. Once the plant material is in a clean state it is bulked up for distribution to nurseries which introduce the plant to normal nursery conditions and use these young plants for their parent-stock block only.

Different aims

This is what this chapter is all about!

Certification schemes have different requirements, eg

- **Genetic make-up.** The Australian Seeds Authority (ASA). www.aseeds.net.au/ Certification means that you can buy seed which is as close as possible to the **genetic make-up** of the variety as selected by the breeder. The ASA is responsible for controlling seed certification in Australia, and oversees two certification schemes:
 - The **OECD Schemes for the Varietal Certification** or the Control of Seed Moving in International Trade. Seed of varieties accepted by the **OECD** authorities is produced in accordance with their rules, may be labelled with **OECD** certification labels, providing immediate international acceptance. **OECD** schemes promote high standards of **varietal purity**; certified seed may **not** be more than a limited number of generations removed from the breeder's seed.
 - The **Australian Seed Certification Scheme** which is used principally for seed not destined for export. The rules of the Australian Seed Certification Scheme are essentially the same as for the OECD seed schemes, with only a few differences in the requirements for post-control testing.
- **Appropriate genetic make-up and guaranteed freedom from specified diseases and pests**, ie seed or vegetative propagation material, conforming to **cultivar** characteristics and **guaranteed free from specified diseases, pests and weeds** to the grower. Certification schemes involve **repeated testing** to ensure **continued** disease or pest freedom.

Importance of certification schemes

Controlling plant pests and diseases by excluding pathogens from crops is a well-established and proven means of control.

- **Viruses and viroids, bacteria, nematodes and soilborne fungal pathogens** are commonly dispersed in infected propagating material.
- The **importance of disease-tested planting material and common clean schemes** for avocado, deciduous fruits, banana, citrus and strawberries have long been recognized.
- **Regular testing to ensure that reinfection has not occurred.** The procedures usually vary with the crop and types of pathogens involved, eg sensitive biochemical techniques are used to test nuclear stock for the viroids causing citrus exocortis and avocado sun blotch. Leaf samples of strawberry varieties can be grafted to sensitive clones of wild strawberry species such as *Fragaria vesca* and *F. virginiana* to detect possible virus infection.

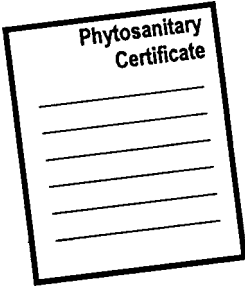
Certified plant bean seed

The production of certified bean seed in the Burdekin region in Qld provides a good example of the control of seedborne diseases through **crop inspection** and **seed lot approval**. Anthracnose, once a serious seedborne disease of French bean is now seldom seen because of the widespread use of certified seed. The major components of most clean schemes are:

1. **Production and maintenance** of the original or nuclear stock of the varieties involved. This may be done **by seed treatments, heat therapy or meristem tip culture**. **Rigorous testing** of this material is necessary to ensure that targeted pathogens have been eliminated. Parent crop plants must be genetically robust and genetically true-to-form.
2. **Regular testing** to ensure that reinfection has not occurred.
3. **Multiplication** of nuclear material through several generations under appropriate conditions of isolation and inspection. This ensures that only healthy, true-to-type material is supplied to growers (page 220).

Phytosanitary certificates

Biosecurity



The **Australian Phytosanitary certificate** is issued in accordance with internationally accepted templates and is used to certify that Australian plants or plant products have been inspected according to appropriate procedures, and that they are considered to be **free from biosecurity pests**, practically free from other injurious pests, and conform to the current phytosanitary regulations of the **importing country**.

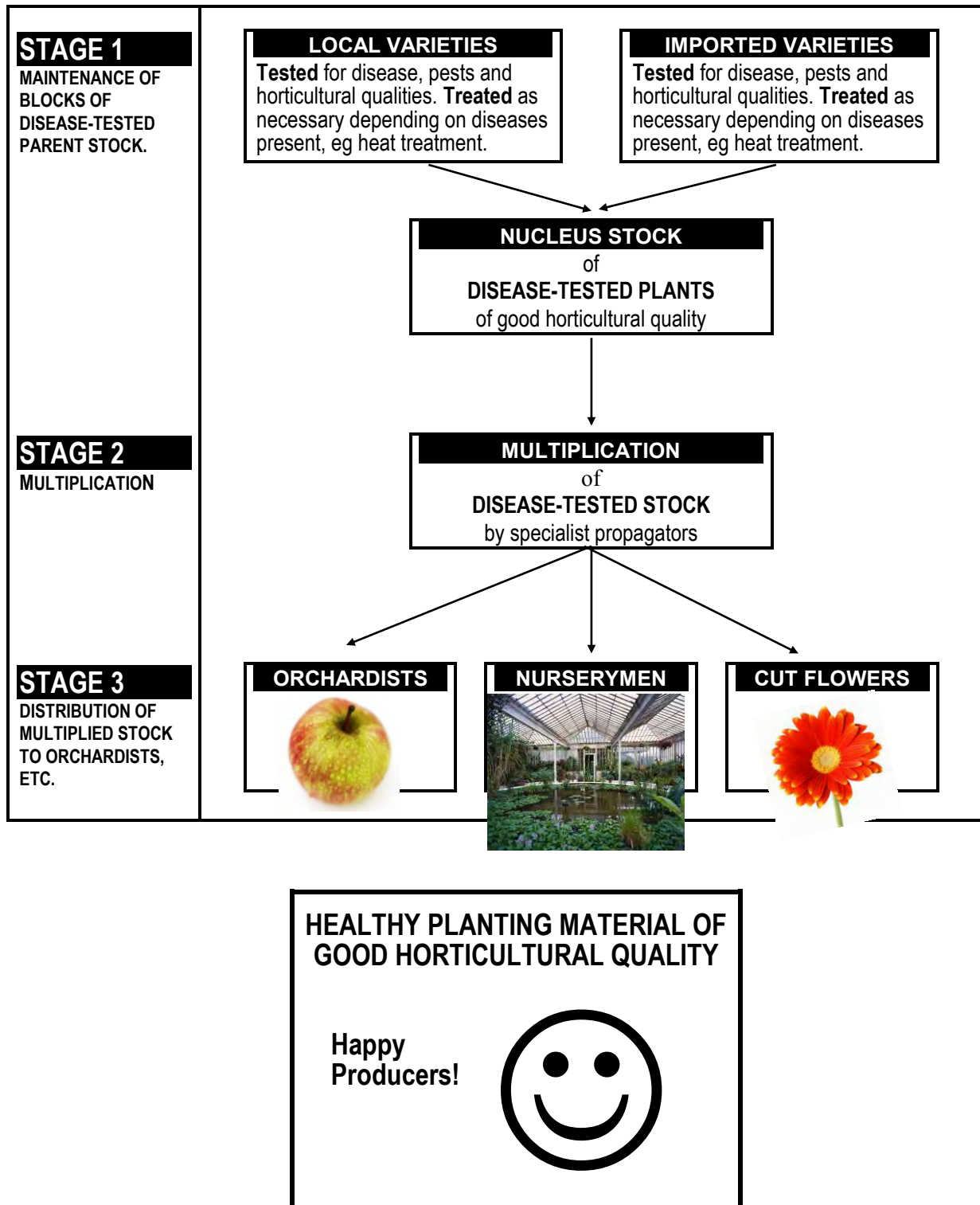
- **A certificate from your State's or Country's Department of Agriculture** that states your plants are free from disease, pests and noxious weed on the date of inspection.
- **For exporting** plant material interstate or overseas, eg potatoes, cut flowers.
- **For importing** material from interstate or overseas phytosanitary agreements, eg importing apples from NZ.
- See also page 194 (Biosecurity).

Steps in certification schemes

Many certification schemes follow the steps outlined in Table 14. Constant testing ensures that the propagation material sold to the producer complies with the requirements of the particular certification scheme, eg

- **Maximum allowable tolerance** of disease in the seed or propagation material.
- **There may be zero tolerance** for some diseases.
- **Minimum standards** for germination, purity and viability of seed.
- **Labeling and record keeping.**

Table 14. Organization of a Certification Scheme



Seed certification schemes

Growers can contact their specific industry associations for sources of disease-tested planting material. Information kits for an industry usually include lists of suppliers. State Departments of Agriculture / Primary Industry may also hold lists. Suppliers and biotechnology companies advertise in industry journals and newspapers. Some growers may consider producing their own disease-tested parent plants.

Seed Industry Association of Australia (SIAA)

QA

The Seed Industry Association of Australia (SIAA) is the peak national body representing the interests of the sowing seed sector whose membership covers plant breeders, seed growers, seed processors and marketing firms. It has a **Quality Assurance (QA) Logo** which will secure Australia's reputation as a supplier of high quality sowing seed.

- **The logo is a certified "trade mark" and can only be used by SIAA members** who have been successfully accredited by demonstrating their compliance with the national **"Code of Practice for the Labeling and Marketing of Seed for Sowing" (the Code)**.
- **The Code requires that a person shall not sell sowing seed contained in a parcel** unless there is clearly written or printed thereon, or on a label securely attached thereto, a statement setting out the following:
 - Crop species. Cultivar Pure seed (min %). Germination (min %). Hard seeds (max %).
 - Other seeds (max %). Net weight. Packer.
 - A statement that **"A seed testing analysis certificate** is available upon request".
 - Chemical / biological treatment details.

Seed certification schemes directed against diseases, pests



Exit holes on bean seed. Larvae of the bean weevil (*Acanthoscelides obtectus*) feed inside seeds, adults emerge through exit holes.

Seed certification schemes directed against bacterial, fungal and some viral diseases are usually directed against diseases and pests **which cannot be controlled** by ordinary seed treatments. Seed certification schemes have several common and major aims including:

- **Complying with the minimum requirements of legislation**, eg the various State / Territory seeds acts.
- **Ensuring that seed of a particular cultivar** remains **true-to-type**, maintains the genetic identity of the cultivar, with minimum **physical contamination** by seed of other cultivars, **no cross-pollination** with compatible related cultivars, restricted number of generations of multiplication, **rogueing** of off-types. It must be correctly **labeled**.
- **Freedom** from seedborne diseases and pests.
- **Being of a high physical** quality.
- **There are specific procedures and standards for each species**, eg
 - **Inspection** of parent crops. Crop standards include rejection of crops if they contain excessive **diseases, pests** and/or **weeds**.
 - **Routine** disease, pest and weed control measures.
 - **Hygiene** of harvesting machinery, requirements for seed drying and cleaning.
 - **Blending** of seed lots.
 - **Sampling and seed testing**, eg no seed containing live insects will be certified.
 - **Certification** by the inspecting agency and final release. The grower may then advertise and sell the plant material as disease-tested.
 - **Seed to be 'certified'** must show disease levels no higher in the field than those allowed by regulation.
 - **Seed quality standards** include minimum germination, minimum % pure seed content, and maximum % other agricultural seed content, etc (page 211).

Examples

Certified seed is available for a wide range of vegetables, eg French bean (*Phaseolus vulgaris*). Some States operate schemes to supply seed free from various diseases to growers. There is a 1% tolerance of peanut mottle virus and bean common mosaic virus.

Because it is too expensive to treat all wheat seed with fungicide for loose smut (*Ustilago tritici*) only **'parent'** seed is treated. This is then grown by specialist propagators to provide large quantities of **certified** seed to growers. Loose smut is not completely eradicated; the tolerance limit of loose smut of wheat in registered seed crops is 0.05%.

States may have their own seed certification schemes, eg

- **SureSeed® is a joint initiative** by Australia's leading seed certification providers, AGWEST Plant Laboratories and SA's Seed Services Australia. It is targeted to meet industry demand for an affordable, lower cost alternative to existing seed certification schemes. The SureSeed® Program is a **QA-based seed program** that enables growers and seed companies to produce and market high quality seed for sowing of known varietal identity and physical quality, including testing for nominated seedborne diseases.
- **Australian Tree Seed Centre at CSIRO is a national and international tree seed bank** focusing on seed collection from Australian trees and shrubs and sets standards in methods of collection and documentation. **ATSC** provides well documented, source-identified seed for planting.

Vegetative propagation certification schemes

Vegetative propagation schemes

QA

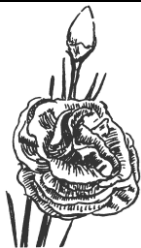


Lesser bulb fly (*Eumerus tuberculatus*) maggots inside bulbs.

Many plants are propagated vegetatively because seeds do not reliably produce plants that are true-to-type. Most certification schemes for vegetative propagation material are directed towards controlling **virus and virus-like diseases** because they **reduce** yield and quality and are the **most difficult** of diseases to control.

- **Eliminating pathogens present in vegetatively reproduced plants**, eg cuttings, corms and bulbs, is **much more difficult** than in seeds.
- **Vegetative propagation is an ideal method** of transmitting diseases, eg virus, bacterial and fungal diseases, from one generation to the next.
 - **Annual and herbaceous perennial plants.** Many virus diseases in these types of plants are additionally spread by insects and other means so that re-infection may occur.
 - **Woody plants.** Many virus diseases in these types of plants, eg deciduous fruit trees, have no insect or other vector. Re-infection is, therefore, not common in many instances. There are some exceptions.
 - **There are no systemic chemicals** which can control virus diseases or some bacterial diseases inside a plant.
 - **Soilborne fungal diseases** are spread on or within vegetative propagation material and movement of infested soil. Disease-tested carnations must only be planted in disease-free soil, eg pasteurized soil in cutting beds. Strict hygiene is recommended.

Ornamental plants



Certifications schemes provide disease-tested planting material for a range of ornamental plants including carnations, chrysanthemums, roses, daphne, and some bulbs.

- **Bulbs, corms and similar planting material** are difficult to treat. Disease-tested planting material is available for a range of species including Dutch bulbous iris, hyacinth, gladiolus, lilies and tulips. Most virus diseases in bulbs, in addition to being spread via the bulb, are also spread by insects. Material is also **tested** for nematodes and a range of bacterial and fungal diseases.
- **Carnations** were one of the first ornamental plants available as disease-tested planting material. All carnation viruses are **spread** in vegetative propagation material, some also by insects and/or foliage contact, secateurs and handling. Disease-tested carnations may, therefore, within 6 months, become re-infected with some virus diseases unless preventative measures are taken.
- **Many companies focus on** new product development, breeding, clean stock maintenance and introduction and marketing techniques. The strategy is to **have a rigorous disease indexing and clean stock program** that ensures new releases will perform for the grower, eg petunias may be indexed for **20 different viruses** before multiplication.

Fruit crops



Symptoms of apple russet ring virus infection on a Granny Smith apple. Photo©Canberra Institute of Technology.

Certifications schemes for the provision of disease-tested planting material for a range of fruit crops including avocados, bananas, citrus, pome and stone fruits, grapevine and strawberries.

- **Citrus bud certification schemes** guarantee freedom from certain virus diseases, that trees are of good horticultural quality and will produce improved quality and quantity of citrus fruit. All citrus viruses are spread by vegetative propagation (bud transmitted). Some are also spread mechanically and by aphids.
- **Pome and stone fruits.** Most viruses are spread only by **vegetative propagation**. *Prunus* necrotic ringspot and prune dwarf viruses are seed and pollen-borne in some *Prunus* spp. **Australian Pome Fruit Improvement Program** provides industry with commercial supplies of high quality virus-free dwarfing rootstocks and budwood.
- **Australian Vine Improvement Association (AVIA)** manages the **National Vine Accreditation Scheme**. A range of vines grafted onto a variety of rootstocks are made available and they facilitate the equitable distribution of high quality propagation grapevine and rootstock material to all producing areas in Australia.
- **Strawberry runners.** All virus diseases of strawberries are **spread** by vegetative propagation and most are also transmitted by insects, new plantings from runners guaranteed free from virus, gradually become re-infected.

Vegetables

AUSTRALIAN STANDARD

Seed potato tubers. Some virus diseases are also spread by insects, some bacterial and fungal diseases are also spread by water, wind and other insects.

- **The Australian National Certified Seed Potato (ANCSP) Standards** as a minimum standard produces premium seed potatoes, considered superior to other international standards.
- **Potato certifications schemes operate** in WA, NSW, SA, Tasmania and Victoria where diseases are kept out and vectors are sprayed to control virus diseases.
- **Crops submitted for certification** are inspected a required number of times during the growing seasons. If approved for certification, they must be of an approved quality, packed in approved bags with approved labels. Records must be kept.
- **There are prescribed maximum tolerance** for certain diseases at field inspections.
- **Zero tolerances only apply** for bacterial wilt and potato cyst nematode, the two diseases that if detected on a property results in severe quarantine restrictions.

MANAGING DISEASE-TESTED PLANTING MATERIAL


Fail to Plan and You Plan to Fail (Tucker 1996)

To ensure the planting material remains free of the specified diseases and pests, parent stock plants and their progeny must be tested for the presence of these specified diseases and pests **at regular intervals**.

<p>Not resistant</p>	<p>Plant material which has been tested and found to be free from specified diseases and pests is not immune, or resistant to, attack by these diseases and pests.</p> <ul style="list-style-type: none"> • Whether disease-tested planting material becomes re-infected with the diseases and pests it was guaranteed free from largely depends on how the diseases or pests are spread on that particular host.
<p>Stock plants Good parents</p>	<p>The objective of stock plants is to produce young or vigorous but not soft cuttings and scions with turgid cells and ample reserves of carbohydrates and other nutrients that are free from pests and diseases. Usually cuttings and scions are collected from:</p> <ul style="list-style-type: none"> • Existing production plants where the loss of one or more stems doesn't affect the overall appearance, or • Plants kept in containers in a separate location for specific use as stock plants, or • Plants grown in the field, or • By purchasing disease-tested material.
<p>Care of parent stock Regular testing of plants, soil, water, etc</p>	<ol style="list-style-type: none"> 1. Isolate. It is important to isolate elite clean tested mother stock from any contact which would contaminate it because viruses are spread very easily. The best holding area is a specially constructed isolation house with insect screening and airlock access doors. 2. Management. When entering the isolation area, it is wise to do any work first thing in the morning before the propagator's clothes come into contact with other nursery crops. Handling is kept to a minimum, with care taken at all times to ensure there is no cross-contamination between varieties. 3. Cuttings. It is advisable to have several secateurs or scalpels on hand and use a fresh one on each new cultivar or variety. This means that if one variety is still carrying a virus or has been infected, the tools cannot carry the virus from one plant group to the next. It is important to take cutting from parent stock plants that are: <ul style="list-style-type: none"> • Established with a good nutrition regime and adequately watered prior to taking cuttings or scions. Cuttings should not be taken under circumstances which are causing water loss from leaves. High temperatures and windy conditions should be avoided. 4. Replace parent stock plants regularly / every year to guarantee continued good results. It is also important for these plants to be free of pests and diseases which would otherwise be transferred to the cuttings and scions. The most insidious diseases are viruses as their presence is not always visible.

Preventing re-infection or re-infestation

Know how the diseases and pests that the certified disease-tested plant material is attempting to control, spread, overseason and which other hosts they may attack, etc.

<p>Industry testing services</p>	<p>Industry testing services are available for soil, water, plant tissues, seed.</p> <ul style="list-style-type: none"> • Seek advice about taking samples, etc. • The diagnostic services will remind growers when testing is due (page 210).
<p>Sources of re-infection and re-infestation Contaminated soil, water, air and plant material, vehicles</p> 	<p>Disease-tested planting material may become re-infested or re-infected in many ways (Table 15, page 225).</p> <ul style="list-style-type: none"> • Soil, growing media or other substrates are a natural repository for a wide range of insects, weeds and diseases and may be contaminated. Anything that carries soil may be contaminated, eg pots, containers, vehicles, boots, etc (pages 183, 200, 201). <ul style="list-style-type: none"> • Insects and mites. Most spend some part of their life cycle in the soil, eg beetles / weevil, caterpillars, wireworms, thrips, snail eggs. • Soilborne diseases, eg <i>Phytophthora</i>, <i>Pythium</i> spp. recently in found in soil going into WA from eastern states. Also nematodes, virus and bacterial diseases. • Soil can become recontaminated with soil deliveries, eg plant disease-tested cuttings in disease-tested soil or resistant varieties in contaminated soil. Soil fungicides are mostly suppressive and do not eradicate infections. • Weed seeds, weed seedlings, vegetative underground weed parts are not uncommon in nursery tubestock and containers (page 224). Some nurseries still sell tubestock with oxalis and other weeds, liverworts and mosses. • Equipment, shoes, etc may be contaminated with infested soil, weed seeds etc. Clean machinery before moving it.

Sources of re-infection and re-infestation
(contd)

Some virus diseases are also spread by insects, some bacterial and fungal diseases are also spread by water, wind and other insects so that some re-infection may occur

- **Water, irrigation analysis**
 - **Water from cropping areas**, nurseries, dams and recycling facilities may be contaminated with diseases, eg *Phytophthora*, *Pythium* and **re-infect disease-tested nursery stock**.
 - **Such water may also be contaminated** with pesticides and or fertilizers.
 - **Water analyses are essential**, whether the water is being used for spray programs or for irrigation.
 - **Water splash** from infected plants may contain bacteria, eg bacterial canker of stone fruit (*Pseudomonas syringae* pv. *syringae*) or fungal spores, eg black spot of rose (*Marssonina rosae*).
 - **Water may not only carry disease organisms** but also **insects, weed parts and seeds**.
- **Wind and air currents** assist spread of flying insects, which may be **vectors** of virus diseases or damage crops in other ways.
 - **Air is full of many pests, fungal spores and weed seeds**. Biosecurity catches fungal spores and trap fruit flies and other insects in surveillance activities.
 - **Fungal spores**, eg spores of grey mold (*Botrytis cinerea*) and powdery mildews spread by wind; rust spores may reach Australia by wind. Biosecurity uses portable samplers to monitor fungal spores in the NT.
 - **Fungal spores, insects and mites are also spread** on dust and leaves.
- **Insect and other vectors** such as western flower thrips (WFT) can spread virus diseases of plants. **Animals** can spread nematodes in their manure, weed seeds may be spread by birds and on sheep's wool. **People** spread infected plant material, fodder, soil and weed seeds attached to equipment and boots, clothes, etc.
- **Plants in adjacent areas** may be affected by the diseases and pests to which the current crop is susceptible and so act as a source of re-infestation.
 - **Plant material may be contaminated** with fungal spores, viruses, bacteria, insects, weed seeds and weed propagules, etc.
 - **Grafting and budding infected material** onto disease-tested plant material.
 - **Contaminated container plants**. The plant itself may carry all the pests and diseases it is susceptible to when growing in the field, eg roses in leaf may carry:
 - Twospotted mite, aphids, thrips, scale, etc on canes.
 - Virus diseases, black spot, rust, down mildew, powdery mildew.
 - These problems are not subject to testing but products should be as free from these pests as possible.



Weed-infested tube stock being planted in an urban native park during revegetation.

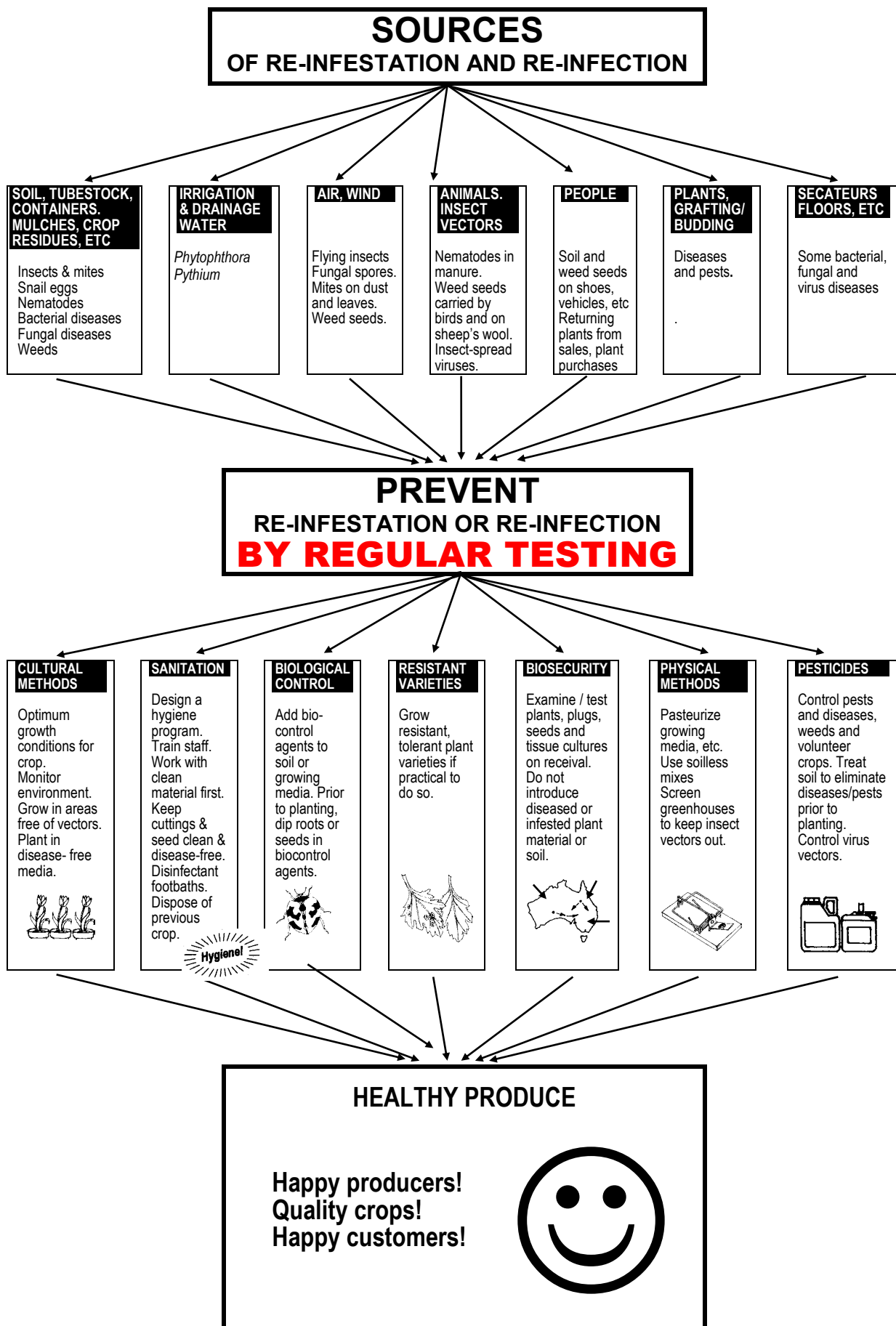
Preventing re-infection and re-infestation

Seed, plant, soil or water treatments may be required




- Management practices are important if quality products are to be produced** and plants are to remain free of the diseases and pests for a considerable time (Table 15, page 225), eg
- **Carefully inspect** all new purchased propagation material.
 - **Plant guaranteed** disease-tested planting material which is free from specified diseases, eg certified seed or other planting material **only** in:
 - Disease-tested and vector-free soil and
 - Irrigate with disease-tested water.
 - **It may be necessary to treat seeds**, cuttings or nursery stock **prior** to planting. Seek advice on general procedures.
 - **It may be necessary to treat soil** to eliminate soilborne diseases **prior** to planting. If reusing media, check it.
 - **It may be necessary to treat water**, eg filter etc. Recycled irrigation water or nutrient solutions used in hydroponic systems require attention.
 - **Control** diseases and pests which may damage crops and spread virus diseases, eg
 - **Control weeds which may act as a "green bridge"** for diseases and flying insects such as aphids and thrips may not only damage crops directly but act as vectors of diseases.
 - **When plants are growing at or near their maximum potential, minor diseases** often assume major proportions and can **reduce** the advantages of using disease-tested stock.
 - **Control methods** outlined in this book (page 15) are an important part of enhancing the use of disease-tested planting material. These control methods are used in various management systems such as integrated pest management (**IPM**), environmental management systems (**EMS**) and best management practices (**BMP**) and increase the chances that the crop will either remain free of the disease, pest organism or minimize its effects.
 - **Record keeping** is essential.

Table 15. Preventing re-infestation or re-infection of disease-tested material.



Using certified plant material

Trade	<p>Source certified disease-tested seed or transplants from reliable suppliers and inspect closely for symptoms of diseases and pests and varietal correctness. Seek advice if unsure.</p>
Be prepared for diseases, etc	<p>Plant pests and diseases are major constraints to agricultural production and food security in developing countries. Food security means many things but includes being prepared for diseases which involves:</p> <ul style="list-style-type: none"> • Having access to germplasm collections that underpin the development of new cultivars and the pre-emptive breeding of resistant and tolerant varieties. • Checking the availability of pest / pathogen-tested plant material, seed, etc. • Having access to a suite of appropriate plant protection chemicals.
Proving pest-free areas (PFAs) Keep records 	<p>If claiming pest-freedom for certification schemes, etc you must provide evidence that the area really is pest-free, eg</p> <ul style="list-style-type: none"> • Keeping the PFA pest free and proving it by regular trapping to see if the pest is present. This method is used to prove area freedom from fruit fly. • Some areas are pest free only at certain times of the year. Again this must be proved. • Have certification, phytosanitary documentation or a vendor declaration. • Pest-free areas can be costly to maintain.
Use of disease-tested propagation material in on-farm Biosecurity <i>includes orchards, nurseries, field crops, ornamental and vegetable crops.</i> <small>(pages 186,187, 200, 201, 202)</small> <div style="background-color: red; color: white; padding: 5px; text-align: center;"> Exotic Plant Pest Hotline 1800 084 881 </div> <small>Report an unusual pest, disease or weed</small>	<p>Six easy ways to reduce the threat of new pests entering and establishing on your farm, nursery, orchard:</p> <ol style="list-style-type: none"> 1. Be aware of biosecurity threats. Make sure workers and contractors are familiar with the most important pest threats. Conduct a biosecurity induction session on your farm to explain hygiene practices for workers, equipment and vehicles. 2. Use quality, pest-free propagation material from known sources Ensure all propagation material (seed, transplants, tubers, corms, bulbs, rhizomes etc) and inputs are fully tested and pest-free. Keep records (batch numbers, source, etc) and retain a sample of your farm inputs. 3. Keep it clean. Practicing good sanitation and hygiene will help prevent the entry and movement of pests onto your property. Workers, visitors and equipment can spread pests so make sure they are decontaminated before they enter and leave your farm. 4. Check your crop. Monitor your crop frequently; knowing the usual crop appearance will help you recognize new or unusual pests or plant symptoms. Keep written and photographic records of all unusual observations. Constant vigilance is vital for early detection of any exotic plant pests. 5. Abide by the law and be aware of laws and regulations established to protect your industry and other horticultural industries in your region. 6. Report anything unusual. Immediately call the Exotic Plant Pest Hotline 1800 084 881.

When to test

Postharvest testing should be carried out as soon as possible after harvest to identify the **best seed for cleaning and seed testing**. Remember laboratory seed testing offers seed buyers and sellers three key benefits that can result in more profitable crop production:

- Establishes the true disease risk associated with a seed lot.
- Provides solid data for acceptance or rejection of a seed lot.
- Highlights the needs for specific disease management.

Presowing testing is a vital link in the chain of **IPM PREVENTION:**

- Identifying threats.
- Selecting resistant varieties.
- Testing and treating seed.
- Selecting paddocks and using crop rotations.
- Adjusting sowing rates, seed depth and weed control.

Post sowing testing may also be important **IPM CURATIVE:**

- Fungicides may only provide partial protection from fungal diseases.
- Harvesting crop early.

If using you own seed, cuttings

If disease-tested planting material is not available or not being used, collect seed and cuttings from plants which are **visually free** from diseases and pests.

PROS AND CONS AND CHALLENGES

PROS

- A **preventative** method aimed at stopping outbreaks of diseases and pests rather than waiting until they are established in the field.
- **If disease-tested planting is available** it should be used, the purchase of certified strawberry seedlings.
- **Quality of planting material** is continually improving due to better diagnostic testing and improved ability of nursery stock to withstand transplanting.
- **Techniques of testing and treating** seed and other planting material are also continually improving.
- The **use** of disease-tested planting material is an important part of Integrated Pest Management (**IPM**) and other management programs.
- **May be the only possible** method of controlling certain diseases which cannot be controlled by other means (chemical sprays, etc), eg
 - Virus diseases of some ornamental plants, fruit crops and some vegetables.
 - Some bacterial and fungal diseases of ornamental plants, vegetables and cereals.
- **It is a very effective method of control** for certain types of diseases, eg virus diseases of woody plants such as deciduous fruit trees, which do not have insect or other vectors. Many virus-tested trees can remain free of specified viruses for life.
- **Compatible** with all other methods of disease and pest control.
- **Many other disease control measures**, eg soil pasteurisation, would be more effective if planting material free of carry-over infection was used.
- **Improved nursery production** with fewer budding failures in trees, increased uniformity, enhanced stock and scion compatibility, reduced deformity, stunting and distorted growth in horticultural crops.
- **Increased crop productivity** and uniformity, eg planting **virus-tested fruit trees** can dramatically increase yield. Crop reductions of up to 85% have been recorded in Golden Queen peaches infected with a combination of prune dwarf virus and *Prunus* necrotic ringspot virus. **Commercial growers** should use guaranteed disease-tested planting material if available, for **all** plantings.
- **Improved fruit quality**. A number of viral infections produce symptoms on fruit, eg pitting, russetting and cracking which reduce marketability. Virus infection can also reduce the storage life of fruit.
- **If a crop can be grown free of a pathogen** for a considerable period of its **early life** and normal growth achieved, a fairly good yield can be obtained in spite of later disease infection.
- Most **perennial plants** in the future will be produced from disease-tested propagating material, many of them through tissue culture.
- **Certification** ensures enhanced reliability of production, reputation and economic viability.
- **Certification schemes** reduce the risk of introducing unwanted diseases, pests and weeds into new areas.
- **Phytosanitary certificates** are necessary for trade.

CONS

- **No guarantee can be given**, however, that any seed sample is absolutely free of pests.
 - Methods of seed testing and treatment are **not** foolproof or 100% effective.
 - For some **virus and virus-like diseases** even heat treatment is not always dependable.
 - **Unknown latent viruses** may be present after treatment and testing, causing unexpected disease outbreaks.
- **Not many plant species are available** as disease-tested planting material. However, numbers are increasing.
- **It is can be difficult to find out** from where disease-tested planting material is available. For many crops there are only **one or a few** suppliers. Check that the source is reliable.
- **If nursery stock**, tissue culture or other propagating material is **contaminated** a disease or pest can be spread over large areas causing large crop loss.
- **Certification schemes** can be time consuming and expensive to set up.
- **Some growers are reluctant to pay** a higher price for quality disease-tested planting material.
- Some types of disease-tested planting material need appropriate and conscientious **management** to prevent re-infection occurring.
- **Some re-infection** of disease-tested material can occur where there are **insect or other vectors** of specific diseases, eg virus diseases of annual and herbaceous plants such as bulbs, chrysanthemum, carnation, and strawberry or when planted into infested soil.
- **Pesticide treated seed** needs to be **carefully handled** and stored. It may be brightly coloured indicating it has been treated with pesticide and may be attractive to children. Treated seed should never be used for feed or mixed with untreated seed. It should be handled with the same care as the **pesticide itself** and stored in a locked storage facility away from untreated seed, veterinary products, pesticides, equipment, pets and children. Birds may feed on it.

CHALLENGES

There are many continuing challenges including:

- Vendor declarations / phytosanitary requirements.
- Tolerance levels of contamination.
- Costs of maintaining pest-free areas.
- Soil is a prohibited import and export (unless accompanied with an appropriate permit) and may carry weeds, insects and diseases.
- Weeds in nursery tube stock and containers.
- Phytophthora in containers and tube stock.
- Scale-infested nursery stock.
- Grain contaminated with insects.
- Contaminated seeds, wrong variety, weed seeds, may carry diseases or pest.
- Contaminated vegetatively propagated plants, eg tubers, bulbs and cuttings.
- Chemical residues.
- Non-GM seed may be contaminated with GM seed.
- Unknown status of nanotechnology in relation to planting material.
- Avoiding re-infestation of clean material if possible.
- Traceability of planting material, eg organic seed.
- The high incidence of general disease in some certified material is of concern in some industries, eg in certified seed potatoes high levels of black scurf, silver scurf and black dot may occur which are diseases for which there no specifications or tolerance levels.

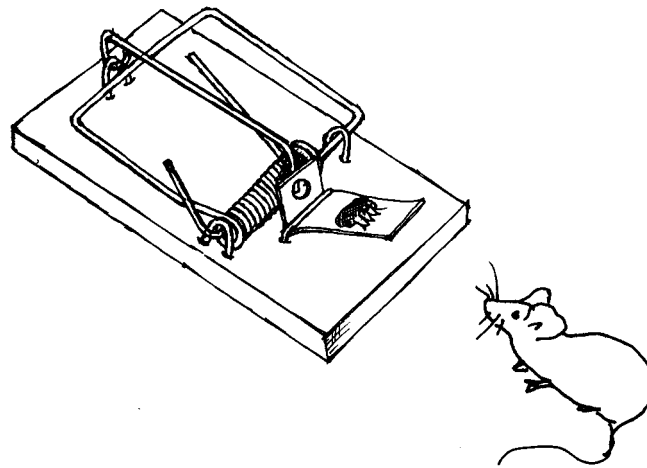
REVIEW QUESTIONS AND ACTIVITIES

1. Explain the meaning of the terms **disease-free**, **disease-tested** or **pathogen-tested** and **virus-tested** planting material. Give examples.
2. Differentiate between **disease-tested planting material** and **resistant varieties**. Give examples.
3. List the main **types of diseases** that disease-tested planting material may be guaranteed free from.
4. Which types of diseases may **tissue cultured plants** carry?
5. Differentiate between **disinfestation** and **disinfection**. Give 1 example of each.
6. Describe 2 ways by which the following may be **disinfected**:
Seeds Cuttings Bulbs Whole plants
7. Describe 3 ways by which **tissue propagation systems** may be used to produce disease-tested planting material. Give 1 example of each.
8. Describe the **3 main steps** in the production of disease-tested seed or vegetative propagation material.
9. What is the **disease hazard** associated with repeated propagation by vegetative means?
10. Describe **legislation, accreditation and certification schemes** which have been developed to improve plant quality. Give examples of each.
11. Explain why accreditation schemes are necessary for **nurseries**.
12. **Explain** why certification schemes are necessary for the following propagation material and a crop of your choice:
Carnation Strawberry Grapevine Potato
13. Describe how the following plants are **freed from virus diseases**:
Apple Potato Chrysanthemum Strawberry
14. Name 2 **sources** of certified planting material for a crop of your choice.
15. Explain why disease-tested planting material of some plants, eg tulips, is **re-purchased regularly** while for others, eg apples, this is not necessary.
16. Explain how disease-tested planting material may be used in **pest and disease management programs**.
17. For which diseases, pests or weeds associated with seed or vegetative planting material might there be **zero tolerance**?
18. How could a crop of your choice planted from certified seed or cuttings be **reinfected**?
19. List the **advantages and disadvantages** associated with using disease-tested planting material as a means of disease and pest control.
20. Perform a **practical exercise** in disease, pest and weed control using **disease-tested planting material**.

SELECTED RESOURCES




- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier, Academic Press.
- Baxter, N. 2011. *Clean Seed Part of the Herbicide: Resistance Strategy*. Ground Cover. Jan-Feb.
- Brown, K. and Ogle, H. J. (eds). 1997. *Plant Pathogens and Plant Diseases*. Rockvale Publications, Armidale, NSW.
- Coleman, E. 2010. *Sweetpotato Diseases: Using Healthy Planting Material as a Strategy for Disease Control*. Qld DAFF.
- Cooke, T., Persley, D. and House, S. 2009. *Diseases of Fruit Crops in Australia*. CSIRO Pub.
- DAFF. 2002. *Review of Post – Entry Quarantine Protocols for the Importation into Australia of Apple (Malus) and Pear (Pyrus) Budwood*. February. AFFA.
- Fleming, D. (ed.). *Deciduous Tree Fruit Cultivars*. cur. ed. Fleming's Monbulk Nurseries, Vic.
- Floyd, R. 2005. *Vegetable Seed Treatments*. Farmnote 90/1990 (reviewed July 2005).
- Freebairn, B. 2012. *Wheat Disease Scare blamed on Seed impurity*. Ground Cover. Jan-Feb.
- Horlock, C. M. and O'Brien, R. G. 2010. *Hot Water Treatment Reduces Seed-borne Bacterial Blotch in Melons*. Qld Horticulture Institute, DPI, Qld.
- Ministry of Agriculture, Fisheries and Food. 1972. *Hot-water Treatment of Plant Material*. Bulletin 201, HMSO, London.
- Mishra, S. R. 2003. *Bacterial Plant Diseases*. Discovery Publishing House.
- Papadakis, M. 2011. *Seeds for the Future: The World's Most Important Seeds are Stored in a Norwegian Island Vault*. Sunday Herald. 16/1/2011.
- Persley, D. 2007. (DPI&F Note).
- Persley, D. 2011. *Integrated Viral Disease Management in Vegetable Crops*. Qld Daff.
- Persley, D., Cooke, T. and House, S. 2010. *Diseases of Vegetable Crops in Australia*. CSIRO Pub.
- Sharma, P. D. 2004. *Plant Pathology*. Rastogi Pub. (Dusting Seeds after Treatment).
- Thomas, G. J., Adcock, K. G. 2004. *Exposure to Dry Heat reduces Anthracnose Infection of Lupin Seed*. Aust. Plant Path. 33(4):537.
- Tucker, C. 1996. *Fail to Plan and You Plan to Fail*. Aust. Hort., June.
- WADAF / VegetablesWA. 2014. *Good Practice Guide for Vegetable Production in Western Australia: Pest and Disease Management*. Available on the Vegetables WA website.
- State/Territory Departments of Agriculture/Primary Industry Factsheets are available online**
- Australian Seed Federation (ASF)
Australian Field Crop Association (AFCA)
Australian Seeds Authority (ASA)
Australian Seed Certification Scheme
Seed Industry Association of Australia Ltd.
Western Australia Seed Growers Association
Biotech Plants
ForBio Plants
Floradata
Florabank
Nuflo
Ramm Botanicals

PHYSICAL METHODS



INTRODUCTION	230
ABRASIVE AND ABSORPTIVE INERT DUSTS	231
ELECTRIC DISCHARGES	231
ENVIRONMENTAL GASES	232
FRIGHTENING DEVICES AND SOUND RESPONSES	232
IRRADIATION	233
LIGHT-INDUCED PHENOMENA	234
PHYSICAL SHOCKS	236
RELATIVE HUMIDITY	237
TEMPERATURE	238
Cooling treatments	238
Heat treatments	239
Plant material	239
Soil	240
Weeds- Thermal weed management	242
TRAPS AND BARRIERS	244
Traps	244
Barriers	249
Climate control	251
Root barriers	251
Filtration, sieving	252
Geofabrics	252
MANAGING PHYSICAL METHODS	253
PROS, CONS AND CHALLENGES	255
REVIEW QUESTIONS AND ACTIVITIES	256
SELECTED RESOURCES	256

INTRODUCTION

<p>What are physical control methods?</p>	<p>Physical control methods have become prominent in recent years due to pests, diseases and weeds becoming resistant to certain pesticides, the need to avoid pesticide residues and the costs of pesticides themselves and their application. Physical methods, sanitation and disease-tested planting material often overlap. Physical methods include using:</p> <ul style="list-style-type: none"> • The properties of the environment, eg temperature and light. • Traps and barriers.
<p>Legislation, standards, certification schemes</p>  <p>AUSTRALIAN STANDARDS</p> <p>CODES OF PRACTICE</p>	<p>Acts, regulations and standards include:</p> <ul style="list-style-type: none"> • Noxious Weeds Acts may prescribe weed control treatments. • Biosecurity Acts regulate treatments. • Vermin Control Acts regulate shooting and trapping. • Pastures Protection Acts control shooting, trapping, steel-jawed traps, etc. • Game and Feral Animal Control Acts. <p>Standards, eg</p> <ul style="list-style-type: none"> • AS 4843–2001. <i>Synthetic weed blocking fabric</i>. • AS 2001.4.21-2006. <i>Method of test for textiles</i>. • AS3660-2000 <i>Series</i> for Termite management. <p>Codes, eg</p> <ul style="list-style-type: none"> • <i>Ethical, Safe and Responsible Hunting</i> (Game Council NSW). <p>Burning.</p> <ul style="list-style-type: none"> • Most agricultural, forestry and horticultural enterprises are sited in a semi-rural or rural environment and fire is often used as a management tool but can also be a serious threat to the business. There is a requirement to protect both lives and assets with appropriate fire protection equipment and water supplies, fire breaks and the management of nearby vegetation. • These requirements are specified by legislation, varying from State to State and even regionally. Many States have regionally located Rural Fire Service offices (there are variations of this name from State to State, or a Shire Council based service that can provide you with information on the legislation and on how to protect your property, when you can legally burn, fire weather forecasts, etc.
<p>IT</p> 	<p>Computing systems make the monitoring of such physical controls as temperature and humidity relatively easy, eg</p> <ul style="list-style-type: none"> • Early warning systems have been developed for diseases, pests, frost, heat waves, storms, etc. • Data loggers record temperature fluctuations in handling, storage and transport of fruits and vegetables. The Quality Is Cool scheme monitors the temperature of fruit and vegetables every few minutes from “field to plate”. • Recording the results of monitoring of sticky traps for IPM programs. • Glasshouse monitoring of temperature and humidity assists pest control. • PMCAM (<i>Programmable Micro-processor Control and Monitoring System</i>) improves the performance and reliability of aeration, drying and fumigation control systems in grain storage facilities in Australia.
<p>Training</p> 	<p>Safety training is required for many methods, including:</p> <ul style="list-style-type: none"> • Using flame or steam weeders, eg applicator safety, potential fire risks. • Using equipment such as brushcutters in woody weed control. <p>Correct use of:</p> <ul style="list-style-type: none"> • Traps for vertebrate pest control must comply with legislation. • Anti-transpirants to protect plants from stress. • Using physical methods in IPM programs.

ABRASIVE AND ABSORPTIVE INERT DUSTS

What are they?	<p><u>The ancient Egyptians used a type of inert dust</u>, so the use of 'physical insecticides' is not new. Ground husks or ash, are used to control insect pests in subsistence grain stores in undeveloped countries.</p> <ul style="list-style-type: none"> • Diatomaceous earth (Permaguard™) is a common inert dust registered for protection of grain in storage with different formulations for household (cockroaches, etc) and garden formulations (aphids, caterpillars, etc) and farm-stored feed grain. • Amorphous silica (Dryacide®) is also registered for farm-stored grain protection.
How do they work?	<p><u>Inert dusts kill insects by abrading and adsorbing their waxy cuticle layer</u>. The insects then dehydrate and die. Stores of seed and feed grain in particular can benefit from their use.</p> <ul style="list-style-type: none"> • Dusts are more efficient at low relative humidities and seem well suited to act as long term protectants under dry or subtropical conditions. • Inert dusts are cheap and often available locally. • Large quantities are needed, frequently up to 0.1% of the weight of the product being protected, which can downgrade the product. • Advantages include long term protection (months to years), no chemical residues, maintenance of grain quality, safe for animal consumption, acceptance of some products by Organic Certification Schemes and ease of application. • Need to protect the eyes and respiratory passages when applying inert dusts; hand creams and gloves prevent hands from drying out. • Must be applied at the correct rate and be evenly mixed through the grain stream. • Apart from admixture to grain it can also be used for structural and spot treatments, eg walls of empty storages, farm equipment (headers and auger). • Inert dusts can be used in combination with other grain protection strategies.
The end-use of the product must always be considered	

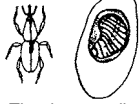
ELECTRICAL DISCHARGES

How do they work?	<p><u>Electric discharges require that pests be brought within a suitable range</u>, either by attractive light wavelengths, forced draught or natural locomotion, eg</p> <ul style="list-style-type: none"> • Electric fences are widely used in agriculture to control large stock and to keep dogs away from snail baits in home gardens. • The Electropure® water purifier. Electrolysis brings contaminating particulates in water, eg <i>Phytophthora</i>, <i>Pythium</i>, <i>Rhizoctonia</i>, algae, bacteria and clay, to the surface of the water where they are floated off. • Electric grid lights emit UV light which attracts flies and some other insects which are then electrocuted. This trap is commonly used where food is produced, processed or retailed (page 235). • Silent Night Model SK961 emits black light and attracts flies, moths, mosquitoes to the interior of the units where they are electrocuted. They can attract and kill beneficial insects as well. They have many uses, including: <ul style="list-style-type: none"> • Monitoring purposes in the horticultural industry. • Many applications in the food and other industries. • Suitable for indoor or outdoor (under cover) applications. • Variety of fitting positions with brackets provided.
Hydrosmart	<p><u>Hydrosmart provides affordable, effective chemical-free treatments</u> to the problems caused by minerals and chemicals in water supplies, eg scale formation and corrosion.</p> <ul style="list-style-type: none"> • Used where chemical treatments are undesirable, eg in the Adelaide zoo. • Utilizes a series of computer generated resonance frequencies to disrupt bonding between minerals and charged compounds; this neutralizes precipitation, decreases scale and deposition of oxides and opposes corrosion. • Widely used in vineyards and agriculture to de-scale irrigation systems, control salinity and enhance plant growth. www.hydrosmart.com.au/
No chemicals No filters No maintenance	

ENVIRONMENTAL GASES

The major environmental gases are oxygen, carbon dioxide and nitrogen

Insects in stored grain



The rice weevil (*Sitophilus oryzae*), larva in the seed.

Insect pests in stored grain may be successfully controlled by:

- **Hermetic grain storage** is a combination of packaging and environmental gas control. The respiration of the grain, insects and fungi, **reduces the oxygen** in a gas tight container to about 5% over a period of some weeks. It creates an atmosphere lethal to insects which use up all the oxygen and then die.
- **Controlled or modified atmosphere (CA)** refers to the process of altering the proportion of atmospheric gases (oxygen, nitrogen and carbon dioxide) to produce a gas mixture toxic to insects. The **CA** process provides a disinfection method that is chemical-free and suitable for "organic" grain. However, it is expensive.

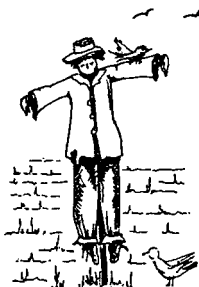
Postharvest diseases

Postharvest diseases of fruit and vegetables may be successfully controlled by:

- **Modified atmosphere packaging (MAP)**. **Oxygen** levels are lowered by the respiration of the fruit or vegetables, reducing the growth of bacterial and fungi which spoil the produce.
- **Sulphur dioxide** has been used to control some postharvest diseases of fruit.
- **Nitric oxide** is being researched to slow down ripening of fruit and vegetables and extend their storage and shelf life.

FRIGHTENING DEVICES AND SOUND RESPONSES

Frightening devices



A scarecrow.

Frightening devices include a variety of visual, mechanical and acoustical methods many of which have been used for frightening vertebrate pests, chiefly **birds**, since antiquity! There are a multitude of ultrasonic scare devices designed to repel them, on the market. Many only work for a short time. Examples of frightening devices include:

- Scarecrows.
- Displays of dead fish or birds and other animals.
- Flashing lights, aluminium foil, cans, dangling ropes, chimes, rags, flags, blown up wine cask balloons.
- Bird-scaring kites, plastic cats to scare birds away.
- Rockets, guns of various types, including electronic gas guns. These can be a problem near residential areas.
- The **Hawk Bird Scarer**, or Terror Eyes, is about 60cm wide and a bright orange sphere. It claims it is one of the world's most effective bird repellents.
- The **Humming Line** is special 5mm wide, **UV light** stabilized monofilament tape strung tightly between fixing points. It is designed to vibrate, even in the very slightest of breezes. The resulting humming sound emitted is an effective deterrent to birds and is particularly effective on crops and around gardens; also aboard boats to keep birds from perching and fouling.
- The **BirdDeter Radar System** detects birds entering the protected area. A radar "detection zone" is created between radar transmitter and receiver units. Birds are detected when they fly anywhere through this area. The system is triggered only when pests enter the protected area via the radar protection zone, producing the maximum scare effect on the birds and preventing them from becoming accustomed to the deterrents. Another benefit is the reduced likelihood of noise pollution.
- There are many other solutions. www.birddeter.com.au


Unfortunately, pests tend to become habituated to many frightening devices rendering them ineffective. Some are only useful in small areas. Birds are reputed not to become habituated to bird-scaring kites (hawks) because they have an instinctive fear of hovering, blunt-nosed fluttering objects, which resemble hawks.

Sound responses

Communication signals are used to control vertebrate pests such as birds, eg

- **Repellent**, eg distress and alarm calls. Pests do not readily become habituated to repellent signals.
- **Attractive**, eg food-finding and courtship calls. However attractive signals are not generally used to control pests.

IRRADIATION

What is irradiation?	<p><u>Irradiation is the act of exposing or the condition of being exposed to radiation</u>, eg the use or application of ionizing radiation, especially in medical treatment and for the sterilization or preservation of food. Control of disease organisms and pests by radiation is dependent on wavelengths, intensity and duration.</p>
Why irradiation?	<p>Pressure to adopt irradiation for the control of diseases and pests of stored fruit and vegetables and other foods has been increased by the restrictions on the use of dimethoate and fenthion for managing fruit fly.</p> <ul style="list-style-type: none"> • Radiation standards for food irradiation have been drawn up by the National Health & Medical Research Council (NHMRC) to protect operators and consumers. There are commercial irradiation facilities in Melbourne and Sydney.
<p></p> <p>AUSTRALIAN STANDARDS</p>	<p>Food irradiation is a process of treating a food to a specific dosage of ionizing radiation for a predefined length of time to slow or halt growth of spoilage microorganisms. Food can only be irradiated if there is a specific purpose, eg to make the food safer for consumers or for quarantine purposes to reduce insect infestation and specific permission must be obtained from Food Standards Australia New Zealand (FSANZ) - Food Irradiation www.foodstandards.gov.au.</p> <ul style="list-style-type: none"> • Irradiated food does not become radioactive, as the food does not come in contact with the energy source so it cannot become contaminated with radioactive material. • The New Zealand Ministry of Agriculture and Forestry has allowed access to the NZ market for Australian mangoes in 2004, papaya in 2006 and litchi in 2008. Irradiation is the approved treatment for insects of concern to NZ. • Labeling. Irradiated foods must be clearly labelled so that consumers can make an informed choice. • The analytical methods for the detection of irradiated foods are standardised by the Codex General Standard for Irradiated Foods.
Foods irradiated in Australia	<p>Since 2001, herbs, spices, some herbal infusions and teas, peanuts, almonds, cashews and pistachios are irradiated in Australia. Since 2002, nine tropical fruits have also been irradiated: breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya and rambutan. FSANZ is currently considering the irradiation of persimmons.</p>
Advantages of irradiation	<p>Reduces food losses and helps maintain quality and wholesomeness:</p> <ul style="list-style-type: none"> • Destroys spoilage microorganisms in food, eg bacteria, fungi, beetles, fruit flies. • Delays physiological processes, eg delays ripening, thereby extending storage life of food, and inhibits sprouting in potatoes and onions. • Reduces the incidence of foodborne diseases caused through contamination of food by <i>Salmonella</i> and other pathogenic organisms, benefits people who are at greatest risk from foodborne diseases, eg hospital patients, and those with compromised immune systems, eg HIV, transplants and some cancer patients. • Other benefits include: <ul style="list-style-type: none"> • One of the main uses is for biosecurity purposes. • In general the effect on vitamins, enzymes and trace elements is less than that caused by treatments such as cooking, freezing and canning. • Used in conjunction with, or as a replacement for, conventional food treatments. • Kills insects on cut flowers. • Prevents spread of pests and diseases in the market place. • Local industries already sterilize medical and other equipment by irradiation. • In suitable foods it does not change the flavor or appearance of food. • Leaves no chemical residues and insects may not be able to develop resistance. • Some seeds have faster germination, faster growth rates, earlier maturity and higher resistance to disease and adverse growing conditions resulting in higher crop yield. • Weed seeds can be de-vitalized. • Can create mutations in plant breeding to produce new varieties. • Inexpensive.
<p>Consumer resistance</p> <div style="border: 1px solid black; padding: 2px;"> <p>Irradiation must not be used to cleanup food which is unsafe or unsuitable</p> </div>	<p>Consumer resistance is strong due to:</p> <ul style="list-style-type: none"> • Possible production of toxic products in irradiated foods, eg aflatoxins. • Break down of proteins and destruction of some vitamins, eg Vitamin A. • May enable low quality food to be sold after losing its nutritional value. • Concerns about inadequate labeling requirements. Other concerns include: <ul style="list-style-type: none"> • At present about 50 countries have approved one or more irradiated food items for human consumption, but use varies. • Organic Standards do not permit the use of irradiation treatments (page 382). • Dosage of radiation required to kill the pathogen may also injure plant tissues. • Irradiation has the potential to alter flavors in some foods, especially fatty foods. sometimes food may change color, odor and flavor. • Environmental contamination and concerns for operator safety. • Irradiation does not prevent re-infestation or re-infection.

LIGHT-INDUCED PHENOMENON

Attractive wavelengths



Light has long been known to be attractive to many insects, especially nocturnal species such as moths. Some means of either holding or killing the insect when it reaches the light is required.

- **Different wavelengths are attractive to different insects.** Visible light has wavelengths of 4000-7600 angstroms:
 - 1800 - 3800 Ultra-violet (many moths, flies, mosquitoes, other photo-positive insects)**
 - 3800 – 4300 Violet**
 - 4300 - 4900 Blue (especially attractive to thrips and shore flies, also aphids)**
 - 4900 - 5600 Green**
 - 5600 - 5900 Yellow (attractive to whiteflies, thrips, fungus gnats, leafmining flies and aphids, some beneficial insects; repellent to some night-flying insects)**
 - 5900 - 6300 Orange**
 - 6300 - 7600 Red**
- See sticky traps on page 247.

Light traps



Light traps have been used in survey work to detect the presence of a pest in an area. However, they have generally been replaced by the use of **sticky pheromone traps** (see pages 247). Light traps are **not** very successful as a means of **controlling** insects, but there are exceptions (page 235). Benefits of light traps include:

- Reducing the **number of pesticide applications** and **biosecurity measures** which might be required, reducing the cost and residue problems which might affect beneficial organisms.
- Being able to **run for long periods without much attention**, needing only a time switch and an occasional inspection.
- Usually a **killing agent is placed in the chamber** to kill incoming insects **before** predators damage them beyond recognition.

Whitewash

Whitewash is used to reduce light intensity in glasshouses and in polytunnels.

- **The lower parts of tree trunks** may be coated with acrylic white paint to reflect excess sunlight and prevent sunburn.
- **Fruit** may be coated with whitewash to prevent sunscald.
- **In Israel whitewash is sprayed on plants to repel aphids.** Crops are irrigated once per week to prevent accumulation of whitewash which might adversely affect the crop. Whitewashes may also reduce the incidence of aphid-transmitted viruses. Because of its calcium component it is thought that whitewash may curb soil-transmitted diseases.
- **In hot climates** white wash may serve to increase crop yields.

Yellow and blue

Sticky traps
Pan traps

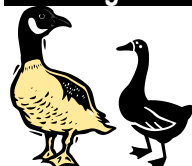


Yellow sticky traps are attractive to many insects, are long lasting and weatherproof. They are used to monitor flying insects. The special shade of yellow attracts a broad spectrum of flying insects including whiteflies, aphids, moths, leafhoppers and leafminers.

- **Yellow boards or stiff plastic sheets**, covered with clear sticky grease, attract whiteflies which stick to the grease. Fluorescent yellow paints are most effective. The sticky material must not mask the color, boards must be cleaned regularly. Yellow sticky traps may be purchased (see page 247).
- **Yellow pan traps trap elephant weevils in vineyards.** Growers were asked to indicate whether they had elephant weevil or vine weevil in their vineyards. Yellow pan traps were placed under vine canopies at the base of the trunks. Plastic bowls about 3.5 cm deep filled with water and a drop of detergent to break the water's surface tension. A pinch of salt to preserve the insects was also added (see also page 248).
- **Yellow bug light bulbs** do not kill or repel insects. They simply attract fewer insects than other light bulbs. A bug light will not magically solve your insect problem, but it will make you and your home less visible to most flying insects. Remember if a few smaller bugs appear at the light, they will attract larger insects. The best thing to do to avoid a swarm of bugs is to turn the light off when you don't need it.

Blue is attractive to thrips and leafminers, they trap very few other insects. They are mainly used for monitoring Western flower thrips (*Frankliniella occidentalis*). See sticky traps page 247.

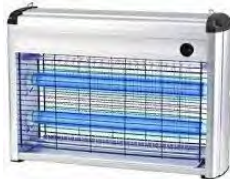
Amber lights disturb geese



One goose can leave 2-4 pounds of droppings on a golf course every day.

- **Away with Geese** is an effective, humane and environmentally friendly way to eliminate geese problems. The unit is solar powered and **emits an amber-colored light, disrupting the sleeping patterns of geese**, ultimately encouraging them to move to a new location.
- **One unit placed in a pond** will effectively protect an area of about 2 hectares continuously each night with no maintenance. Placed in the middle of a pond. Some ponds may require 2 or more units to provide complete line of site coverage.

Ultra-violet light (UV light)
Blue-light “zapper”



UV light attracts and kills some flying insects. There are many different types.

The electric light grid is probably the best known light trap. It is widely used in food shops and some are available to nurseries and greenhouses, significantly reducing chemical use. Certain flying insects such as flies, moths (and some beneficial insects), are attracted by **UV light** of specific wavelengths and then electrocuted. Their hygiene and effectiveness has been improved, eg use of insect glue boards, adhesive film and louvered screens to trap and conceal flying insects of every kind. No “zapps” of high voltage electricity every time a fly is caught and the ugly sight of dead insects. Other uses of UV light include:

- **UV water sterilizers** kill soil fungi and bacteria in contaminated water. It is difficult to get a complete kill. **The effectiveness of treatment** depends on the strength of the **UV** lamp, the duration of exposure, the flow rate, clarity and salinity of the water, the types of ions present and the geometry of the treating chamber.
 - **Various filters** may be recommended before treatment, eg mesh to remove coarse particles, charcoal to remove odors. Others which retain and trap minerals in the water such as phosphates, toxic poisons and mercury, may also be recommended.
- **Pulsed UV light kills bacteria and mold on the skin of many types of fruit.** The treatment also improves fruit quality and extends shelf life up to 80 days.
- **UV light** is strongly absorbed by cell proteins and nucleic acid. It is used to sterilize operating theatres, culture rooms, etc. It has little capacity to penetrate matter.

Colored shade netting

Light spectrum management.

Certain varieties of colored shade cloth can manipulate the growing conditions and growth habit of a variety of crops.

- **RED** stimulates overall plant growth, it steps up growth.
- **GREY** stimulated side branching.
- **BLUE** encourages dwarfing and flowering delay.
- **Colored shade netting** can become expensive but has reduced temperatures in propagation greenhouses in the heat of summer and retains the heat in the winter.
- **Enables adaptation to market preferences**, with clear economic advantages.
- **An alternative to current labor-consuming methods** (such as pruning and thinning) and intensive use of growth regulators and other chemicals.
- Today’s growers **optimize light with screens that also manage temperature.**

Colored films
Smart films

Light spectrum management.

Hi-tech films for polytunnel covers with different characteristics which either block or allow through different wavelengths of light have biological effects on the plants, pests and diseases growing beneath them, eg

- **UV blocking films claim to reduce certain diseases and pests**, reducing the need to apply fungicides. Others reduce the need for plant growth regulators, eg
 - **Incidence of Botrytis and other diseases.** In order to produce viable spores most fungi need the stimulus of wavelengths in the **UV range of light of 3500-3800** angstroms. All polythenes and glass block up to about 3500 angstroms but if you can take out light up to 3800 angstroms you can stop disease from spreading. Some claim to reduce levels of both *Botrytis* and powdery mildew and can be used over 4 seasons. Some also offer an **Anti-Botrytis film**.
 - **Insects.** Research from Israel also suggests that UV blocking films may control insects such as thrips and whiteflies and the viruses they transmit. Anti-algal and other films are also being trialed.
- **Plant growth regulation.** Color plastic films could take over some of the roles of plant growth regulators. Researchers have trialed the use of photo-selective greenhouse covers to control plant height in *Lisianthus* as an alternative to using chemical growth regulators. The photo-selective polyethylene films either:
 - Absorbed far-red light (reducing stem elongation) or
 - Absorbed red light (stimulating stem elongation).
 - A combination of growth regulators with photosensitive films could be successful in reducing the amount of chemicals used.
- **Specialist orchard films for management of fruit and vegetables** are available for plant and tree health. www.insense.com.au/
- **SunUp Reflective Orchard Film** reflects 85% or more of the sun’s UV rays up into the underside and central areas of trees where most of the difficult-to-color fruit hangs. The Brix level (a measure of the carbohydrate level in plant juices) can also increase which means better tasting fruit. www.insense.com/au
- Some types of film reduce the chances of plants being scorched.

Reflective mulches

Reflective aluminium mulches and highly reflective plastic sheeting can be used as a mulch to repel adult aphids, thrips and possibly other virus vectors. Aphids are attracted towards blue sky and are **disorientated by reflective surfaces on the ground**. In hot climates, reflected heat can cause burning. Overseas, planting cucurbit crops through highly reflective plastic sheeting protects them from aphid injury. Such mulches cease to function as soon as the crop canopy covers them.

- **Sunup Reflective Mulch** for weed and pest management in vegetable crops is available, especially for Western flower thrips management.

Directed solar radiation

“ReduFuse” is a removable glasshouse coating that converts direct solar radiation into diffuse light that penetrates more deeply into crops and ensures lower plant temperatures. Crops grow more strongly and crop yield and quality increase.

PHYSICAL SHOCKS

Soil cultivation, grain turning

Physical shocks can inhibit insect development.

- **Soil cultivation** during the fallow season before the sowing of crops, or after harvest, acts as a physical shock to insect development. Many insects pass some stage of their life cycles in the soil.
- **Grain turning** has abrading, crushing and other disturbing effects on insect development, and can significantly reduce populations of stored grain insects.

Weed seed bank

Weed seed management has become the No. 1 IWM tool.



Weed seeds in the soil – Next year's weeds, but how many years will seeds survive in the soil?

Targeting weed seeds at harvest enables growers to plant crops according to calendar and season rather than have seeding operations dictated by the need for pre-sowing weed control. As a large percentage of grass weeds are still on the plant at harvest they have the potential to enter the header making collecting weed seeds during harvest a viable option.

The Integrated Weed Destructor (IWD) is a modification of the original ***Harrington Weed Seed Destructor (HWSD)*** which destroys the weed seed contained in harvester chaff by crushing it and so reducing weed populations.


- **Many growers indicated** that they were reluctant to tow the ***HSD*** behind their harvesters.
- **The new IWD is mounted within the rear of the harvester** to destroy weed seeds as they exit in the chaff fraction. It is still in the prototype stage.

The technology behind the HSD / IWD.

- The units completely destroy any seeds contained in the chaff and re-spreads them over the field, eliminating the need to stop and empty chaff carts. Field trials by the ***WA Herbicide Resistance Initiative*** have demonstrated little residual viable weed seed after treatment by the destructors.
- ***IWM is the key word to weed control in paddocks*** incorporating chemical and cultural options. The ***HSD / IWD system*** offers a novel approach, destroying weeds seeds in chaff from headers, alleviating the need to collect the chaff and carry it off field or burn it. It has a valuable role to play in ***IWM*** and it can:
 - Lower the weed seed bank.
 - Delay the onset of herbicide resistance.
 - Aids in the management of herbicide-resistant weed populations.
- **The system** it is the only option that destroys weed seeds during harvest at a single pass while allowing the conservation of all crop residues and does not require any post-harvest management. It provides a similar level of weed-seed kill in chaff carts and windrow burning (page 73).
- ***Trials to date*** have shown that usually at least 95% of the weed seeds that exit the header in the chaff fraction during harvest are destroyed. These high rates have been achieved repeatedly under commercial harvest conditions in wheat, barley and lupin crops.
- ***Ryegrass emergence was reduced by 40-60% at each of the test sites in WA.*** Long term views must be taken in assessing the impact of harvest weed-seed management systems on weed populations. While the trial focused on ryegrass, it was also effective in controlling wild radish, wild oat and brome grass.
- **The HSD has been found to be as effective as chaff carts and windrow burning** in reducing ryegrass emergence (*The Harrington Weed Seed Destructor is a tool in IPM*. GRDC May June 2011. Case study GRDC Growers' Report 2008-2009).

Wild radish can maintain viable seed in the seedbank for 10 years

RELATIVE HUMIDITY

Greenhouses	<p>Fungal diseases such as downy mildews and Botrytis can effectively be suppressed by lowering the humidity using air blowers (page 37).</p>
Storing bulbs and corms	<p>Storage diseases of these plants can be prevented by ensuring that they have been properly dried prior to storage.</p>
Fruit 	<p>Fruit must not carry surface moisture during storage and transit, which could result in decay of the fruit by fungi and bacteria.</p> <ul style="list-style-type: none"> • Many fruits can be stored for a long time and kept free of disease if they are dried sufficiently before storage and if moisture is kept below a certain level during storage. • Desiccation is a complete or nearly complete deprivation of moisture (as by vaporization or by evaporation). It is used to preserve food. <ul style="list-style-type: none"> • Grapes, plums, dates and figs can be dried in the sun or through warm air treatment to produce raisins, prunes, dried dates and figs respectively. They are generally unaffected by fungi and bacteria as long as they are kept dry. • Slices of fleshy fruits such as apples, peaches and apricots can be protected from infection and decay by fungi and bacteria if they are sufficiently dried by exposure to the sun or to warm air currents. • A banana may be desiccated in a food dehydrator. • Food may also be freeze desiccated. • See also page 238.
Grain storage, legumes, nuts <p><12%</p>	<p>All grains, legumes and nuts may carry fungi, bacteria, insects and mites that can cause decay in the presence of sufficient moisture. Pest development is inhibited by drying grain until its moisture content is less than 12% and keeping it at 12% during storage.</p> <ul style="list-style-type: none"> • Harvest produce when properly mature. • Avoid mechanical damage both during harvest and subsequent handling. • Dry in air, or treat with heated air, until the moisture content is reduced sufficiently to about 12% moisture before storage. • Subsequently store under conditions of ventilation which do not allow build-up of moisture levels beyond about 12%.
Aeration of stored grain	<p>The ideal silo is one that can be both aerated for cooling grain, yet sealed gas-tight and fumigated when storage pests are detected (Baxter 2011). Under favorable conditions a single pair of insects can become a raging infestation in 3 months and conditions can be favorable for grain insects for much of the year. Recommended pest control includes:</p> <ul style="list-style-type: none"> • Elimination of contaminating insects. Hygiene in harvesting, transport, handling and storage equipment, white painted bins, grain protectant application and removal of insect refuges around store. • Making the storage hostile to pests –The ability to aerate grain storage offers more than just diversification to an enterprise (Penfold 2011). <ul style="list-style-type: none"> • Grain harvested at high moisture content can be air dried for safe storage. • It is a proven, safe technology. • Aeration also offers the ability to prevent field molding and toxic formation, capacity to suppress insect infestation, remove the heat from respiration of grain, insects and molds and to prevent localized hot spot development. Ability to rapidly remove fumigants in stored grain. • Fumigation is central to stored grain pest control. <ul style="list-style-type: none"> • Phosphine is the only fumigant widely available for on-farm fumigation. Research studies with phosphine have shown it will kill all species of all ages of grain insects (eggs, larvae, pupae and adults). • To ensure complete kill it is important that the phosphine is retained in stored grain long enough. In practice though, phosphine will be retained for long enough only if the storage is adequately sealed or phosphine is added continuously. • In Australia a low level of resistance to phosphine is common, but this low level of resistance does not lead to control failure if used according to label instruction in sealed storages. Elsewhere in the world phosphine resistance is not uncommon but it is comparatively low as yet, in Australia. • Keeping new insects out of the store, sealing the storage and maintaining hygiene around storage area. • Early recognition and fixing failures in the above actions, eg trapping, inspection and fumigation.

TEMPERATURE

Temperature is the most widely used physical method of plant disease control.

Cooling treatments “Quality is cool”

Refrigeration, cooling



The common refrigerator

Keeping fruit and vegetables cool from ‘field to plate’ ensures the delivery of high-quality produce to the consumer (Agrios 2005).

Refrigeration is probably the single most important, most widely used and most effective environmental factor controlling postharvest deterioration of cut flowers, fruit and vegetables, etc. The higher the temperature the faster the rate of deterioration.

- **Low temperatures at or slightly above freezing point, do not kill disease organisms** that may be **on, or in, plant tissues**, but they do retard their growth and development, reduce spread of existing infections and the start of new ones.
- **Most perishable fruit and vegetables are refrigerated as soon as possible after harvest, transported** in refrigerated vehicles and **stored** in refrigerators until used by the consumer. Temperature data loggers **monitor and record** temperature fluctuations every few minutes from the field to retail outlet.
- **Forced air cooling (FAC)** is where cool air is passed **through** containers of cut flowers instead of over them, so that cooling is more rapid. Grain driers circulate cool air through stored grain.
- **Natural cooling and forced ventilation** is also used to a minor extent for fruit and vegetables. **Ice** is used to cool vegetables.
- **Quick hydrocooling or air cooling** may precede regular refrigeration of succulent fruits and vegetables, to remove the excess heat carried in them from the field as quickly as possible, preventing the development of any new or latent infections.
- **There are many “improved” cooling systems** to maintain produce quality and shelf life, eg forced cooling, Mobile Cooling Systems; Liquid Ice Systems, etc.

Freezing

Although many bacteria are killed by exposure to cold, freezing is not a reliable method of sterilization.

- **If a contaminated product is frozen**, eg its microbial load will tend to be maintained but when thawed many of these organisms will still be alive and so spoil the product.
- **Its primary use is the preservation of cultures**, bacteria in particular. Many bacteria and viruses can be stored in the **deep freeze** at **-20 to 70°C**. Others including fungal cultures and yeasts are stored at **4 to 7°C under refrigeration**.
- **Freezing and desiccation**. Desiccation (the absence of water) metabolic activity ceases followed by a decline in viability. Combining rapid freezing with dehydration enables storage for long periods of time.

Postharvest cold treatments for fruit flies

Biosecurity

Cold treatments are used as a quarantine measure in USA to prevent the re-introduction of the Mediterranean fruit fly (*Ceratitis capitata*).

Postharvest cold treatments of fruit as a biosecurity measure are used as an alternative treatment for access of specified fruits to certain markets. Tropical and subtropical fruit may be subject to chilling injury. Steps for successful cold treatments must be followed carefully. Examples include:

Queensland Fruit Fly: Postharvest Cold Treatment

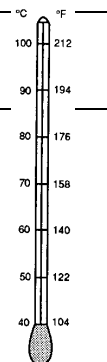
- 0.5°C - 0.5°C for at least 14 days; or
- 0.5°C - 3.5°C for at least 16 days; or in the case of lemons, 14 days.

Mediterranean Fruit Fly: Postharvest Cold Treatment

- 0.5°C ± 0.5°C for at least 14 days; or
- 1.0°C ± 0.5°C for at least 16 days; or in the case of lemons, 14 days; or
- 2.0°C ± 0.5°C for at least 18 days; or in the case of lemons, 16 days or
- 3.0°C ± 0.5°C for at least 20 days or in the case of lemons 18 days.

COLD TREATMENTS

THESE ARE SUBJECT TO CHANGE



Heat treatments

How do heat treatments work?

Consider the canned goods on your supermarket shelves. Canning requires the complete sterilization of food and container.

Many disease organisms live in, or on, propagating material, eg seeds, bulbs, nursery stock, and can be transferred to disease-free areas when planted out. These organisms can be eliminated by heat and/or chemical treatments (page 214).

- In some cases the effect of heat may be indirect, eg the host may produce **fungitoxic substances**.
- **Heat under pressure** is used to kill microorganisms, eg pressure cookers or autoclaves, and is able to penetrate readily the materials being sterilized. Time depends on the nature and volume of the material being sterilized.
- **Dry heat has limited application** and is not as effective as moist heat but is the most convenient way of sterilizing objects such as empty test tubes, inoculation loops, etc. Dry heating laboratory glassware for **2 hours at 160°C** is sufficient for sterilization.

Plant material

Hot water treatment (HWT)

Some diseases can be eliminated by HWT. The water temperature and length of treatment must be measured accurately as too little may not kill the disease organisms and too much may damage the seed, propagation material or other plant part (pages 213, 214).

- **Seed treatments**
- **Vegetative propagation material treatments**
- **Some fruits**, eg navel oranges, intended for movement within Australia or export to New Zealand may be disinfested of certain fruit flies by hot water treatments, eg hot water immersion for **15 mins at 45°C** (see below)

Hot air treatments

Hot air treatments are numerous and varied, including:

- **Hot air treatment (curing)** of certain **storage organs** removes excess moisture from their surfaces and hastens the healing of wounds, preventing infections.
 - **Keeping sweet potatoes at 28-32°C for 2 weeks** helps wounds to heal and prevents infection by *Rhizopus* and soft rot bacteria.
 - **Hot air curing of harvested ears of corn** removes excess moisture from them and protects them from attack by fungal and bacterial saprophytes.
- **Forced heated air** continuously applied from beneath an open bottom bench reduces incidence of *Botrytis* stem blight of geranium.
- **Most insect pests of stored grain** are killed by **3 hours exposure to 60-65°C**.
 - Overseas, many mills equip buildings with heating pipes enabling them to raise the temperature to **51-65°C** for several hours during periods of warm weather. This kills all the insects in the building and is **less expensive than fumigation**.
 - Heat treating machines raise the temperature of grain as it is passed through.
 - Small quantities of grain can be heated in an oven at **65°C for 30 minutes**.
 - Infrared, microwave, radiation and other forms of heat have been studied as a means of controlling insect pests in stored grain but at present they are uneconomic.
- **Vapor heat treatment (VHT)** disinfects tropical fruits, eg mangoes, entering Japan, against fruit flies. Fruit is heated with humidified hot air until a core temperature of **47°C is maintained for 15 minutes** (see below).

Postharvest heat treatments for Queensland fruit fly Biosecurity

Postharvest heat treatments of fruit as a biosecurity measure are used as an alternative treatment for access of specified fruits to certain markets. Some fruits may be subject to injury. Steps for successful hot water treatments must be followed carefully. Examples include:

Post harvest Hot Water Treatment. Mangoes

The fruit has been treated by full immersion in hot water at a temperature of 46.0°C for at least 10 minutes, where measured in the water, and as near as practicable to the seed of at least 3 fruits.

Vapour heat treatment. Mangoes

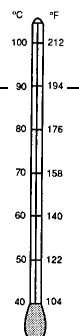
Vapour heat treated in a facility approved by the Manager Plant Standards: At a temperature of 46.5°C for 20 minutes; or 47°C for 15 minutes.

High temperature forced air. Pawpaws

The fruit has been in a hot air chamber, at a temperature of 47.2°C, for at least 3.5 hours, as measured in the seed cavity.

HEAT TREATMENTS

THESE ARE SUBJECT TO CHANGE



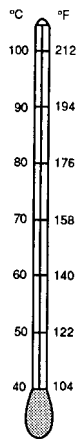
Soil

Field steam sterilization of soil

Various methods are being trialed for field and protected cropping sterilization including:

- **Flame heat.** Mobile machines in the UK can sterilize soils at a range of different moisture levels. Sterilizers are self-propelled and pick up a section of top soil as they move along planting rows. Inside the machine the soil is delivered to a rotating drum where it is exposed to flame heat that kills nematodes, pathogens, weed seeds and eggs in nematode cysts. Machines are designed for different uses, eg protected cropping, outdoors.
- **Steam sterilization.** Some growers use steam sterilization as an alternative soil treatment because it provides the same level of control of both plant pathogens and pests as the banned methyl bromide.
- **Sandwich steaming is capable of performing field applications** and is a very effective way to kill nematodes. The soil is treated with steam from two sides – from the surface covered with a steam hood and simultaneously from the depth by a steam plough. The maximum steaming-depth is **50 cm** at the moment.

Pasteurization / sterilization of soil, media



Soil, potting media and recycled pots may carry diseases or pests that will damage plants grown in them. **Aerated steam** (steam diluted with air) can be used to **pasteurize** or **sterilize** soil / potting media.

- **Pasteurization kills harmful bacteria and other organisms** in soil, water or food by heating at specific temperatures for certain periods of time. **Pasteurization** is the process of using mild heat to reduce microbial populations in milk, beer and other foods **at 63°C for 39 minutes** (classic pasteurization) or more commonly **72°C for 15 seconds**. It is used to kill pathogenic organisms because they are more sensitive to heat. Domestic cooking kills many pathogenic organisms.
- **Sterilization eliminates all living organisms** from soil, containers, water, etc.

Temperatures at which various types of pathogens, insects and weed seeds are eliminated from soil, seeds, and other propagative organs.

TEMPERATURE 0°C (30 min)	BACTERIA AND FUNGAL PATHOGENS	INSECTS, OTHER SOIL ANIMALS	WEEDS
>82	Elimination of a few heat-tolerant viruses		Elimination of heat tolerant weed seeds
72-82	Elimination of most pathogenic viruses, and heat-tolerant plant pathogenic bacteria	Elimination of most insects	Elimination of weed seeds.
60-72	Elimination of most plant pathogenic bacteria and fungi	Elimination of some worms, slugs, centipedes	
50	Elimination of plant pathogenic fungi that produce zoospores		

Pasteurization of growing media

Many nurseries use soilless mixes

Pasteurization of growing media (NIASA cur. edn).

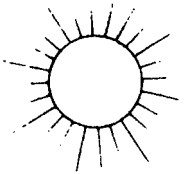
- **Mix potting media thoroughly at the moisture content required for planting.** Leave for 4 hours to allow spores to take up water and reach a stage of development at which they are more susceptible to damage by heat than when they are dry.
- **Bring soil or potting media up to 60°C over a period of 30-45 minutes** and hold at that temperature for **30 minutes**.
- **Most parasitic bacteria, insects and other organisms and some weed seeds are killed**, but beneficial organisms that form resistant spores survive the treatment and help prevent re-contamination of the material.
- **Excessively high or prolonged high temperatures** should be avoided as **such conditions destroy all normal saprophytic microflora in the soil**, and may result in the release of toxic levels of some salts, eg manganese and an accumulation of toxic levels of ammonia.
- **Advantages of pasteurization** include:
 - Kills parasitic organisms, many beneficial ones are not harmed.
 - Fewer chemical changes in soil compared with sterilization.
 - No damage to plastic containers.
 - Lower heating costs.
 - Only approximately 3 hours waiting time after treatment.
 - Penetration of heat can be measured during treatment.
 - Safer for operator than the higher temperatures of sterilization.

Re-used containers are steam-treated at **72°C for 30 minutes** which kills weed seeds as well as soilborne pathogens.

Composting)

Composting is described on page 71.

Solarization of soil



Solarization has a long term effect (2-3 seasons) in both disease control and yield increase.

It also decreased soil salinity

1µm = 0.0001 cm

Solarization can reduce pre-plant levels of **some diseases of some crops**.

- **Heat from the sun may raise the temperature** near the surface of soil or potting media to levels high enough to kill or reduce populations of some pests, eg mites, most soilborne disease organisms (bacteria, fungi, nematodes), and some weeds and weed seeds.
- **Soil solarization increases the temperature of the surface layers of the soil** by 10-15°C up to approximately 50°C. The longer high temperatures can be maintained, the better the level of control achieved.
- **You must know which diseases, pests and weeds are a problem in your crop.**

Effective soil solarization usually includes:

- **Carrying it out** during periods of **maximum daily temperatures and light intensities** (clear skies, long day lengths and little cloud).
- **Ensuring that the soil** is free of weeds, debris and large soil clods. It must have a level and smooth surface by raking out any plant remains.
- **Irrigating heavily 1-2 days before laying the plastic.** Soil moisture conducts heat more quickly and more deeply into soil and increases heat sensitivity of soil pathogens and weed seeds.
- **Placing a thin (50-100 µm), clear plastic sheeting on the soil**, holding down edges with soil to ensure wind cannot get underneath. The plastic acts like a greenhouse trapping solar energy and preventing heat losses caused by evaporation and convection. If using for long periods or as a mulch, use **UV stabilized plastic**.
- **The longer the period of solarization the more effective the control.** Recommended periods vary from **3 weeks** to up to **6 weeks** in less sunny and cooler weather. Leave for **at least a month, during mid-summer**. The sun's heat will penetrate deep into the soil, killing many unwanted organisms.
- **After solarization avoid cultivation deeper than 10 cm** to avoid reintroducing pathogens and viable weed seeds into the surface layers of the soil.
- **Advantages of solarization.**
 - Plants grown in solarized soils or potting mixes show improved growth, partly due to the control of microorganisms and stimulation of the activity of various microorganisms which either fight disease or promote plant growth.
 - No toxic products appear to result from solarization.
 - Effects often last longer than 1 season.
- **Disadvantages of solarization.**
 - Depends on strong steady sunshine.
 - Areas remain unplanted for a minimum of **1-6 weeks**.
 - Difficult to control the temperature of the medium.
 - Difficult to dispose of large amounts of plastic.

Soil reductive sterilization (SRS)

Soil reductive sterilization (SRS) achieved by amendment with wheat bran followed by flooding and covering the soil surface with polyethylene sheeting for 20 days was highly effective for controlling *Fusarium* wilt disease in carnation crops. Disease control may be related to a combination of high soil temperatures and anaerobic processes. Efficacy of SRS persisted for more than one season and was statistically equivalent to soil disinfection with methyl bromide (Yossen et al 2008).

- **SRS by induction of anaerobic conditions** provides control of soilborne pathogens in cold and wet climates where temperatures are too low for solarization to be effective.
- **The addition of easily degradable material** such as wheat bran or sucrose drives fermentation and contributes to soil anaerobiosis where organisms that require oxygen die out.
- **The integration of SRS into farming systems** has the potential to control soilborne pathogens, restore the natural microbial equilibrium in soil and allowing the recycling of decomposable organic materials.

Microwaves



Microwaves are deleterious to human health and care must be taken to shield people from radiation.

Microwaves may be reflected, transmitted or absorbed by matter in their path. Metallic materials totally reflect microwaves. Most non-metallic materials such as glass and plastics are partially transparent to microwaves. Material containing moisture, such as food and even people, absorbs microwave energy. Uses include:

- **Sterilizing potting mixes and growing media.** Because exposure times are so short, microwaves may be more energy efficient than many of the methods currently in use. However, the process is generally suitable for small quantities only.
- **Microwaves heat the water molecules in the soil** and so raise the soil temperature. The water is ultimately converted to steam in the medium. Microwaving is essentially a **steaming process** with the steam being generated within the medium itself. Microwave sterilization is effective at reducing or eradicating fungal populations. Depending on exposure time, partial or complete sterilization may be achieved.
- **Australian Radiation Protection and Nuclear Safety Agency (ARPNSA).**
www.arpsa.gov.au/is_mwave.htm
- See also page 243.

Weeds – Thermal weed management

Burning has been used to control weeds and prepare planting beds since the beginning of agriculture (page 73). Thermal weed management has seen a resurgence in the last few years due to implementation of *IPM* programs and increased acreage of organic agriculture.

Heat treatments could be used to control weeds where there are environmental and health issues relating to the use of *herbicides* in public and other areas. Operators must be trained in their safe use.

Flaming or thermal techniques should be used in integrated weed management programs.

Burning



Harvest weed seed management is the number one IWM tool. Burning narrow windrows creates higher temperatures than whole paddock burning, greatly increasing control of a range of weed seeds while leaving most of the paddock with adequate stubble to minimize wind erosion (Baxter 2010). See also page 73.

A management burn is planned, controlled and conducted to achieve a management objective; it must not go beyond the desired area.

- **It is also used to control exotic woody and other weeds.** General guidelines for burning to control woody weed growth are readily available.
- **Local regulations** may restrict or prohibit burning at certain times of the year. Check.

Flame guns, infrared burners, steam wands



Propane can be dangerous, affected by wind, grass fires, etc. Check with local fire officials to see if a permit is required.

Fire risk

Flame guns and steam wands kill the aboveground parts of weeds, and can be used to control seedlings, annuals and young softwooded perennials. Roots of woody perennial weeds are **not** killed. The most sensitive are **broadleaved annuals** with **upright growth patterns**. To increase the effectiveness of the burners for weed control, growers can encourage weed germination prior to using the equipment.

- **Flame guns** are used to control weeds on paths, drives, along fences, crazy paving and on bare soils (Quarles 2004). A flame is passed quickly over the weed to kill it by desiccation and cell disruption.
 - **They can use a lot of fuel**, produce a hot blue flame and can be slow to operate.
 - **Hand held or tractor / ute pulled.** Flamers are waved back and forth over a weed.
 - **Ground must be prepared.** watered, weeds allowed to germinate, flamed, then the crop planted. Resistant crops such as corn and onions and potatoes can be flamed after planting. Flame guns can be competitive with herbicides and possibly could be used to weed between rows as the crop develops.
 - **Growers can reduce incidence of disease** such as apple scab which overwinter inside fallen apple tree leaves, opportunistic beneficial microbes then rapidly recolonize.
 - **Pesticide resistant insects** such as Colorado potato beetle overseas can be controlled by flamers. Flamers are also used instead of pesticides to kill insects in trap crops.
 - **Potato foliage can be desiccated** before harvest with flamers instead of herbicides.
 - **Flaming versus infrared.** Most literature shows that flamers are more effective than infrared. Flamed weeding had higher yields than when weeds were controlled by cultivation. Most effective organic method is hand weeding but a combination of cover crops with flaming came closest to hand weeding in terms of weed control.
- **Infrared burners** heat ceramic or metal surfaces to generate the infrared radiation directed at the target weeds. Some weed burners use a combination of infrared and direct flaming to kill the weeds.
 - **In general, flame weeders are considered to be more effective** because they provide higher temperatures, but burner height and plant stage are important too.
 - **Infrared weeders cover a more closely defined area** than those of the standard flame weeder, but may need time to heat up.
- **Steam wands.** Operators must be trained in the safe use of steam wands.
 - **Water is superheated** and delivered as steam to an applicator head via an insulated hose. The steam enshrouds the weeds at temperatures of between **95-110°C** destroying weeds within seconds.
 - **Rainfall increases the energy** needed for hot water weed control by 20%. Drought stressed plant are more easily killed.
 - **Steam** can be applied in any weather, there is no drift, and at any time of the year.
 - **A hot foam system** is approved for organic production. Hot water and flaming were both effective in controlling pasture weeds (Quarles 2004).
 - **Weedtechnics** (Sydney) is developing a diesel-powered machine which can be fitted on the back of a utility, a trailer, pumps out steam at the applicator head which rapidly raises the temperature of water in plant cells, destroying soft tissue. Targeted weeds wilt immediately, brown off within 3 days and decompose into the soil, adding organic matter (2010).
 - **Atarus Ranger Weed Burner** is a 3kg aluminium gas cylinder giving 45 minutes usage. Broad flame pattern with separate booster flame control for stubborn and woody weeds. **Atlas Stinger** Model V640 is the latest in thermal weed control for use with all terrain vehicles and is configured for use on fence lines. The unit combines steam with hot gases and air to give the best possible medium for speed of application and lowest fire potential.

Microwaves



How do microwaves work? Microwaves may be reflected, transmitted or absorbed by matter in their path. Metallic materials totally reflect microwaves. Most non-metallic materials such as glass and plastics are partially transparent to microwaves. Material containing moisture, such as food and even people, absorbs microwave energy. Check the Australian Radiation Protection and Nuclear Safety Agency (ARPNSA) website.

- **Microwave energy kills weeds** by heating them, either by cooking the emergent plants or by steaming seeds underground. The microwaves excite the water molecules in the plant, literally cook the stem and kill the seeds by energizing water in the soil to steam them. Plants irreversibly wilt after a few seconds of treatment.
- **Weed control.** Research is underway to develop a prototype machine that destroys weeds at a cost comparable to conventional herbicide methods and as an alternative to herbicides. This would be particularly useful where weeds have developed herbicide resistance or where residual weed control is an ongoing problem and where chemical use is limited or where weeds have long-lived seeds.
- **Microwave technology** is now being adapted to help eradicate weeds in cropping systems, eg as a pre-sowing knock-down treatment or to eradicate weeds growing in crop rows (Marino 2012).
 - **To treat emergent weeds several microwave modules and / or generators** are attached to a vehicle and **precision agriculture technology** targets inter-row weeds as the vehicle moves slowly through the paddock.
 - **The system should work like a boom spray** hitting weeds with beams of microwave energy. When killing weed seeds in the soil the system will have to move more slowly across the paddock, heating vast tracks of soil to **an excess of 80°C** and using huge amounts of energy to do so. The microwave process pasteurizes the topsoil, killing bacteria and other biota as well as weed seeds **down to about 6cm**. The effect on the soil biota is temporary and the heating has no effect on the soil's nutrient value and while it does reduce the microbial activity, the bacterial colonies re-establish from below.
 - **Wind or rain does not affect microwave weed treatment** which extends the application periods compared with conventional spraying methods.

Others

Endogenic heat for composting

Endogenic heat, produced by the natural process of composting and fermentation, is used in the formation of compost, for gardens or mushroom growing (see page 71 for details).

- **Temperatures reached should approach 60°C** which is sufficient to kill most disease organisms.
- **However, the temperature of the majority of compost heaps** is poorly controlled so that this temperature is not usually attained.

Ultrasound, high energy pulses

Ultrasound shows promise as a postharvest phytosanitation treatment against external pests of some apple and some other fruits and could be incorporated into the packing line (Hansen 2001). However, results so far have been inconsistent. Pests included codling moth eggs, twospotted mites (*Tetranychus urticae*) and Western flower thrips (*Frankliniella occidentalis*). Check the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) website.

Microwaves





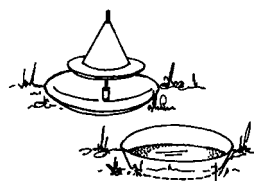
Microwave technology is also used for many other processes other than soil and weed treatments, eg

- Flower drying.
- Quick drying (less than a week) of hardwood timber (traditional methods take up to a year).
- Detection of some species of termites. It is a **non-destructive** diagnostic technique.

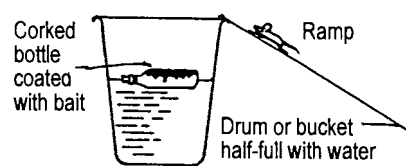
TRAPS AND BARRIERS

Traps

How do traps work?	<p>Traps have many modes of action, eg</p> <ul style="list-style-type: none"> • Most traps must have an attractant, eg food, sex, shelter, and a means of killing or holding the pest. • Traps may also be placed in known tracks, and the pest may be killed or held by sticky adhesives or various types of metal traps. • Pests can also be attracted by light and particular colors, eg colored sticky traps (see page 247). • Traps should be managed appropriately, eg all farms in a region must trap foxes at the same time.
Purpose of traps	<p>Traps are used to monitor and / or control pests directly.</p> <ul style="list-style-type: none"> • Traps are mostly used in survey work, indicating when a pest is present in an area, so that sprays or other control measures may be timed more precisely, resulting in reduced costs and residues. • Direct pest control, eg the common mouse trap is used to control mice.
Area-wide Collective action	<p>Area-wide / Group control programs. There are a number of benefits of group control programs which are largely driven by landholders but use the knowledge and experience of Pest Control rangers who can advise on the best timing for baiting and other control methods and the most appropriate control depending on the season, pest prevalence and breeding patterns, eg rabbit, foxes, feral goats, pigs and wild dogs.</p>
<p>Legislation</p> 	<p>State / Territory Trapping Legislation. eg Prevention of Cruelty to Animals Acts, Animal Care and Protection Acts, Animal Welfare Acts, have been developed in all States and Territories. Check to see what traps you can legally use in your State or Territory and follow Standard Operating Procedures (SOPs) for trap use.</p>
<p>Food traps</p> 	<p>The rat or mouse trap is probably the best known food trap. A water bucket food trap can be used for catching large numbers of mice (Fig. 22 below). A bucket is 1/2-3/4 filled with water and an empty bottle, coated with molasses, animal fat or other attractive material, allowed to float on the surface of the water. The mice climb up a stick leaning against the edge of the bucket, then fall into the water and drown. Other food traps include:</p> <ul style="list-style-type: none"> • Feral cat, fox, wild dog and pig cage traps are available for hire from some local Pest Control Authorities. Bait trailers are available for rabbit baiting. • Possum cage traps are used to relocate possums from houses to nearby bush areas. Check local legislation regarding this. It is usually illegal to trap native animals. • Indian myna traps are used on some built up areas in Australia. Birds are then killed humanely. • Snails and slugs become intoxicated from feeding on beer and die. They may also fall into the beer and drown. • Fly food traps containing rotting meat in bottles or other containers are the basis of many modern fly traps. Flies are attracted to the bait, enter the trap and are unable to get out. Modern versions of these traps contain organic material that is reputed to contain no harmful chemicals or toxins and have no smell. • Home-made traps attract and kill fruit flies. However, they are best used to indicate the presence of fruit flies and consist of brown sugar, yeast, vegemite and ammonia. These also attract other flies. www.yates.com.au/products



Beer traps are used to control snails. The snails become intoxicated from feeding on the beer and die.



The water bucket trap is an effective method of catching large numbers of mice.

Fig. 22. Examples of food traps.

Sex traps
Monitoring and control

Pheromone traps are used to monitor moth and beetle pests before and after treatment. Some types of pheromone traps provide **direct control** of pests (page 101). Others act as an early warning system or for surveillance purposes.

- **Fruit flies, eg**
 - **QFly bait which may be prepared or bought as a kit**, contains protein or yeast hydrolysate which **attracts both male and female fruit flies** and **maldison** which kills them. Fruit fly is effectively controlled when bait is applied at the **recommended rates and frequencies**.
 - **Dak.pot® Lure and Insecticide Trap** contains a pheromone which **attracts male Queensland fruit flies (QFly) (*Bactrocera tryoni*)** and an insecticide (maldison) which kills them. This trap does **not** satisfy legislative requirements for effective control (page 101).
 - **Male Annihilation Techniques (MATs)** are designed to reduce the male population. These lure and kill devices are placed on the perimeter of the source property or distributed by air. Celotex wafers impregnated with methyleugenol (male specific parapheromone attractant) containing 3% dibromspinosad (insecticide). Note that these lure and kill devices can compete with male fly traps making monitoring more difficult.
 - **Fruit net bagging** to trap Oriental fruit fly in Taiwan (Ho et al 2006).
 - A large number of female and male flies were trapped by using fruit net bags with sticky paper (guava sticky-bag) and thus significantly reduced the percentage of infested fruits by 19-57% in the guava orchard.
 - Tests showed that by putting the bag at 2 meters apart and replenishing the fruit bait every 7-10 days could capture more than 97% of female and male flies in the orchard and was more effective than using protein hydrolysate bait.
 - The methods were also effective in reducing the fruit fly population in other orchards such as sapodilla, carambola, citrus and persimmon.
- **Codling moth (*Cydia pomonella*)** pheromone traps are now widely used to monitor codling moth populations in orchards enabling a reduction in the total pesticide applications required (page 101). Codling moth kits can be purchased (Fig 23 below). Insense & desire Pest Management. www.insense.com.au/
- **Pheromone lures are available for many other insects, eg**
 - Stored product moth and beetle pests
 - Lightbrown apple moth
 - Corn earworm, native budworm (*Helicoverpa* spp.)
 - Diamondback moth
 - Macadamia nut borer
 - Oriental fruit moth
 - Red cedar tip moth
 - San Jose scale
 - Persimmon clearwing borer
 - Potato tuber moth
 - Earwigs
 - Citrus red scale
 - Cutworm spp., armyworm spp., wireworms
- **Early warning system for fruit-spotting bugs.** Fruitspotting bugs are considered by some to be the most damaging pest in the horticultural sector after fruit fly. They are small and green, only about **1.7mm long** and hard to spot in an orchard.
 - A sexual attractant produced by male fruitspotting bugs is being trialed to attract female bugs. Finding the bugs as soon as they arrive in a crop can tell a grower when to spray to prevent damage.

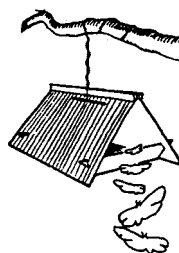
These tiny fruitspotting bugs are considered by some to be the most damaging pest in the horticultural sector after fruit fly

Managing lures:

- **Lures are often specific**, eg a codling moth (*Cydia pomonella*) lure only attracts male codling moths. Oriental fruit moth lures will only attract oriental fruit moths.
- **If two different lures are used** or if there is even a trace of a lure left, results will be conflicting.
- **With all pheromone monitoring systems, reusable traps** must be dedicated to use with one type of lure. For similar reasons old lures must be removed from the area being monitored.



Dak.pot® contains a pheromone which attracts male Queensland fruit flies (*Bactrocera tryoni*) and maldison to kill them.

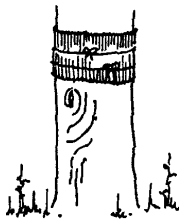


Female codling moth (*Cydia pomonella*) pheromone lures attract male codling moths for monitoring. Photo©Insense and desire Pest Management.



Fig. 23. Pheromone traps

Shelter traps

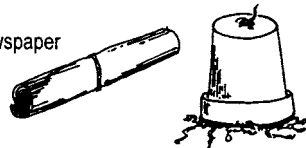


Bands of corrugated cardboard are tied around the trunks of pome fruit trees in spring to provide places for codling moth larvae to pupate

Shelter traps are mostly used by home gardeners, eg

- **Earwigs.** Rolled up newspapers or upturned plant pots filled with shredded newspaper make excellent earwig traps. Empty traps every 3-4 days and destroy the earwigs, rolled newspapers can be destroyed.
- **Slugs.** Leave boards overnight on damp soil in garden beds, in the morning destroy the slugs which have sheltered underneath.
- **Codling moth larvae.** Bands of corrugated cardboard are tied around trunks of pome fruit trees in spring to provide places for codling moth larvae to pupate. Remove, destroy and replace bands every 6 weeks during spring, summer and autumn. It is also used against other insects that can climb the trunk, those which congregate around the base of the tree during the day or those that pupate in dark crevices.
 - Also used against fruit tree root weevil, white cedar moth larvae and for vine weevils when they emerge.
 - Cardboard traps around the upper portion of vine trunks or layers of hessian, newspaper, etc around the base to trap adult weevils and earwigs.

Rolled newspaper



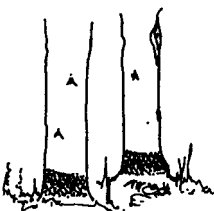
Earwig traps of rolled newspaper or upturned flower pots full of shredded newspaper

Track traps



Legislation. Use of traps is regulated under the Prevention of Cruelty to Animals Regulations 2008. These regulations specify the types of traps that can be used, the conditions of use and where they can be used.

- **If intending to use traps ensure legal requirements are met.** Leg hold traps can only be used to trap rabbits, foxes and wild dogs. Leg hold trapping of all other species is prohibited.
- **Traps must be set to minimize any harm** caused to a trapped animal and to minimize the risk of catching non-target species.
- **Serrated steel-jawed leg hold traps can no longer be used** to trap any animal and the sale of them is illegal.



Grease bands at the base of trees prevent ants crawling up the trunk.



Track traps include the all-too-familiar metal traps of various types. These traps are extremely cruel as the animal must remain, usually in pain, in the trap until it dies or the trap is inspected. Land Protection Boards or their equivalent, **specify the types of traps** which may be used to trap vertebrate pests, eg foxes, wild dogs.

- **Sticky track traps include:**
 - **Bird repellent gel products.** When a bird lands on a treated area its feet break through the seal and touch the gel. The bird experiences no pain but does not like the feeling and will fly away and warn others not to land.
 - **Sticky gel around the base or trunks of trees** trap ants attracted to scales and other honeydew-producing insects feeding on trees. Larvae of the **elm leaf beetle** (*Pyrrhalta luteola*) can be trapped when moving down trunks to pupate. Alternatively, other sticky materials such as wrapping tape can be wound around the trunk (adhesive side out).
 - **Houseflies stick to sticky paper traps** hanging from ceilings.
 - **The feet of mice** become entangled in sticky material.
 - **Cockroach traps** are used to **identify** situations **needing treatment** and **detect** the first signs of re-infestation **after treatment**. The trap contains rolled oats and water as an attractant and a sticky area to trap the cockroaches.
- **Area-wide management**, eg all farms in a region must trap foxes at the same time.
- **Tamper-resistant stations** for baiting and monitoring crawling insects such as cockroaches. Suitable for schools, day care centres, etc.
- **Metal traps for rabbits, etc.**

NOTE

Several types of traps are used for the live capture of a variety of small-medium sized animals for monitoring and research purposes.

Standard Operating Procedures (SOPs) provide advice on the use of traps for non-lethal trapping of terrestrial vertebrate fauna.

Colored sticky traps

What pattern of monitoring could you use in your work situation?



Rolls of yellow sticky plastic can be purchased and stretched along rows

Colored sticky traps are used for detecting, monitoring and partially controlling many important pests. They offer many benefits, including:

- **When used for monitoring pest populations**, ie for the
 - **Early detection** of certain pests.
 - **Effectiveness** of control measures.
 - Regular monitoring can show **regular seasonal patterns** of pest occurrence.
 - Used for monitoring in **Integrated Pest Management (IPM)** programs.
- **Compatibility** with biological control techniques and help time release of biocontrol agents.
- **Save costs** by allowing spot sprays instead of blanket sprays.
- **Prompt intervention** with appropriate controls before crop quality is affected.
- **Reduce reliance** on chemical measures.
- **Harmless** to the environment.
- **Useful in many situations**, eg in commercial and domestic buildings, in orchards to monitor codling moth and other pests, pests in glasshouses and gardens.
- **Reducing the insect populations** without the use of toxic chemicals.
- **Protection** against heavy infestation.

Which color is best? This is still under debate (see page 234).

- **Yellow traps** are attractive to a wide range of small flying insects, eg winged aphids, thrips, whiteflies, fungus gnats, fruit flies (both male and female), black flies, shore-flies, mosquitoes, midges.
- **Blue traps** are most attractive to **western flower thrips (WFT)** (*Frankliniella occidentalis*); however they trap very few other insects - leafminers. Both male and female **WFT** are attracted to **blue, violet, yellow and white** in that order. Green, orange and UV-reflecting white hues are unattractive.
- **White traps** are used in WA to trap **WFT** (they are easier to see on white background).
- **Transparent traps** are used in vineyards to trap Lepidoptera and Neuroptera. They can be constructed by stretching a vertical screen of transparent plastic film, eg kitchen film between 2 stakes and coated with pest glue. Webs of orb-weaving spiders in vineyards often construct aerial webs between rows can also trap insects.

Identifying the insects on the traps.

- **Growers need to distinguish** between aphids, whiteflies, thrips, fungus gnats and other insects, also between the common pest species within these groups, eg
 - Greenhouse whitefly (*Trialeurodes vaporariorum*) from silverleaf whitefly (*Bemisia argentifolia*).
 - Western flower thrips (*Frankliniella occidentalis*) from greenhouse thrips (*Heliothrips haemorrhoidalis*), onion thrips (*Thrips tabaci*) and melon thrips (*Thrips palmi*).
- **Various texts, online sources and apps** are available, but it may still require the services of an entomologist.

How often should traps be checked?

- **Generally weekly.** However, some people recommend daily inspections. Some convenient checking regime should be put in place.
- **If traps are left in the greenhouse over weeks**, pests caught in previous weeks have to be recounted. This is tedious and causes staff to lose enthusiasm.
- **Disposable gloves** keep the sticky material from worker's hands, but a bottle of a cleaner or solvent will also be useful.
- **Place traps** in grid-like fashion and in the **same positions each time** preferably with a number assigned to each site. Place just above the crop height with positions being adjusted with the growth of the crop. Additionally a small number of traps can be placed in critical places, eg near doorways.

How many traps?

- **No set rule but 1 per 100m² is suggested.** If pest populations prove to be uniformly distributed then the number can be reduced. Outdoors a minimum number of 10-12 traps per hectare are recommended. Cost, time and usefulness of the information being collected often decide how many traps should be used.
- **For monitoring purposes**, smaller traps in sufficient numbers to make the exercise worthwhile, is recommended.

Traps may be bought readymade; some can be made by hand. Suppliers include:

Bugs for Bugs www.bugsforbugs.com.au
 Australasian Biological Control (ABC). Good Bug Producers www.goodbugs.org.au
 BioResources Mactrix www.bioresources.com.au/
 IPM Technologies www.ipmtechnologies.com.au/
 Insense and Desire Pest Management www.insense.com.au/
 Garden Centres

<p>Light traps</p> <p>UV</p>	<p>UV Light Vortex Insect Control trap for cotton and other crops. www.vortexics.com.au</p> <p>Solar powered, non-chemical treatment option, ideal for <i>IPM</i> strategies, cost effective, and proven tool in reducing in crop <i>Helicoverpa</i> eggs and larvae numbers.</p> <ul style="list-style-type: none"> • Ideally suited to spray sensitive areas, low maintenance. • Trials have little or no effect on beneficial insect species. • Continued use of the trap can lower the chemical load on the environment and reduce the development of insecticide resistance. • The wheelie bin-sized Vortex Bugbin attracts flying insects with a solar-powered UV light. Disorientated by the light the insects are drawn into a drum of swirling water where they become trapped in a mesh filter and drown. The Bugbin can be used anywhere but particularly effective against <i>Helicoverpa</i> moths. Each bugbin is effective on up to 5 hectares of crop. The company recommends that it be used year-round in order to reduce the local insect population. Ideally the bugbin should be used as part of an <i>IPM</i> program.
<p>Flying spore traps</p>	<p>The CRC for National Biosecurity is developing a “flying fungal spore trap” for use in surveillance and the identification of outbreaks of plant pathogens that already cause diseases in Australian crops, ie</p> <ol style="list-style-type: none"> 1. Develop remote sensing of airborne fungal spores for more efficient surveillance. 2. The development of a trapping system that could detect the presence of a specimen via an in-trap camera and relay the information wirelessly or by mobile phone connection to a web-based interface. 3. The next stage is to develop specific miniature cameras that can detect specific UV and other signatures to differentiate between related but different species of fruit flies, moths and beetles.
<p>Miscellaneous traps for insects</p> <p>CO₂ and UV attract female mosquitoes</p> <p>Other flying Insect traps</p> <p>Non-flying Insect traps</p>	<p>Mosquitoes, sandflies and midges use carbon dioxide to navigate to people. The Ambush Mosquito Trap works by targeting female mosquitoes as the males do not bite. By eradicating the females, the reproduction cycle is broken. The Ambush lure contains octenol and lactic acid, an area of the trap has been sprayed with titanium dioxide which when exposed to ultra violet light generates CO₂ to imitate human breath. A UV light also attracts mosquitoes and biting insects. Once the mosquitoes are close to the trap, they get sucked in by powerful fan. The trapped mosquitoes are collected in the catch container where they soon dry out and die. Under normal conditions the Ambush Mosquito Trap will exterminate the mosquito population in an area up to approximately 1500m².</p> <ul style="list-style-type: none"> • Beneficial wasp traps in vineyards. Fruit fly traps were adapted to catch wasps in the vineyards that may be potential predators or parasites of the elephant weevil. The traps consisted of a large 2L bottle with 2 smaller 600ml bottle cut off in a funnel shape and put in either side of the larger bottle (Gardening Australia 2002). Elephant weevil frass used as bait, attracted wasps by chemical stimuli. Water was put in with the frass at the bottom of the 2L bottle to disperse any chemical attractants. • The window trap is a large frame which is hammered into the ground with a clear sheet in between the frame to resemble a window. At the base of it a flower punnet is situated which has water, detergent and salt like the yellow pan trap (page 234). These traps are placed at the end of each row of the vines to catch insects which have a habit of flying down rows. The clear sheeting is not visible to the insects so as it flies along a row it runs into a window trap at full flight knocking itself into the punnet. The punnet containing, water, detergent and drowns, the salt preserves the insect. • Pitfall traps for monitoring non-flying and ground-dwelling arthropods including Hemiptera (true bugs), Neuroptera (lacewing larvae), spiders, ants and beetles in a vineyard. <ul style="list-style-type: none"> • Dry pitfall traps consists of wide-mouthed containers sunk into the soil so the opening is flush with the ground surface; • Wet pitfall traps contain liquids such as ethylene (anti-freeze). To get a quick kill pitfall traps can be monitored for a particular species pest and beneficials. • Qld Dept. of Environment and Resource management have developed Standard Operating Procedures (SOPs) for using pitfall traps. www.uq.edu.au • Soil plugs are used to assess the type and number of arthropods living in the soil. This can be done by digging a plug of soil using an auger or shovel in the top 15cm of soil where most of the arthropods are and counting the number of mites, earwigs, slugs, earthworms, centipedes, slaters, etc that you find. This may be in response to the application of mulch or the change in vineyards practices, eg less cultivation, less chemical usage. <ul style="list-style-type: none"> • What you find will depend to some extent on the time of year that you take the plugs.

Barriers

<p>How do barriers work?</p>	<p>The main purpose of barriers is to:</p> <ul style="list-style-type: none"> • Keep the pest and its host or victim apart. Control birds, rabbits and other vertebrate pests and some insects, eg termites, aphids, thrips. • Covers are available for all types of crop protection including frost, heat, rain, hail, wind, sunlight and birds.
<p>Vertebrate pests</p> <p>AUSTRALIAN STANDARDS</p>	<p>Since the beginning of time vertebrate pests have had to be controlled.</p> <ul style="list-style-type: none"> • Pest-proof containers, eg <ul style="list-style-type: none"> • Rat and mouse-proof containers are used for storing seed and foodstuffs. • Lids on garbage containers keep out rats, possums, dogs and cats. • Fences, eg <ul style="list-style-type: none"> • Dog and rabbit-proof fences. • Prickly plants can act as a deterrent to animals, including humans. • Salt-affected and other areas can be fenced off to allow them to rehabilitate. • Anti-roosting systems prevent birds from landing but do not harm them, eg <ul style="list-style-type: none"> • Expandable coils stretch out over narrow edges and the back of billboards. • Bird Beware spikes is a readily assembled anti-roosting system designed to stop medium to large pest birds from roosting in many areas. • Netting has long been used to protect fruit crops from birds and fruit bats, eg <ul style="list-style-type: none"> • Various types of tree netting are available. Dwarfing rootstocks ensure that netting trees is easier. • Scaraweb forms a spider web over seedbeds and fruit trees. Holes are instantly repairable and it rots away after a few months. • Whole crops may be enclosed, eg netting may be suspended over 5 ha of blueberries. • White gale hail netting protects orchard and trees. It may be UV resistant and allow water and air through. The netting creates a microclimate, temperature changes are moderated and crop damage from frost is significantly reduced. Crops are also protected from high winds, hail, excessive moisture loss, birds, small mammals and airborne insects. Weed growth, water splash and evaporation are inhibited. • Fruit bagging is used in the home garden using paper bags, stockings. • Tree guards help establishment of young trees during the first 2-3 years of growth: <ul style="list-style-type: none"> • They protect them from wallabies, hares, rabbit, sheep, goats and pets; also from dry winds, frosts and cold. They make herbicide applications easier and safer. • They improve conditions for plant growth, acting like a mini-greenhouse, increasing the temperature of the soil and increasing CO₂ in the air. • There are many types of tree guards, eg waxed cardboard, plastic film, hessian, wire netting, shade cloth. Some are made for special crops, eg Vineyard Trellis Post and Post Extension System.
<p>Snails and slugs</p>	<p>Snails and slugs will not move over rough surfaces.</p> <ul style="list-style-type: none"> • Mulches of bark or chips are an effective deterrent. • Circles of bark, chips or other rough materials around plants form an effective barrier. Make sure that there are no snails or slugs within the circle. • Metal collars placed around seedlings protect them from snails, slugs and cutworms (moth larvae) attack.

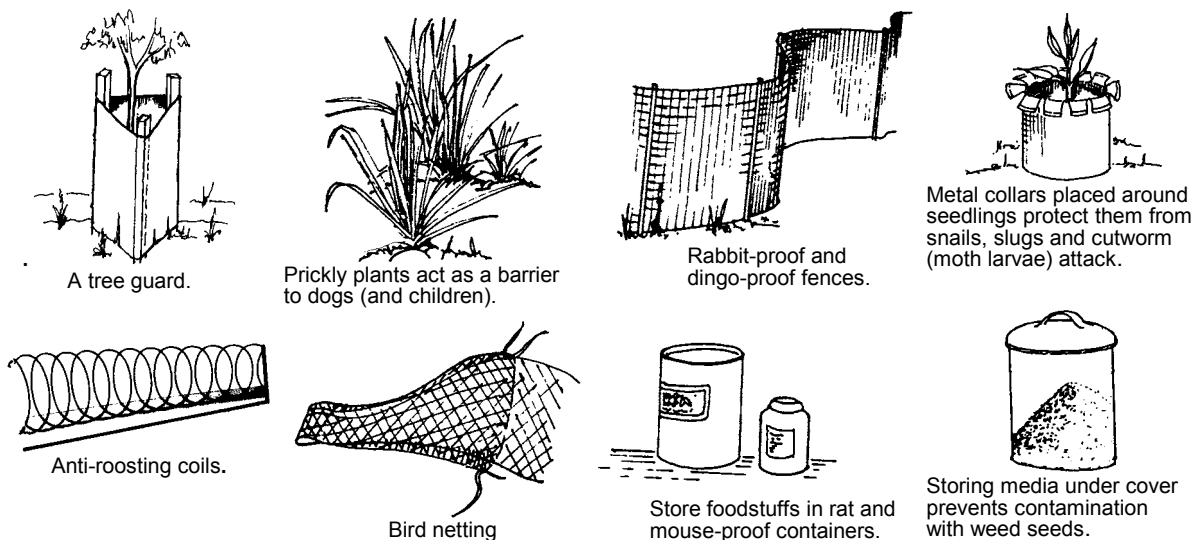


Fig. 24. Examples of barriers.

Insect and allied pest barriers

AS/NZS ISO STANDARD

Today's modern growers optimize light with screens that also manage temperature

Biosecurity post-entry facilities

Marketers of thrips screens often claim 100% blockage but there is insufficient data to support that claim

AUSTRALIAN STANDARDS

Greenhouses with appropriate screening provide a physical barrier to insect pests and vectors of diseases **reducing the need for insecticides**. Insect screens should be included in a good integrated pest management (IPM) system. The material to be used should be selected only after careful consideration of a number of factors, including air-flow reduction, ability to exclude pests and cost.

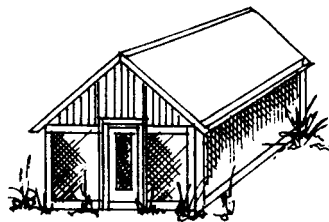
- **Products** must comply with a relevant standard.
- **It is important to know which insects need to be screened out**, eg **aphids, whiteflies or thrips**, so that appropriate mesh size can be selected. The hole size depends on the smallest pest to be excluded: Western flower thrips (0.192mm), melon aphid (0.340mm) and silverleaf whitefly (0.462mm).
- **Seek advice on airflow**, primarily a function of hole or mesh size, varies widely among screen products.
- **Redpath Biomesh** is a monofilament polyethylene UV stabilized yarn mesh. It is very closely woven and is used to **guard against pests as small as 0.28mm**. Biomesh may be used outdoors over a simple framework or used in greenhouse or animal shelter applications to exclude small pests. The color (natural) still allows excellent light transmission. www.redpath.com.au/
- **Is 100% exclusion necessary?** This will depend on the type of crop being grown, eg virus-tested plants (presuming transmission by aphids, thrips or other pests) can often justify the cost of an exclusion screen. If total exclusion is necessary as in **biosecurity post-entry premises**, then vents and doorways need to be covered. Material entering the greenhouse must be insect-free. If only a reduction of population is adequate a larger hole size may suit.
- **Control of weeds** adjacent to greenhouses can reduce the **incidence of insect pests**.
- **Entrance chambers (with 2 doors) to glasshouses** help reduce the entry of insects.
- **During winter greenhouse vents** are usually closed preventing entry of many insects and reducing likelihood of virus spread by this means.
- **Screening also helps to retain biological control agents** within the greenhouse. NZ keeps bumble bees inside greenhouses for pollination.

Screens outdoors.

- **Plastic or net covering of row crops** may protect a crop from infection by preventing insect pests and vectors of diseases from reaching plants.
- **Mosquito netting or Marix cloth** will protect Brassicas at transplanting from cabbage white butterflies and cabbage moths. Often useful for home gardeners.
- **Products include** ChromatiNet, Aluminet, anti-insect, anti-hail and anti-bird nets, wind breaks and decorative nets. They protect plants from the elements and pest attack while increasing crop yields.
- **UV resistant fabrics can deliver** climate control, temperature reduction, energy savings, light spectrum management and plant protection and last for many years.

Insect-proofing containers and structures.

- **Insect-proof packaging** prevents the pest reaching the product.
- **Lids on food containers** and garbage cans protect against flies.
- **Sealing cracks in drawers**, around pipes and skirting boards screen out cockroaches.
- **Termite control in houses.** Mechanical barriers assist in controlling some termite species but are most effective when accompanied by regular inspections and maintenance of these barriers. Australian standards include:
AS 3660.1—2000 *Termite management—New building work*
AS 3660.2—2000 *Termite management—In and around existing buildings and structures—Guidelines*
AS 3660.3—2000 *Termite management—Assessment criteria for termite management systems*
- **Ditches around crops** can stop invading crawling pests, eg redlegged earth mites.
- **Bulk air movement** may prevent larger insects, eg house flies, entering buildings.
- **Casuarina buffer zones** can be a first line of defense against windborne insects.



Insect-proof shadehouses prevent insects carrying virus diseases to plants inside.



A ditch dug around a crop prevents armyworms (caterpillars) advancing into the crop from surrounding infested weedy areas. The armyworms fall into the ditch.



Food is packaged in insect-proof containers, eg aluminum foil, etc

Fig. 25. Examples of insect barriers.

Diseases

Hortideck is a rigid high density polyethylene sheeting for standing pots on.

It has one flat surface while the other is covered in a regular series of bumps.

- **Pots sit raised up**, creating an air barrier between the pots and the growing surface, enabling them to be kept away from the water runoff, therefore helping the prevention of water and soil borne diseases being transferred between plants.
- **The sheeting acts as a weed mat** reducing the need for herbicides.
- **Roots are air-pruned** when they grow out of drainage holes and so potted plants are prevented from rooting in the ground. **RockerPot® Tree Systems** are available from Trentcom APS Pty Ltd, a company that specializes in **air root-pruning systems**.
- **It is UV stable** and will last for at least 10 years.
- **Prevents vigorous roots** from entering the blue metal screenings, sand or soil surfaces and to prevent weed seeds germinating and establishing.

Wrapping seeds in a type of plastic (Intellicoat®) protects them from fungal attack in cold wet soil and then disintegrates when the weather improves and the soil warms up enough for the seeds to germinate.

Edible coatings are important in the quality, safety, transportation, storage and marketing of many fresh and processed foods. Coatings are based on a wide range of proteins, polysaccharides, lipides and resins and many others. They:

- Protect food from microbial and insect attack.
- Prevent water loss in storage.
- Prolong shelf life.

Climate control

Reflective films reflective materials

Anti-fogging agents and treatments, are chemicals that prevent the condensation of water in the form of small droplets on a surface which resemble fog

Many greenhouses make extensive use of screening for climate control. This often involves a screen for winter and a separate screen for summer. The materials sold for this purpose are usually not suitable for keeping out pests.

- **Many materials are used as thermal screens** to increase night temperatures and decrease day temperatures. Protection of plants from climatic conditions is often unnecessary during certain seasons. Moveable roof systems which are motor-driven and controlled by temperature move into place whenever extremes of hot or cold temperatures are likely to occur. **Materials include spunbonded polyester fibre** (Marix®), polybubble, suntuff polycarbonate (for insulation) and aluminium foil (page 235).
- **Aluminium materials** are mainly used to control heat in greenhouse. Aluminium shade cloth inside glasshouses reflects heat, reduces sunscorch, day-time over-heating and night-time heat loss. Night-time cooling slows plant growth and allows water to condense onto plants increasing *Botrytis* diseases. **Aluminet®** is a high-quality, reflective shade cloth that is used for greenhouses and vegetables:
 - Energy saving, lightweight and easy to handle. High tensile strength.
 - High reflectability and improved light diffusion, **UV** stabilized.
 - Protects against frost.
- **Anti-fogging agents.** Most greenhouses films today contain an anti-fogging agent, however, this treatment does not last forever. They also allow more light to reach plants. Some can be re-applied and regain the “non-drip” benefits.

Root barriers

Root barriers, root pruners

Trees have runaway roots which steal moisture and nutrients and damage paths

Root barriers for trees are easy to install and handle, structurally sound, a permanent solution and a waterproof cut-off wall. They are a light weight plastic shield (just 0.75mm thick) and specially designed to form an impenetrable barrier against tree roots and excessive damp and moisture. The impermeable barrier prevents moisture moving sideways through the soil. It stops moisture leaching away from buildings.

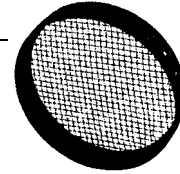
Root pruning systems. Regular irrigation of golf courses fairways is a great attraction to trees lining fairways, grass tennis courts.

- **Root Pruners available for the turf industry** slice roots up to 150mm in diameter with little surface disturbance and a working depth of **230mm**.
- **Rootmasters** have a very large circular saw with specially adapted trenched teeth and penetrates the soil to **600mm**. The cut is usually made beyond the drip line so there is no detrimental effect on trees. The saw cuts a trench 75mm wide and it fills the trench with soil behind it.

Filtration, sieving

Mechanical sieving

Mechanical sieving and grading of seed and separation by **flotation** are means by which seed can be freed of infective **disease propagules**, eg galls, sclerotia, and the survival stages of certain insect **pests and weed seeds**.



Water filtration

1µm = 0.0001 cm

Filters with pores sizes between 0.1-0.2 µm must be used to effectively remove disease organisms from water. This means that a large amount of pump energy is required to push water through the filter. Unless the water supply is very clean, filter membranes need to be cleaned frequently. If there are many particulates, high algal or silt content, water may need to be pre-filtered prior to disinfection.

- **Various types of bio-filtration systems** have been developed which also combine filtration with the stimulation of suppressive microorganisms, eg bacteria (*Pseudomonas*) and fungi (*Trichoderma* spp.) that breakdown disease-causing fungi, eg *Fusarium*, *Phytophthora*, *Pythium*. Some systems 'clean' the water while recycling nutrients. Advantages include:
 - No need for chemicals or technical instrumentation.
 - Low energy consumption, minimal maintenance.
 - Great adaptability in components and applications
 - Costs of building and running may be significantly less than other methods of filtration.
- **Filtration is commonly used for sterilizing aqueous solutions** containing heat-sensitive material. The filter must have holes too small for the passage of contaminating microorganisms, while still allowing passage of the liquid. A variety of bacterial filters are available.

Geofabrics

Advantages

Weed blocking fabric, should let rain through, keep moisture in, be biodegradable, improve plant health, prevent soil spillage and suppress weeds. It is used for:

- Bunker lines for golf courses, mats for soil protection.
- Pot tops in rolls or squares, reduces herbicide use and evaporation (up to 75%). Also prevents soil and nutrient splash from sprays.
- Protecting soil from erosion.
- As an underlay for decorative mulches.

AUSTRALIAN STANDARDS

Australian standard include:

- AS 2001.4.21–2006. *Method of test for textiles. Color fastness tests.*
- AS 2001.2.3.1–2001. *Method of test for textiles. Physical tests.*

Types of materials include:

- **Biodegradable bagasse** is a fibrous by-product of sugar cane, can be used in parks, gardens and revegetation areas.
- **Indian coir** from the outer husk of coconuts is eco-friendly and biodegradable.
- **Terraform™ Jute Matting geotextile** protects young trees and shrubs by reducing competing weeds and the need to use herbicides. Allows air and water to pass through unimpeded, the soil beneath can breathe promoting growth of desired plants while reducing evaporation and minimizing watering needs. 100% biodegradable.
- **Weed Gunnel** is a permeable and degradable weed blocking fabric specifically developed for the agricultural, landscape and organic industries. It is an excellent organic registered weed control mat, it is stabilized for extended life.
- **Permathene** is woven polyethylene fabric for weed control in nurseries, landscaping and horticulture. The structure is tight enough to prevent light reaching the soil so weeds cannot grow, but allows air and water to pass through to prevent soil souring.
- **Hort Fleece** is a white, nonwoven polypropylene material designed to aid in protection of plants **from insects, frost and extreme weather**.
 - The fabric is draped over a variety of field crops to protect seedlings, sensitive buds and flowering plants.
 - It assists in temperature control, adjusts temperatures underneath on average 2 to 6°C.
 - Hort Fleece insulates the area under the fabric while allowing water to pass through at the same time trapping in heat.
 - It is breathable so it doesn't have to be removed during sunny days.
 - Has a high degree of light transmission to assist in the growing process.
 - The fabric traps in ground heat, creating a greenhouse environment to stimulate and accelerate growth while assisting in maintaining temperatures while allowing for water from irrigation or rain to penetrate through the membrane. Pests cannot get past the row cover to the plant, and moisture within the covered area condenses on the cover and falls back into the soil.
- **Mulches** are generally described on page 46.

MANAGING PHYSICAL METHODS

Physical methods have become prominent in recent years, mainly because pests, diseases and weeds have become resistant to certain pesticides, their increasing cost and the need to avoid pesticide residues. They **do not prevent re-infestation** so must be used in an **IPM program with other appropriate control methods**. Generally growers are familiar with how most physical methods work.

Greenhouse insect screens

Insect screens



In IPM systems, exclusion of pests should always be one of the first tactics considered to reduce the need for other control measures. Reductions in pest populations, lower incidence of insect-transmitted diseases and fewer pesticide applications have been documented when screens are used (see also page 250).

- **Excluding pests using greenhouse screens is now more cost effective.**
- **Always check that insect screen will screen out the insects you want to control**, eg thrips and whitefly, etc.
- **The use of insect screens is not currently widespread** in Australia with most production nurseries and cut flower growers utilizing other effective **IPM** strategies to eliminate or exclude thrips and whiteflies. New greenhouses may use insect screening for the main wall and roof coverings.
- **Widely used in biosecurity post-entry quarantine facilities** where plants are held for a period of time.
 - **Biosecurity includes an airlock** between the administration area and the glasshouses to prevent insects coming in and out, as well as **sophisticated hygiene practices**.
 - **Approved imported plants and vegetative material is imported bare-rooted**, and then disinfected. Imported seed is inspected on arrival and decontaminated if necessary and then treated according to import permit conditions, eg surface sterilization, hot water, etc. With very few exceptions all seed must be grown for one generation in the post-entry plant quarantine greenhouse.
 - **Pesticides are used when necessary.**

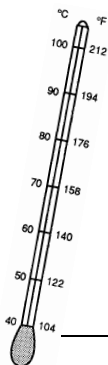
Re-infestation of treated timber

Biosecurity

Foresters and quarantine specialists from around the world met in Canada in 2005, to discuss issues such as **heat treatments and fumigation** of timber for export. They were also acting as an advisory body to the International Plant Protection Convention. The *International Standards for Phytosanitary Measures 15 (ISPM 15)* and *Guidelines for Regulating Wood Packaging Material in International Trade*. Concerns included:

- **The international protocol** on methyl bromide, heat treatment procedures and proposed new protocols.
- **The re-infestation by timber pests** hitchhiking on wood packaging material after it has been treated. While there have been a number of experiments demonstrating re-infestation, the delegates agreed more work is needed to determine the best approach to this problem.
- **Bark freedom protocols** were discussed with Biosecurity. Australia has always had bark freedom requirements for imported timber. Timber with bark attached provides hiding places for pests impedes the thorough penetration of methyl bromide into the wood and makes inspection more difficult.

Heat stored grain



Phosphine is the only fumigant currently widely available for on-farm fumigation. It will kill all species of all ages of grain insects (eggs, larvae, pupae and adults). More than 80% of the Australian cereals, oilseeds and pulse crops are treated with phosphine. A declining proportion is treated with residual chemical protectants.

- **Increasing market preference for residue-free grain.** The development of high level resistance to phosphine, support the use of heating technology which provides a rapid, non-chemical alternative to fumigation for control of stored grain insects.
- **Heat disinfection is likely to be used widely in the grains industry** within the next 10 years particularly in an **IPM** approach to grain protection.
 - **Fluid-bed disinfection.** Hot air convection is a fluidized bed and involves rapid heating then rapid cooling to safe handling and storage temperatures. The predetermined temperature to which the insects are treated kills all developmental insect stages including the larval and pupal stages that develop inside grain kernels. The effectiveness of different heat treatments regimes is influenced by the target temperature, exposure time, insect species, their age structure, initial grain temperature and moisture content. The grain flows across the fluidized bed with an air temp of **80-90°C** and is completely disinfested within 3 minutes.
 - **In-situ disinfection** of grain shows promise for use in small capacity farm silos. The ambient air is heated to the required temperature and fan-forced into the grain; the concept is similar to that used for rapid cooling of grain using aeration.

Rabbit controlAustralia wide,
region based

Biocontrol

Physical methods
Pesticides**Managing rabbit populations is a long-term strategy.**

- **Biological control.** Virus diseases are not the be-all and end-all. Rabbits have been knocked in the short-term but have recovered from biocontrol and the chances are that they will do so again. Rabbits become stressed with the combined effects of a long dry period, calicivirus virus and myxomatosis.
- **Most rabbit control must be carried out by landholders.** Professional rabbit control officers help groups achieve effective and sustained rabbit control follow up with:
 - Ripping/blasting warrens and burning harbors (blackberries and rubbish areas).
 - Poisoning and fumigation remain the basis of long term rabbit control.
 - Applying 1080 (specialized training required for those using 1080 and other chemicals). Vertebrate pest agencies Australia-wide support the development of a **National Rabbit Control Training and Extensions Package**, for all officers.

Phytophthora diseases of cut flowers

Phytophthora Diseases of Cut Flowers. 2014. Dept. of Agriculture & Food WA.

Bull banksia (*Banksia grandis*). *Cygnis insignis* Public domain. Oz native plants.

ERADICATION (2014)
Trials in WA indicate that **Pc** can be eradicated from bushland sites by completely removing living hosts (page 401)

NOTE

Spores are still produced from sprayed infected plants and zoospores are still produced so phosphite may slow or prevent plant deaths but not necessarily prevent the spread of inoculum to infested areas.

Phytophthora diseases commonly occur with in-ground production and are difficult to eradicate once present. **Pc** may be present but if the rate of root replacement keeps pace with the rate of root death, disease may not be noticed. **Preventative and Curative control methods** are outlined below (Dept. of Agric. & Food WA 2014). **Management of Pc** for Biodiversity Conservation in Australia is described on page 401.

Preventative

- **Culture**
 - **If purchasing land** ensure it is **Pc-free**
 - **Grow susceptible varieties in soilless media** or hydroponics. Hydroponics do not necessarily eliminate the risk, spores spread by wind, enter on diseased plant material.
 - **Composts and mulches**, especially marri and karri and other hardwood bark, are highly suppressive after composting. On large areas they can be used for weed suppression and soil moisture retention during summer. Limitations on transport and incorporation and needs to be continually applied for continuing benefit. Growers need to ensure they do not introduce **Pc** in mulches, soil, etc.
 - **Both waterlogging and drought** will stress plants making them more susceptible to disease. Good irrigation practices can eliminate much of this root infection at depths **>2m** (root infection has been recorded at depths **> 2m**).
 - **Where soil has a compacted layer**, ripping may be useful. Mounding beds can also help in some situations.
 - **Water supplies in contact with the ground must be suspect**, eg dam water or water drawn from streams or soaks. Water should be tested regularly for the presence of **Pc**.
 - **Salinity** can exacerbate the disease.
 - **Wounding** from frost or nematodes also aids infection. Excessive rates of N can make plants more susceptible.
 - **Manipulation of pH and calcium** can have a positive effect in some cases.
 - **Sanitation**
 - **If grown in a particular area or in soilless media in bags** or containers then these may be possible to remove them.
 - The **Nursery Industry Accreditation Scheme Australia (NIASA) Best Management Practice Guidelines** (cur. ed.) outlines best practice in production nurseries, eg water management and in-ground production. Hygiene in plant propagation (Nursery Papers Dec 2004).
 - **Biocontrol**
 - **Biofumigation** with mustard (*Brassica juncea*) suppresses **Pc** in the laboratory but efficacy does not seem to translate into the field.
 - **Trichoderma** does have a suppressive effect but stimulates the production of oospores.
 - **Resistant, tolerant varieties**
 - **Lists of resistant native species** and varieties are available.
 - **Use resistant rootstock** if available as a way of growing susceptible species or reducing losses from infection (page 154).
 - **Biosecurity**
 - **Pc may be moved around in soil** (vehicles, tools, footwear, animals) - adopt the clean on and clean off approach. Wash vehicles, boots etc, on **entry and exit** (page 202).
 - **Pc may be moved around in water** (run off from your own or a neighbor's property).
 - **Do not introduce disease plant material.**
 - **Disease-tested planting material**
 - **Ensure propagation material or planting material is disease-free** and from an accredited nursery. Growers need to ensure they do not introduce **Pc** to their property.
 - **Physical methods**
 - **Soil solarization is cheap and effective.** Clear plastic on cultivated moist soil for 4-6 weeks in summer. The soil temperature rises to above 60°C and kills **Pc** and other pathogens but not the beneficials. Limitations include obtaining sufficient heat at depth and using over large areas (see also page 241).
 - **Pesticides**
 - Fumigants, various registered products.
- Curative**
- **Fungicides**
 - **Phosphite** (various brand names) is registered for **Pc** as a foliar spray. There is a minor use for aerial or ground applications to native plants; trunk injection is not specifically listed but lasts longer than foliar applications. Other fungicides are also registered.
 - **Toxicity.** Phosphite and other fungicides have low phytotoxicity but this varies with species especially in hot weather. Seek advice about how and when to apply it.

PROS, CONS AND CHALLENGES

PROS

- Usually physical methods are non-polluting, there are exceptions.
- They are often simple.
- Many have application in high value intensive horticultural and vegetable crops.
- Many have potential in **integrated pest management (IPM)** programs, eg they are adaptable, specific, can be used by relatively unskilled labor and the necessary equipment is readily available.
- Some are cheap to implement.
- Pest resistance does not generally develop.
- A range of **heat and cooling treatments** can reduce pests and diseases without the harmful residues of chemical systems.

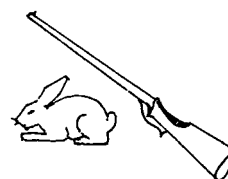
CONS

- Physical methods **do not prevent reinfestation**.
- Many are only **partly effective**, and often do not provide economic control.
- Some methods which do provide economic control may **not** meet exacting export or plant biosecurity requirements requiring a nil insect presence.
- Consumers may not accept minimal damage.
- Some pests may become habituated or develop resistance to some physical methods.
- High capital costs of many often limit their introduction.
- In some cases, they are only effective for a short time so they have to be repeated.
- Some are labor intensive and so are only suitable for home gardeners or small areas.
- Some are cruel, eg trapping, shooting.

CHALLENGES

- **Using physical methods effectively in IPM** programs as much as economically possible.
- The **Australian Animal Welfare Strategy (AAWS) and the National Implementation Plan (2010-14 online)** guides the development of new, nationally consistent policies and will enhance existing animal welfare arrangements in all Australian States and Territories. The strategy was developed by the Australian Government with assistance from the **National Consultative Committee on Animal Welfare**, in consultation with State and Territory governments, animal industry organizations, animal welfare groups and the general public. The strategy covers the humane treatment of all animals in Australia including livestock / production animals, animals used for work, sport, recreation or display, companion animals, animals in the wild, aquatic animals, and animals used in research and for teaching purposes. The animal welfare framework in Australia includes:
 - Legislation.
 - Codes of Practice.
 - Reporting Performance and Benchmarking.
 - Auditable Industry Quality Assurance Programs and Self-Regulation.
 - Education and Training.
- **There are numerous State Games Councils and Codes of Practice** in Australia which espouse ethical, safe and responsible hunting. **Shooting** is used to control foxes, wild dogs, feral goats, rabbits and other vertebrate pests. Culling kangaroos is always a contentious issue.

- **It is illegal to hunt pigs with dogs** without the consent of the landholder and then preferably in line with the Code of Conduct / Practice (Australian Pig Doggers & Hunters Association). There have been many calls to ban the practice.
- **Feral goats** can cause an immense amount of damage to the fragile environment of national parks through overgrazing of rare tree seedlings, shrubs, etc as well as erosion problems. They also pose a threat as vectors of diseases as foot rot and Q-fever as well as exotic diseases like Foot and Mouth disease. Feral goat control along the escarpment of Wadbilliga National Park uses Judas goats.
 - **Judas goats** are first trapped within a control area and then fitted with a collar to which is attached an electronic transmitter, the Judas goat animal is then released back into the same area to link up with its respective mob. The ranger then uses a sophisticated antenna and receiver to locate the Judas and eradicate any goats found with her. The Judas then moves onto the next herd in the vicinity and the process is repeated. This method has been particularly successful in areas where rough terrain where conventional methods are all but useless.
- **Irradiation** is meeting much consumer resistance. There is a need to explain more clearly how the process works.
- **More investigation of new technologies**, eg
 - Ways of using near infra-red spectroscopy and micro-gas chromatography to measure fruit and vegetable quality.
 - Hand held near infra-red (NIR) units are capable of testing fruit on the tree. Fruit can be non-invasively tested for sweetness before picking. Minimum carbohydrate (soluble sugar and / or starch) standards exist for many fruit and are recorded in standards set by **Australian United Fresh (AUF)** and major retailers but current methods are slow and not widely applied (Innovations – Aust. Hort. Jan 2012). **NIR** has been used to guarantee sweetness in some lines of melons.
 - For mechanical harvesting and handling and for adding value to vegetables.
 - 3D printing.
 - Non-chemical weed control.



REVIEW QUESTIONS AND ACTIVITIES

- List 6 **physical methods** of control and give 1 example of each.
- Describe 6 ways in which **heat** can be used to control pests, diseases and weeds. Give 1 example of each method.
- Explain how the **following control methods work**, the problems they are used against and how effective they are.

Weed seed destructors	Ultra-violet light
Hot water treatments	Irradiation
Relative humidity	Sticky yellow traps
Lack of oxygen	Sticky pheromone traps
Carbon dioxide	Cooling (fruit fly)
Compost	A method of your choice
Refrigeration	
- List **advantages and disadvantages** of using physical **methods** of disease and pest control.
- Describe **barriers** which could be used against the following pests and other problems:

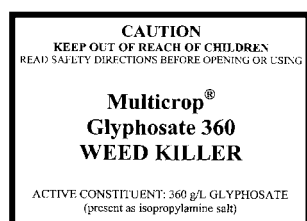
Dogs	Weeds
Cutworms	Rats
Birds	Thrips
Snails	Hail
- Describe **traps** which could be used against the following pests, how effective they are and how do they work:

Fruit fly	Codling moth
Mice	Flies
Foxes	Earwigs
- Explain how physical methods can be used in **IPM programs** in your industry.
- Perform **practical exercises** in disease, pest and weed control using physical methods.

SELECTED RESOURCES

- Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.
- AS 4843—2001. Australian Standard™. *Synthetic weed blocking fabric*.
- Australian Standard AS3660-2000 Series
- AS 3660.1—2000 *Termite management—New building work*.
- AS 3660.2—2000 *Termite management—In and around existing buildings and structures—Guidelines*.
- AS 3660.3—2000 *Termite management—Assessment criteria for termite management systems*.
- Baxter, N. 2010. *The Answer is “Blown” in the Wind*. Ground Cover. May-June.
- Baxter, N. 2011. *Wet Harvest Lessons May Require a Storage Rethink*. Ground Cover. Sept-Oct.
- Brown, J. F. and Ogle, H. J. (eds). 1997. *Plant Pathogens and Plant Diseases*. Rockvale Pubs., Armidale, NSW.
- CPSM. 2005. *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia*. Parts 1-4. funded by the Commonwealth Government Department of the Environment and Heritage by the Centre for Phytophthora Science and Management, Murdoch University, WA.
- GRDC. 2011. *The Harrington Weed Seed Destructor is a Tool in IPM*. May-June.
- Case study GRDC Growers’ Report 2008-2009.
- Handreck, K. A. and Black, N. D. 2002. *Growing Media for Ornamentals, Plants & Turf*. UNSW Press.
- Hansen, J. D. 2001. *Research Continues into Ultrasound Treatments to Control Surface Pests of Fruit*. HortTechnology. April-June.
- Ho, K. Y., Hung, S. C., Lee, H. J., Hse, T. C. and Chu, Y. I. 2006. *Effectiveness of Fruit Net-Bag in Trapping the Oriental fruit fly Bacterocera dorsalis (Diptera: Tephritidae) in Taiwan*. Plant Protection Bulletin (Taipei) 2006, 48 (2).
- International Atomic Energy Agency, Vienna, 2002 *Dosimetry for Food Irradiation*. Technical Reports Series no. 409.
- Jessop, P. 2009. *Management Burning of Invasive Native Scrub: Principles*. Primefact 852, NSW DPI.
- Jessop, P. 2009. *Management Burning of Invasive Native Scrub: Techniques*. Primefact 853. NSW DPI.
- Leonard, E. 201. *Harvest Weeds Kill Experience Shared*. Ground Cover. Nov-Dec.
- Loder, H. 2008. *Frost Protection in Viticulture: a User’s Guide for South East Irrigators*. Coonawarra, SA: Wingara Wine Group.
- Marino, M. 2012. *Microwave Energy a Potential New Weed Killer*. GRDC. Jan-Feb.
- Maynes, K. 2006. *Turf Superstar Emerges*. Aust. Hort. April.
- McGrath, P. 2000. *Thumbs up for Smart Films*. Grower 24. Feb.
- Nursery Industry Accreditation Scheme Australia (NIASA). 2010. *Best Management Practice Guidelines*. 4th ed. NGIA.
- Nursery & Garden Industry Association (NGIA) 2004. *Hygiene in Plant Propagation*. Nursery Papers. Dec. 2004. Issue 11.
- Penfold, K. 2011. *Aeration has Multiple Applications*. Ground Cover. May-June.
- Pryke J. S. and Pringle, K. L. 2008. *Postharvest Disinfestation Treatments for Deciduous and Citrus Fruits of the Western Cape, South Africa: a Database Analysis*. S. Afr. Jn. Sci. vol.104 (3-4). Mar-Apr.
- Quarles, W. 2004. *Thermal Weed Management: Hot Alternatives for Urban Areas and Organic Farms*. The IPM Practitioner Vol XXVI No 5/6, May June.
- Rebbeck, M. A. and Knell, G. 2007. *Managing Frost Risk: A Guide for Southern Australia Grains*. SARDI.
- Thomas G. J. and Adcock, K. G. 2004. *Exposure to Dry Heat Reduces Anthracnose Infection of Lupin Seed*. Aust. Plant Path. 33:537-540.
- Yossen, V., Zumelzu, G., Gasoni, L. and Kobayashi, K. 2008. *Effect of Soil Reductive Sterilization on Fusarium Wilt in Greenhouse Carnation in Cordoba, Argentine*. Aust. Plant Path. 37:520-522.
- Company Tackles Runaway Roots*. Aust. Hort. July 2011
- Centre for Phytophthora Science and Management, Murdoch University, WA.
- www.cpsm-phytophthora.org
- Dieback Working Group - www.dwg.org.au*
- Phytophthora Diseases of Cut Flowers*. 2014. Dept. of Agriculture & Food WA.
- Weed Gunnel* www.weedgunnel.com.au/
- Weed War Gets up Steam*. Land. Oct 7 2010.

PESTICIDES



WHAT ARE PESTICIDES? 258

LEGISLATION 259

Commonwealth legislation 259

The NRS, APVMA and The Agvet Code 259

Other Commonwealth legislation and advisory bodies 266

State / Territory legislation (control of use) 268

Local government (councils) 270

Regulations, Codes, Standards, Duty of Care 271

USER LICENSING 273

USER TRAINING 274

Nationally Accredited User Training courses 278

AusChem, Chemcert 278

SMARTtrain 280

MANUFACTURERS AND RETAILERS 281

Agsafe 281

PESTICIDE CHEMICAL LABELS 283

Understanding pesticide chemical labels 287

A. Warnings and product description 288

B. Directions for use 289

C. General instructions 290

D. Precautions 291

E. First Aid, storage and disposal 292

SAFETY DATA SHEETS (SDSs) 293

ISSUES OF CONCERN AND OPPORTUNITIES 297

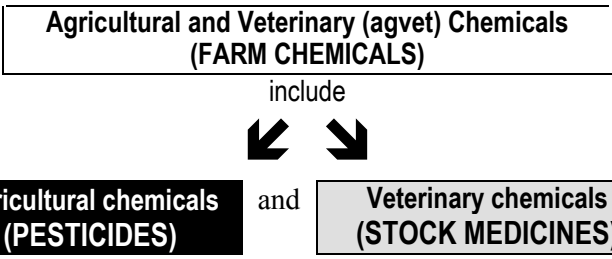
MANAGING PESTICIDES 314

REVIEW QUESTIONS AND ACTIVITIES 315

SELECTED RESOURCES 316

WHAT ARE PESTICIDES?

Background Terminology



What are pesticides today?

The term **'pesticide'** means literally **'killer of pests'** and originally the word pesticide referred to chemicals used to kill 'pests'. Pesticides are used to control pests, diseases and weeds to keep crops and food healthy.

- A **'pest'** is commonly described as any plant or animal living where humans do not want it to live (see also page 173). **The main plant 'pests' of economic importance** include insects, mites, snails, vertebrate pests, nematodes, virus and virus-like 'organisms', bacterial and fungal diseases and weeds that are injurious to plants or plant products
- **Today, the term 'pesticide' has a much wider meaning.** An **agricultural chemical product** is a substance or mixture of substances that is represented, imported, manufactured, supplied or used as a means of directly or indirectly, eg
 - Destroying, stupefying, repelling, inhibiting the feeding of, or preventing infestation by or attacks of, any pest in relation to a plant, a place or a thing; or
 - Destroying a plant; or
 - Modifying the physiology of a plant or pest so as to alter its natural development, productivity, quality or reproductive capacity; or
 - Modifying an effect of another agricultural chemical product; or
 - Attracting a pest for the purpose of destroying it.
- **Some pesticides are extremely dangerous** to the person using the chemical and have a signal heading of **DANGEROUS POISON** while others are relatively safe to the person using the chemical (page 288). Registration of biological chemical pesticides must go through the same approval process as synthetic chemicals.

Agricultural chemical products include:		
Herbicides (weedicides, weedkillers) Herbicide marking dyes Defoliant, desiccants Crop markers Insecticides Miticides (acaricides) Molluscicides (snail killers) Bactericides Fungicides Nematicides	Fumigants Algicides Rodenticides Pheromones Lures Baits Repellents Synergists Surfactants Tank cleaners	Biological chemical products Biological control agents Genetically modified organisms Genetically modified plants Insect growth regulators Plant growth regulators Natural oils Disinfectants Dairy cleansers (on-farm use) Sanitizers
Household and home garden products for pest and weed control AND any substance declared to be an agricultural chemical product		

IT, knowledge, communication



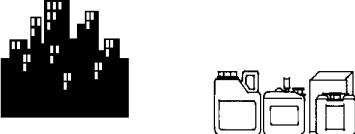

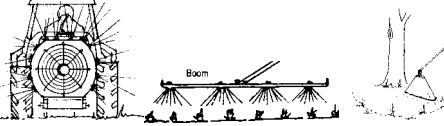
PUBCRIS
 Infopest GROWCOM

The Australian Pesticides and Veterinary Medicines Authority (APVMA) website is the main source of information, it also has links to State legislation www.apvma.gov.au

- The **APVMA website** maintains current details about agvet chemical products registered for use in Australia or for permits.
- **Users can access this information online** via the **PUBCRIS (Public Chemical Registration Information System) database** or the **Agricultural and Veterinary Permits Search database**, both of which can also be accessed through the **APVMA's** iPhone/iPad mobile app. <http://portal.apvma.gov.au>
 - **Infopest GROWCOM** provides label information to the **PUBCRIS** database.
- **Other sources of information on registration include:**
 - Herbiguide – www.herbiguide.com.au/
 - The web sites of **chemical companies** provide labels and safety data sheets (**SDS**).

LEGISLATION

The Australian government is responsible for assessment and registration of agvet chemicals and their regulation up to and including the point of retail sale. State / Territory governments regulate control of use, including basic training requirements and licensing of commercial operators. Pesticide users must comply with their responsibilities in their own State / Territory. There are also various **codes, standards** and **'duty of care'** requirements.

Commonwealth government –		State & Territory governments
<p>Assessment, registration, regulation UP TO & INCLUDING POINT OF RETAIL SALE</p> 	<p>Retail sale</p> 	<p>Control of use BEYOND POINT OF RETAIL SALE</p> 

Commonwealth legislation

The NRS, APVMA and The AgVet Code

The **National Registration Scheme for Agricultural and Veterinary Chemicals (NRS)** is the framework for managing agvet chemicals in Australia. The **Australian Pesticides and Veterinary Medicines Authority (APVMA)** administers the **NRS** in partnership with State / Territory governments and collaboration from other Commonwealth agencies.

Assessment and Registration APVMA



The Australian Pesticides and Veterinary Medicines Authority (APVMA) is an Australian government statutory authority within the **Australian Government Department of Agriculture (DA)**. The **APVMA** administers the **Agricultural and Veterinary Chemicals Legislation Amendment Bill 2012 (The Agvet Code)** and its Regulations www.apvma.gov.au

- **APVMA scientifically assesses and registers** agvet chemicals **before** they can be supplied, sold or used. All registered products must be suitably formulated and properly labelled and when used according to instructions must:
 - Be effective, that is, the product does the job it claims it shall do.
 - Be safe to the host, users, consumers and the environment.
 - Not unduly jeopardize trade with other nations through residue problems.
- **Product registrations are renewed annually** for the following year.
- **The APVMA has the power to deregister or impose additional** restrictions on the use of any agvet chemical if new information questions the safety of that product.
- **Identifying and responding** to emerging regulatory issues.
- **The Agvet Code** requires notices to be published in the Gazette containing details of registration of agvet chemical products and other approvals granted by **APVMA**, eg
 - Notice of registrations.
 - New agricultural active constituents.
 - New agricultural chemical products.
 - Amendments to Maximum Residue Limits.
 - Regulatory updates.
- **APVMA manages various programs**, eg
 - PUBCRIS (database of registered chemical products).
 - Permits.
- **Registrable products** are not made only from synthetic chemicals, but may also be made from or consist of natural, herbal or biological ingredients. **Before an agricultural biotechnology product**, eg a **genetically modified (GM)** crop, is available for use in research or commercial applications, it undergoes a comprehensive risk assessment by the Office of the Gene Technology Regulator. This assessment aims to identify any risks that the **GM** crop may pose to human health and the environment.
- **APVMA maintains its own expertise** in relation to residues and chemistry evaluation.
- **The APVMA uses the services** of a number of Australian and State government agencies as advisers to help with some of these evaluations of applications for registration of agvet chemical products.
- **Work health and safety.** Protecting the health and safety of all those who work with chemicals in agriculture and horticulture production is a fundamental goal of the **APVMA** assessment and registration of agvet chemicals (pages 300, 426).

<p>The AgVet Code 2012</p>	<p><u>The AgVet Code 2012 contains 5 amendments</u> to the AgVet Code 1994, these cover:</p> <ol style="list-style-type: none"> 1. Assessing labels with consideration only to those matters prescribed in the legislation and regulations, eg adequate instructions for the safe and effective handling and use of a product. It does not assess elements such as color, logos, etc. 2. Trade issues are considered when considering whether label instructions are adequate; ensuring that APVMA can act promptly to update label instructions to meet the requirements of trading partners (export withholding periods, etc). 3. Approved persons. Applicants that are companies incorporated in Australia will no longer be required to advise the APVMA which individuals in the company are authorized to contact the APVMA about the application. 4. Formalizes the permit process whereby the APVMA may seek comment from the manufacturers of the chemical product that is proposed for use under a minor use or emergency permit. 5. There are minor product variation provisions so that applicants can notify the APVMA when they make specified low risk variations to their registered products.
<p>Harmonizing assessment, registration and control of use A proposal</p>	<p><u>The National Scheme for the assessment, registration and control-of-use</u> of agvet chemicals is seeking to improve the efficiency and effectiveness of the regulation of agvet chemicals by harmonizing the assessment, registration and the control-of-use elements (Tim Harding & Associates and Rivers Economic Consulting 2011):</p> <p><u>In Australia, issues have arisen from the highly fragmented control-of-use systems</u> of the States and Territories, eg</p> <ul style="list-style-type: none"> • The uncoordinated risk management of agvet chemicals. • Inconsistent regulation of user access to chemicals. • Unnecessary regulatory burden as a result of duplication. <p><u>The National Scheme</u> will harmonize these elements of jurisdictions' control-of-use legislation, while continuing to allow variations to use provisions necessary to respond to regional needs.</p> <ul style="list-style-type: none"> • All aspects of control of use, eg training, monitoring, auditing, compliance, etc, will be managed by the States and Territories under harmonized legislation and associated subordinated legislation. <p><u>The impacts of the National Scheme</u> are expected:</p> <ul style="list-style-type: none"> • To be positive overall and vary by jurisdiction. • To reduce industry costs, especially where businesses operate across jurisdictional boundaries. • To provide better coordination between jurisdictions in regards to control-of-use policy issues and • To provide an increased evidence base for ongoing improvements to the scheme.

Table 16. APVMA organization.

APVMA
www.apvma.gov.au

APVMA online services portal <http://portal.apvma.gov.au>
 (Pubcris, Permits, Adverse experience, Registration, Self-assessment, etc)

All registered products must be effective, be safe to people and the environment and not jeopardize Australian trade relations with other nations.

PUBCRIS

Database of registered products
 Labels (may be updated)
 Active constituents must be approved either before or at the same time the product is registered

PERMITS

Minor use
 Emergency use
 Research
 Export
 Other compliance action
 Restricted chemical products

REGULATORY GUIDELINES

Agricultural Manual of Requirements and Guidelines (Ag MORAG) provides information on data requirements and guidelines for applications to register or approve agvet products, labels, active constituents and issue permits
 Risk Compendium
 License schemes, Manufacturer license
 Labels
 Advertising
 Audits
 Levy (on sales of registered products)
 Trade advice on pesticides
 Traps in advertising
 Safety Data Sheets (SDS)
 Application summaries
 Application submissions AVPMA portal
 Online Levies and Annual Fees (OLAF)
 Monitoring compliance in the market place
 Office of Gene Technology Regulator (OGTR)

CHEMICAL REVIEWS

Adverse experience reporting about existing registered chemicals that have been used with the approved label
 Product recall of registered products
 Cancellation of registration
 Registered uses altered
 Restricted chemicals
 Recall of unregistered chemicals
 Complaints

TOXICOLOGY

Withholding period (WHP)
 Maximum Residue Limits (MRLs)
 Residues
 National Residues Surveys (NRSs)
 Export Slaughter Intervals (ESIs)
 Re-entry Intervals (REIs)
 Trade issues
 Spray drift
 Buffer zones
 Australia NZ Food Standards Code (ANZFS Code)
 Guidelines for Health Surveillance.
 Guidance Note for the Assessment of Health Risks Arising from the Use of Hazardous Substances in the Workplace.

QUALITY ASSURANCE (QA) & COMPLIANCE

Audits to improve its effectiveness of delivery of its regulatory functions, eg improve recording, monitoring and reporting registration time frame, improve action on MRLs, reviews of chemicals, compliance in the field and in the market place, trade requirements:
 Non-compliance
 Non-compliant products
 Unregistered products
 Extend or reduce registered uses

MONITORING COMPLIANCE

An extensive **food residue testing system** involving Local, State and Commonwealth regulators.
DA undertakes random, targeted and compliance residue monitoring through the **National Residues Survey**
Food Standards Australia New Zealand (FSANZ) monitors the food supply through the **Australian Total Diet Study**. This system is supplemented by wide ranging testing undertaken by commodity groups and supermarket chains.
Environmental monitoring by Commonwealth, State and Territory environmental protection agencies, statutory authorities and tertiary institutions.

LINKS

Other Commonwealth departments, etc
 Biosecurity
 Infopest Growcom (peak horticultural body)

State websites, eg
 APVMA in the field

International links, eg
 AgVet chemicals
 Food standards
 MRLs
 Codex Alimentarius Committee on pesticide residues
 International Stockholm and Rotterdam conventions

RESOURCES AND PUBLICATIONS

Available on iPhones and the APVMA website

Commonwealth gazette, eg notices on registrations, cancellations, MRL standards, variation to food standard:
 New active constituents, new formulations
 Regulatory Guidelines, Regulatory updates
 Manuals, Fact and Information Sheets
 Annual reports
 E-chatter (community consultation), Community E-Bulletin
 The Australian Pest Animal Strategies 2007.
 National Biosecurity framework.
 National and Regional regulation of potential pest animals.
 Also residues, overseas trade, WH&S, environment and efficacy safety and labeling

<p>Permits</p>	<p>The APVMA has a permits scheme that allows for the legal use of chemicals in ways different to the uses set out in the product label. Obtaining a permit requires the applicant to satisfy the same criteria as for registration. The APVMA may seek comment from the manufacturers of the chemical product that is proposed for use under a minor use or emergency permit.</p> <p>Permits that may be considered by the APVMA are for one of four purposes:</p> <ul style="list-style-type: none"> • Minor Use—applies to situations usually involving low acreage, small portions of high acreage crops, or animal species that are not covered by the product label. • Emergency use—for situations such as outbreaks or exotic pests and diseases. • Research—which allows chemical products to be used in research trials for scientific purposes, such as determining suitability of a product for a new use or generating data necessary to register a product. • Export—which allows the holder to possess and supply an unregistered chemical product or an unapproved active constituent for export purposes only. 								
<p>Regulatory guidelines Risk Compendium and AgMORAG</p>	<p>The Regulatory Guidelines describes the policies and processes used by the APVMA to assess and manage risk across its regulatory activities. The Guidelines are developed through an open and consultative process with stakeholders and clients and are revised when required.</p> <ul style="list-style-type: none"> • Chemical products must be manufactured in compliance with the GMP Code (Good Manufacturing Practice Code). A manufacturer must implement an effective system of quality assurance (QA). • Licensing schemes, registering products, advertising and regular auditing usually every 18 months to 2 years, provide APVMA with evidence of their compliance with APVMA requirements. • Manufacturers Regulations and Guides, levies and audits. • Manual of Requirements and Guidelines (Australia). Ag MORAG (Agricultural Manual of Requirements and Guidelines) provides information on data requirements and guidelines for applications to register or approve agricultural chemical products, labels, active constituents and issue permits. It contains the Ag Labeling Code which sets out requirements and best practice for product labels. • Proposed changes to the Control of Use. 								
<p>MRLs and WHPs See pages 289, 308, 429</p>	<p>Maximum Residue Limits (MRLs) are set by the APVMA for agvet chemicals in agricultural produce, particularly produce entering the food chain. The APVMA regularly updates withholding periods (WHPs) for products used on plants and Export Slaughter Intervals (ESIs) and WHPs for products used in sheep and cattle.</p> <table border="1"> <tr> <td> <p>Withholding Period (WHP)</p> </td> <td> <p>The WHP is the period that must elapse between the last application of a chemical and harvesting of plants, grazing or cutting for stock food, consumption by humans and animals after postharvest use.</p> </td> </tr> <tr> <td> <p>Maximum Residue Limit (MRL)</p> </td> <td> <p>The MRL is the international and Australian Standard for residues and is the highest concentration of a residue of a particular chemical that is legally permitted or accepted in a food or animal feed.</p> </td> </tr> <tr> <td> <p>Re-entry Interval (REI)</p> </td> <td> <p>The REI is the period of time immediately following the application of a pesticide during which unprotected workers should not enter a field. These restrictions on entry are to protect persons from potential exposure to hazardous levels of pesticide residues.</p> </td> </tr> <tr> <td> <p>Plant Back/Re-cropping Interval (PBI)</p> </td> <td> <p>The PBI is the time that is required before a particular crop can be grown, following a previous herbicide application. Crops vary in their product sensitivities and therefore have different plant back recommendations. All crop types grown in Australia are susceptible to herbicide carryover if care is not taken and plant back restrictions are not followed.</p> </td> </tr> </table>	<p>Withholding Period (WHP)</p>	<p>The WHP is the period that must elapse between the last application of a chemical and harvesting of plants, grazing or cutting for stock food, consumption by humans and animals after postharvest use.</p>	<p>Maximum Residue Limit (MRL)</p>	<p>The MRL is the international and Australian Standard for residues and is the highest concentration of a residue of a particular chemical that is legally permitted or accepted in a food or animal feed.</p>	<p>Re-entry Interval (REI)</p>	<p>The REI is the period of time immediately following the application of a pesticide during which unprotected workers should not enter a field. These restrictions on entry are to protect persons from potential exposure to hazardous levels of pesticide residues.</p>	<p>Plant Back/Re-cropping Interval (PBI)</p>	<p>The PBI is the time that is required before a particular crop can be grown, following a previous herbicide application. Crops vary in their product sensitivities and therefore have different plant back recommendations. All crop types grown in Australia are susceptible to herbicide carryover if care is not taken and plant back restrictions are not followed.</p>
<p>Withholding Period (WHP)</p>	<p>The WHP is the period that must elapse between the last application of a chemical and harvesting of plants, grazing or cutting for stock food, consumption by humans and animals after postharvest use.</p>								
<p>Maximum Residue Limit (MRL)</p>	<p>The MRL is the international and Australian Standard for residues and is the highest concentration of a residue of a particular chemical that is legally permitted or accepted in a food or animal feed.</p>								
<p>Re-entry Interval (REI)</p>	<p>The REI is the period of time immediately following the application of a pesticide during which unprotected workers should not enter a field. These restrictions on entry are to protect persons from potential exposure to hazardous levels of pesticide residues.</p>								
<p>Plant Back/Re-cropping Interval (PBI)</p>	<p>The PBI is the time that is required before a particular crop can be grown, following a previous herbicide application. Crops vary in their product sensitivities and therefore have different plant back recommendations. All crop types grown in Australia are susceptible to herbicide carryover if care is not taken and plant back restrictions are not followed.</p>								
<p>Expiry dates</p>	<p>Product expiry dates are currently updated during the renewal period in July each year. The APVMA is simplifying how variations to approvals and registrations are processed by reducing red tape and preventing the expiry of active constituent approvals and preventing the application of dates after which a registration cannot be renewed.</p>								

Spray drift

See also page 307



The APVMA is responsible for ensuring that off-target spray drift does not harm human health, the environment and Australia's international trade. **New labeling is now more prescriptive about the use of drift-reduction practices** (Leonard 2011), product labels may include new stipulations about **droplet size, weather conditions during spraying** and **no-spray buffer zones** (see also page 307).

- **The APVMA has committed to assessing** and updating the labels of all currently registered products subject to spray drift regulation to include comprehensive instructions for managing spray drift risk.
- **Keeping detailed spray records** not only provides a useful management tool but it is a Federal and State / Territory requirement. Requirements do vary.
- **Spray set-up and equipment use** is a central part of accurate spray application. There are free spray drift application workshops. www.ispray.com.au
- **The GRDC Paddock Diary** operation recording pages include information required by Federal legislation which must be recorded **within 24 hours of application** and kept for a **minimum of 2 years**. Meteorological data during application is required, eg wind speed, etc. It should be recorded at the start and end of the spray operation.

Droplet size Nozzle type	Weather conditions during spraying, eg	No-spray buffer zones, eg
		500 metres 250 metres 100 metres 50 metres, 20 metres

Resistance management

See pages 288, 303, 427

Croplife Australia

Herbicide, fungicide and insecticide resistance warnings on commercial labels.

- **Check with the APVMA product database, PUBCRIS**, for up-to-date information on products and active constituents. Resistance warnings include advice on the **mode of action** of the herbicide, fungicide or insecticide. This allows users to choose pesticides with **different modes of action** as an important step in the overall management of pesticide resistance.

GROUP M HERBICIDE

- **Croplife Australia Resistance Management Strategies** do not replace the information on product labels. They are a guide only and do not endorse particular products, groups of products or cultural methods in terms of their performance. www.croplifeaustralia.org.au
- **Resistance warning statements**. These instructions should be followed, so that the insect, disease or weed does not become resistant to the chemical you are applying.

RESISTANT WEEDS WARNING

Insecticide Resistance Warning

Monitoring

1 2 3 4
5 6 7 8

The APVMA is responsible for the assessment and registration of pesticides and veterinary medicines and for their regulation up to and including the point of retail sale in Australia. The **APVMA** is also responsible for **monitoring compliance in the marketplace** and for reviewing registered chemical products to ensure that they continue to meet high contemporary standards.

Disposal



CropLife Australia and its members are committed to a **full 'life cycle'** approach to industry stewardship. Members adopt and promote ethical and responsible practices from discovery and development of a crop protection or biotechnology product, through to its use and final disposal.

- CropLife Australia has established **AgStewardship Australia** in partnership with the National Farmers' Federation, the Australian Local Government and other organisations to oversee the **Industry Waste Reduction Scheme** (page 282).
- CropLife's subsidiary, **Agsafe**, runs the recycling programs, **drumMUSTER** and **ChemClear®** along with training and accreditation programs for the agricultural chemical supply chain. www.drummuster

Work Health & Safety

See also page 300

Protecting the health and safety of all those who work with chemicals in agriculture and horticulture production is a fundamental goal of the **APVMA** assessment and registration of pesticides and veterinary medicines.

- **The APVMA considers the possible extent of worker risk** from the chemical product and how that risk and its consequences can be mitigated.
- **The APVMA only allows chemicals** to be used for which there is a safe threshold of exposure, ie for exposure below that threshold there is no known impact of risk.
- **Places greater responsibility on industry** to manage the risks from chemicals and to provide safety information on the substances.
- **Requires manufacturers and importers to gather information** on the properties of their chemical substances.

Reviews of registered agvet chemicals

Reviews are held to check:

- The safety of people using the product;
- An effect that is harmful to public health;
- An unintended effect that is harmful to animals, plants or to the environment;
- A prejudice to trade or commerce between Australia and places outside Australia;
- Whether the product is effective when used as instructed on the label;
- Label instructions for the safe and effective when used as instructed on the label.

Pesticides are not registered with the APVMA forever. They are reviewed to ensure they continue to meet contemporary standards.

Existing Chemical Review Process (ECRP). The public, industry, user groups and operators assist the **ECRP** in accessing relevant information. The maximum residue limit (**MRL**) may be changed. New pesticides may replace the use of older more hazardous products, or because of the development of resistance.

- **Chemicals under review are listed on the APVMA website. Restrictions** may include:
 - Having appropriate training to gain access to certain pesticides.
 - Mandatory prior notification of neighbors for application within specified buffer zones, mandatory downwind buffer zones.
 - May limit application rates or limit the number of sprays per crop per season.
 - Restricting use to certain months of the year.
 - Only spraying with appropriate equipment and under suitable weather conditions to minimize spray drift. Provide environmental warnings.
 - Keeping auditable spray records, maintain records of supply.

Special Review Programs allow **APVMA** to immediately review chemicals if issues arise which may alter the terms of their registration or cause them to be withdrawn. **Twelve chemicals** found in about **364 registered products** are currently under special review by **APVMA** including phenothiazine, vinclozolin, propazine, metham-sodium and dazomet. Outcomes of reviews are published in the *Commonwealth Gazette*. www.apvma.gov.au

Adverse Experience Reporting Program. **APVMA** considers adverse experience reports for registered pesticides submitted by product users, registrants and the general community. An adverse experience is “an unintended or unexpected effect (deleterious) on plants, plant products, animals, human beings or the environment, including injury, sensitivity reactions or lack of efficacy associated with the use of a chemical pesticide when used according to label directions”, eg

- People affected by fumes when exposed to pesticides.
- Damage to neighboring crops.
- Poor weed control after herbicide application.
- Animal health issues.
- Human health issues.
- Crop and plant damage.
- Residue issues.
- Problems that lead to unacceptable exposure to users.
- Environmental damage.
- Lack of efficacy.

Recalling procedures of agvet chemicals involves quickly and efficiently retrieving and / or modifying a chemical product, or batches of a product, that do not comply with the **APVMA's** registration requirements, or that may have an undesirable effect on humans, animals, plants, the environment, or trade and commerce between Australia and other countries. Products recalled may:

- Be unregistered, or suspended.
- Have label wording in a foreign language and lack of **APVMA** approval numbers.
- Pose a risk of harm to people, animals or the environment, may not be effective for its intended purpose, has a non-compliant formulation, or an unapproved label.
- Be an immediate enforcement tool for removing a product from the market place for remedial action at the manufacturing plant.
- Recall guidelines are on the website. During the last 12 months **APVMA** has monitored 32 voluntary recalls and managed 6 compulsory recalls.

Cancel registration. Usually there is a phase out period. Registration of endosulfan cancelled in Australia because of new information on its environmental fate and effects. Human health was not a factor in the **APVMA** decision. Volatile formulations of 2,4-D subject to spray drift have been cancelled.

Restricted chemical products (RCPs) can be identified by the words on the label:

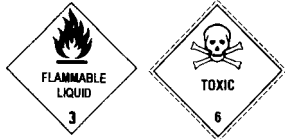

RESTRICTED CHEMICAL PRODUCT ONLY TO BE SUPPLIED OR USED BY AN AUTHORISED PERSON

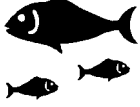

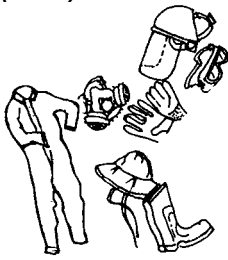
- **Relevant State / Territory authorities** authorize a person's right to access **RCPs** once they have successfully completed relevant training. Many restricted products are being phased out. The **APVMA** may declare a product to be a **RCP** if the product:
 - May have a harmful effect on human beings.
 - May have any unintended harmful effect to any animal, plant or the environment.
 - Requires special training (special knowledge, skill or qualification in the preparation or handling of the product) to be able to handle or use the product.
 - Requires special equipment to use the product safely.
 - **APVMA** verifies in writing that it is in the public interest for a product to be so declared.
 - The requirements for a person to be considered authorized to use an **RCP** may vary in each State / Territory.

Quality Assurance (QA) & Compliance	<p>APVMA requires and monitors compliance with legislative requirements. There is a focus on Quality Assurance (QA) and compliance of pesticides up to and including the point of retail sale. Supply and use of unregistered products is a punishable offence.</p> <ul style="list-style-type: none"> • QA programs ensure that APVMA's registration procedures and regulatory processes are at the forefront of World's Best Practice (WBP). <ul style="list-style-type: none"> • APVMA's Quality System is accredited under the International Standard ISO 9002. • Agvet regulation is constantly changing and is available free online. • Registrants of agvet chemicals are required to maintain analysis records for each batch of active constituents used in products and to make these records available for inspection by APVMA, enabling enforced compliance with APVMA's standard for each active constituent. • Spray drift management outlines product data guidelines for the assessment of spray drift risk and product labeling requirements. • APVMA employs three strategies to ensure products comply with the Agvet Code: <ul style="list-style-type: none"> • Prevention—provides greater understanding of registration and compliance requirements through educating stakeholders on their roles and responsibilities. • Quality facilitation—publication of a wide range of standards and guidelines. • Monitoring and enforcement—active investigation of alleged breaches and implementation of risk based enforcement strategies. • Products sold must continue to meet standards approved at registration, eg <ul style="list-style-type: none"> • Testing products to ensure compliance with the registered formulation details and regulatory standards. • Surveillance of the market place for unregistered or date expired products, unapproved or defaced labels or products subject to recall notices, eg regularly visiting retail premises to ensure products and suppliers (nurseries, supermarkets, rural chemical suppliers, hardware stores) are complying. • Monitoring advertising and promotions to ensure that false claims are not made. • Controlling supply of restricted agvet products.
STANDARD ISO 9002	
International policies	<p>Australia participates in a number of international forums that develop policy on international aspects of agvet chemicals, eg</p> <ul style="list-style-type: none"> • Stockholm Convention on Persistent Organic Pollutants (POPs) currently regulates 22 toxic substances – 15 of which are pesticides – that are persistent, travel long distances, bio-accumulate in organisms and are toxic. • The Rotterdam Convention. The Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade. The Convention regulates information about the export / import of 43 hazardous chemicals, 32 of which are pesticides; the pesticides azinphos-methyl and liquid formulations containing paraquat dichloride at, or above, 276 g/L may be added to the list. The Convention on International Trade in Hazardous Chemicals and Pesticides 1998 requires that pesticides banned or severely restricted in at least 2 other countries now cannot be exported unless explicitly agreed by the importing country. • The Basel Convention aims to protect human health and the environment against the adverse effects of hazardous wastes, eg Control of Transboundary Movements of Hazardous Wastes and their Disposal regulates the export / import of hazardous waste and waste containing hazardous chemicals. synergies.pops.int • The Montreal Protocol on substances that deplete the ozone layer, eg methyl bromide. • International regulations on chemical residues. • The Codex Committee on pesticide residues.
Persistent organic pollutants	
International Trade	
Hazardous wastes	
Ozone layer Chemical residues	
Publishers and advertisers	<p>Not only must all agvet chemicals supplied to the Australian market be registered by the APVMA but the Agvet Code also regulates the advertising of agvet chemicals, eg claims must not be incorrect or false, or make claims or permit claims about registered agvet chemicals that are inconsistent with instructions on the approved label.</p>
Public release summaries	<p>Public release summaries are issued for new active constituents and independent information on chemistry, manufacture, toxicology, metabolisms.</p>
Prosecutions	<p>Unlawful sales of date-expired products, selling, supplying and advertising unregistered agvet products can result in prosecution.</p> <ul style="list-style-type: none"> • Non-compliance may result in recall of products, relabeling of containers, further testing, or prosecution of suppliers who continue to supply non-complying products after a warning from an inspector. • Chemicals and Food Safety. Persons handling, applying or administering pesticides and causing damage to the environment, non-target crops, other persons and animals; or trade in noncomplying commodities may be prosecuted. Assessment is a toxicological evaluation, ie the Maximum Residue Limit (MRL) and the dietary exposure evaluation. • If illegal imports of pesticides are detected the APVMA has the power to recall, prevent supply, seize and dispose of any illegal pesticides.
APVMA actively investigates all breaches	
Fees	<p>Fees are levied on registrants for registration applications. There are also various fees on registered products.</p>

Other Commonwealth legislation and advisory bodies

In considering whether to grant an application for registration of an agvet chemical product, the **APVMA** must be satisfied that the product will be safe and effective and that its label is suitable. As part of making this broad assessment in relation to a chemical product, the **APVMA** conducts a number of separate evaluations, including chemistry and manufacture; toxicology, metabolism and kinetics, residues and trade, workplace health and safety and the environment. The **APVMA** uses the services of a number of Australian and State government agencies as advisers to help with some evaluations of applications for registration of agvet chemical products.

Efficacy	APVMA seeks advice from independent experts.
Signal headings on labels	<p>Poisons and Drugs Acts govern the scheduling of pesticides and are based on the Standard for the Uniform Scheduling of Drugs and Poisons (SUSDP) which is the recommendation of the National Health and Medical Research Council (NHMRC). They also regulate the availability, packaging, labeling, sale and storage of the more hazardous pesticides (see also page 288).</p> <div style="text-align: center; border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"> <p>KEEP OUT OF REACH OF CHILDREN READ SAFETY DIRECTIONS BEFORE OPENING OR USING</p> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="border: 1px solid black; padding: 5px; width: 30%; text-align: center;"> <p>CAUTION <small>KEEP OUT OF REACH OF CHILDREN READ SAFETY DIRECTIONS BEFORE OPENING OR USING</small></p> </div> <div style="border: 1px solid black; padding: 5px; width: 30%; text-align: center;"> <p>POISON <small>KEEP OUT OF REACH OF CHILDREN READ DIRECTIONS BEFORE OPENING OR USING</small></p> </div> <div style="border: 1px solid black; padding: 5px; width: 30%; text-align: center;"> <p>DANGEROUS POISON <small>KEEP OUT OF REACH OF CHILDREN READ SAFETY DIRECTIONS BEFORE OPENING OR USING</small></p> </div> </div>
Dangerous Goods	<p>The Transport of Dangerous Goods by Rail and Road (National Uniform Legislation) Act 2010 and accompanying Regulations, effectively adopt the Commonwealth package of model legislation and the Australian Code for the Transport of Dangerous Goods by Road or Rail (ADG Code) 7th Edition which covers the classification, packaging, marking and transport of dangerous goods. Relevant standards under the ADG Code include:</p> <ul style="list-style-type: none"> • National Standard for the Storage and Handling of Workplace Dangerous Goods [NOHSC: 1015 (2001)]. • National Code of Practice for the Storage and Handling of Dangerous Goods [NOHSC: 2017 (2001)]. The purpose of this national code of practice is to provide practical guidance and advice on how to comply with the National Standard for the Storage and Handling of Workplace dangerous Goods [NOHSC:1015(2001)]. <p>Dangerous Goods Acts provide for the safe transport of dangerous goods and are based the ADG Code. Dangerous Goods are those substances with particular properties, eg explosibility, flammability, toxicity, etc) which are likely to cause hazards to people or the environment. Most farm chemicals are not classified as dangerous goods but those that are classified are generally classified as Class 6 (Poisons) and/or Class 3 (Flammable liquids),</p> <div style="text-align: center; margin: 10px 0;">  <p>Dangerous Goods class diamonds</p> </div>
Dangerous Goods	<p>Further information is available from the APVMA website www.apvma.gov.au</p>
STANDARDS	
CODES OF PRACTICE	
Food safety Dietary risk assessment Pesticide residues in food	<p>Food Acts, Pure Food Acts and similar Acts are based on the Australia New Zealand Food Standards Code which is the recommendation of the National Health and Medical Research Council (NHMRC).</p> <ul style="list-style-type: none"> • Safety of chemical residues in food. In Australia, Food Standards Australia New Zealand (FSANZ) and the APVMA work together to comprehensively assess the safety of chemicals used in food production and any residues of these chemicals that may occur in food. FSANZ makes sure that potential chemical residues in food are within levels that are known to be safe for people to eat. Residues of agvet chemicals are permitted in certain food provided they comply with specific limits in the FSANZ Code. These limits are known as the maximum residue limits or (MRLs) and apply to both domestic and imported foods. MRLs are published on the APVMA website. • Food containing residues above the legal permitted level, or residues which are not legally permitted, may be confiscated and destroyed. Persons offering them for sale are prosecuted. • Directions for use. Users of pesticides who follow DIRECTIONS FOR USE on current registered labels can be confident that any residue which remains in the fruit, vegetable or other food commodity will not exceed the legal MRLs for pesticides. • Adherence to label withholding periods is most important.
	

Gene technology	<p>The object of the Gene Technology Act 2000 is “to protect the health and safety of people, and to protect the environment, by identifying risks posed by or as a result of gene technology and by managing those risks through certain regulated dealings with GMOs” (Office of the Gene Technology Regulator 2008).</p>
Environmental impacts 	<p>Air Pollution Acts, Clean Waters Acts, Environment Acts and similar Acts. Provisions include:</p> <ul style="list-style-type: none"> • Establishment of standard emissions into air, water and other environmental components. • Standards for pesticides in water which influence the choice of pesticides and application methods in water catchments. • Control of factory effluent and choice and use of land fill and other disposal sites. • Discharge of chemicals that contaminate water. • Disposal of pesticides, and pesticide containers and the sale of unsafe appliances. • Environmental Risk Assessment Guidance Manual for AgVet Chemicals (Feb 2009). • Environmental data is currently evaluated by various Commonwealth Departments, eg <ul style="list-style-type: none"> • Department of the Environment. • National Framework for Chemicals Environmental Management (NChem). • Reports are available online.
Compulsory application	<p>Pesticide applications may be compulsory.</p> <ul style="list-style-type: none"> • Commonwealth Quarantine Act, 1908 currently controls movement of plant material within and into Australia. Treatment / fumigation may be compulsory (page 176). • Export Control Act 1982 controls the conditions to be met for the export of agricultural produce to overseas countries. Some countries require some crops to be treated with specific chemicals before export is permitted (page 176). • Australian Plague Locust Commission (APLC) was established by agreement between the Commonwealth and the States of NSW, Victoria, SA and Qld. The APLC's responsibility is to survey some 2 million kilometers of eastern Australia and to control locusts using approved insecticide sprays.
Safety issues 	<p>Toxicology studies include reproduction studies, the acceptable daily intake (ADI) for humans, FIRST AID and safety directions on label. Factors considered include:</p> <ul style="list-style-type: none"> • Detailed assessment of toxicology and human health data. • Worker exposure studies • Work Health and Safety (WHS) including monitoring safety information on the label, SDSs and education / training requirements. • Assessment of effect on the environment including persistence, disposal through accident, degradation in water, light and soil, bio-accumulation, mobility in soil, leachability, ecotoxicity studies in birds, fish, etc. Environment Australia aims to ensure that agvet chemicals do not have adverse effects on the environment and do not leave unacceptable residues in produce marketed in Australia and overseas. • Residue information must include the fate of residues during storage, processing and cooking and proposed Maximum Residue Limits (MRLs). Withholding periods (WHPs), plant-back intervals (PBIs) and re-entry intervals (REIs) for glasshouses, orchards, field crops, both high (over waist height) and low (under waist height) are prescribed. • The product must not be toxic to the target crops and animals. • The Office of Chemical Safety (OCS): <ul style="list-style-type: none"> • Evaluates and reports on toxicology and metabolism studies; proposes First Aid and safety directions; determines poison schedule classifications and establishes Acceptable Daily Intakes (ADIs) and Acute Reference Doses (ARDs). • Evaluates the WHS aspects of an application and recommends safety directions and occupational controls on use and advises on safety data sheets (SDSs).
Work Health and Safety (WHS) 	<p>Work Health and Safety Acts and their Regulations address the various aspects of workplace health, eg employer responsibilities.</p> <ul style="list-style-type: none"> • Regulation of workplace hazardous substances. State and Territory legislation based on the National Model Regulations for the Control of Workplace Hazardous Substances has been introduced to control the use of hazardous substances in the workplace. These regulations minimize the risk of adverse health effects due to worker exposure to hazardous substances including hazardous agvet chemicals. In most States / Territories there are special provisions for the protection of those employed in the handling and application of the most hazardous pesticides, eg exposure standards, health surveillance, provision of safety data sheets (SDSs). <ul style="list-style-type: none"> • The type of personal protective equipment (PPE) that must be supplied to workers and provision for hygienic and safe working conditions may be specified by these Acts. • Dangerous trades and dangerous substances usually come within the provisions of these Acts as do various types of nuisances.

State / Territory legislation (control of use)

Once a registered chemical product is sold or supplied to an end-user, it is controlled by State and Territory legislation through legislative initiatives, codes of practice manuals or standard operating procedures (SOPs).

Legislation



Legislation may change with time

You can access the State / Territory websites via links from the APVMA website

All States and Territories have Acts of Parliament which lay down the laws to which owners and occupiers (and managers) are duty bound to comply. These Acts all have **companion regulations** that provide more details as to what broadly needs to be followed in order to comply with these Acts, eg

- Hazardous and Dangerous Goods Acts
- Aerial Spraying Acts
- Work Health and Safety Acts
- Environmental Acts
- Pesticides Acts
- Poison Acts
- Noxious weeds

Standards, Codes of Practice, etc. The National Standard for Storage and Handling of Dangerous Goods [NOHSC:1015 (2001)] will provide consistent requirements for the storage and handling of dangerous goods.

The penalties for breach of each Act are severe for both individuals and corporations. There are many prosecutions each year, eg you are liable to prosecution if you provide advice that causes a:

- Residue violation.
- Breach of legislation.
- Off-target damage.

Remember, an installed tank, not just the tank itself must comply with the provisions of legislation, regulations and Australian Standards, etc.

Harmonizing control-of-use

The **National Scheme for assessment, registration and control-of-use of agvet chemicals** harmonizes elements of jurisdictions' **control-of-use legislation**, while continuing to allow variations to use provisions necessary to **respond to regional needs**. It includes:

- **Minimum licensing and training requirements** for businesses and individuals. This does not preclude jurisdictions from doing more or retaining existing licence requirements to address regional risk.
- **Chemical usage record keeping requirements** for chemical usage and veterinary prescribing and compounding rights.
- **Nationally coordinated produce monitoring systems** that will monitor the level of chemical residue in or on produce.
- **Variations to approved uses** (also known as off-label use) will be less extensively harmonised. Chemical users will be allowed to apply any registered chemical to an approved crop (unless such practices are specifically prohibited on the label / permit):
 - For pests other than those stated on the label / permit,
 - At a lower application rate,
 - With lesser frequency or
 - Mixed with another agricultural product.

All aspects of control of use, eg

- Licensing and training
- Notification of use
- Notifying neighbours
- Record keeping
- Monitoring residues
- Audits and compliance

is managed by the States and Territories

Compulsory application of pesticides

The application of pesticides may be compulsory for key diseases, pests and weeds of national economic importance. Alternative methods are provided for in some instances, as long as control is satisfactory.

- **Plant Diseases Acts, Plant Protection Acts and similar Acts.**
 - These are powerful Acts which are intended to prevent the **introduction of diseases and pests** into a State / Territory and to provide for their control and / or eradication should they enter.
- **Noxious Weeds and Vermin Acts.**
 - Legislation deals with many aspects of **noxious weeds**, eg serrated tussock, and **vermin control**, eg rabbits.
 - Landholders may be required to control certain **specified pests**, eg fruit fly, weeds.
 - Statutory authorities are responsible for **enforcing provisions** and controlling the pests on public land.
 - Some statutory authorities carry out control measures for landholders for a **fee**. If pesticides are required for such operations, they are designated by the appropriate authority.

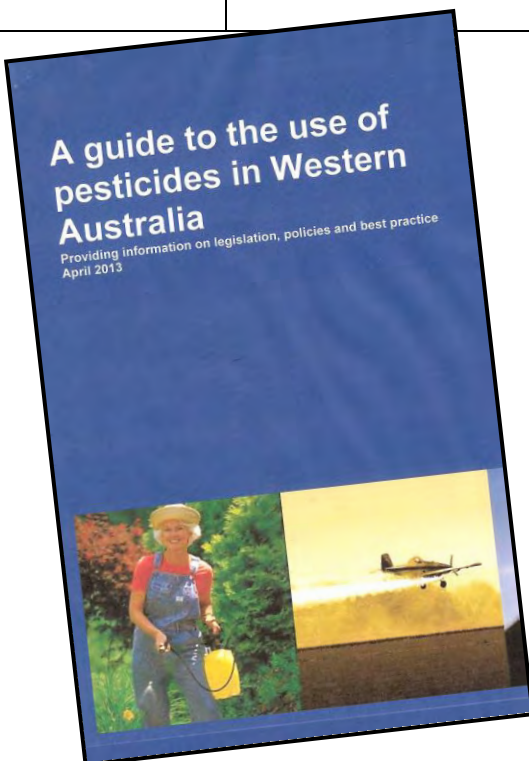
State / Territory government agencies responsible

In some States, more than one agency is involved. Check State / Territory websites for information. They are kept up to date and easy to use.

- There is no excuse for not keeping up to date on legislation, standards, codes of practice, storage and handling, transport, environmental effects, licensing and training requirements, disposal, compliance requirements and penalties.


States and Territories have online Guides for the Use of Pesticides in their State / Territory

STATE/TERRITORY	AGENCY RESPONSIBLE These may change with time
Australian Capital Territory	Environment and Sustainable Development (Pest and Weed Control)
New South Wales	NSW Department of Primary Industries Office of Environment and Heritage
Northern Territory	Department of Primary Industry and Fisheries (Chemical Services)
Queensland	Department of Agriculture, Fisheries and Forestry (DAFF)
South Australia	Department of Primary Industries and Regions South Australia (PIRSA) (Chemical Use)
Tasmania	Department of Primary Industries, Parks, Water and Environment
Victoria	Department of Environment and Primary Industries (Chemical Use)
Western Australia	Department of Agriculture and Food Department of Health



Name of the Act(s), standards, codes of practice in your State/Territory which regulates the **control of use** of pesticides:

Local government (councils)

<p>Names</p>	<p><u>The six States and the Northern Territory have many Local governments</u> within their borders.</p> <ul style="list-style-type: none"> • The State or Territory government defines the powers of the Local governments and decides what geographical areas those governments are responsible for. • The naming conventions for local governments vary across Australia. They can be called councils, cities, shires, towns, or municipalities, local land services, but they are still controlled by the State or Territory government. • In the Australian Capital Territory, responsibilities usually handled by local government are administered by a department of the Territory government.
<p>Legislation, Codes of practice, etc</p>  <p>CODES OF PRACTICE</p>	<p><u>Each Local government has the equivalent of a legislature</u> (an organized body of persons having the authority to make laws) and an executive.</p> <ul style="list-style-type: none"> • National Codes of Practice (COPs) and Standard Operating Procedures (SOPs) for the humane control of pest animals must be complied with when undertaking control programs. • The control of wild dogs in NSW is legislated by the <i>Rural Lands Protection Board Act 1998</i> which requires the owners and occupiers of land to continuously suppress and destroy wild dogs on their property. The management of wild dogs in NSW is therefore the responsibility of the land owner or manager. Predation and hybridization by feral dogs (<i>Canis lupus familiaris</i>), has been listed as a Key Threatening Process under the <i>Threatened Species Conservation Act 1995</i>. • Council may serve a notice on landholders requiring control of these species. • Council may prioritize weeds, pests for control. • Control noxious plants on council-owned land. • Most local councils have: <ul style="list-style-type: none"> • Feral Animal Management Plans. • Weeds programs. • Insect pest programs. • Biodiversity Conservation Strategies.
<p>Coordination of activities</p>	<p><u>Councils may resolve to support landholders</u>, land managers and landcare groups in a Shire to undertake a strategic wild dog, fox and cat control programs and co-ordinate control with the Livestock Health and Pest Authority (LHPA) and National Parks and Wildlife Service (NPWS).</p> <ul style="list-style-type: none"> • Councils may assist as collection centers for the recycling of pesticide containers (DrumMuster program). • In major outbreaks of pests, activities may involve cooperation with Departments of Agriculture. They may be required to assist with biosecurity activities.
<p>Pest control activities</p>	<p><u>Local governments handle community needs such as:</u></p> <ul style="list-style-type: none"> • Green waste recycling, waste collection. • Controlling pest animals, eg feral pigs, wild dogs, rabbits, goats, etc. <ul style="list-style-type: none"> • Determining the most appropriate method for managing the impact of pest animals needs to consider several factors, including efficacy, cost-effectiveness, practicality, target specificity, operator safety and also humaneness (animal welfare impact). Options may include: <ul style="list-style-type: none"> • Baiting using 1080 • Trapping • Shooting • Exclusion fence and guard animals • Noxious insect control, eg European wasps. • Noxious weed control, eg Weeds of National Significance (WONS), eg lantana, cat's claw creeper, parthenium (<i>Parthenium hysterophorus</i>), St John's wort, • Rats, mosquitos, cockroaches and European wasps are common pests that are of public health concern. They are nuisance pests that are capable of carrying disease and contaminating foods. The Adelaide City Council is working with residents and businesses to prevent and minimize the presence of these pests. • Crown land on behalf of the State or Territory governments. • Crown land on behalf of the Australian Federal Government.

Regulations, Codes, Standards, Duty of Care

Regulations	<p><u>A regulation is a legal instrument to support an Act of Parliament</u>, eg the National Model Regulations for the control of Workplace Hazardous Substances aims to protect the health of people who work with these substances and cover:</p> <ul style="list-style-type: none"> • Identifying the hazardous substances. • Labeling of containers of hazardous substances. • Using safety data sheets (SDS). • Assessing the risks to health. • Controlling risk to health by various means including: <ul style="list-style-type: none"> • Prohibiting the use of some hazardous substances. • Training employees. • Monitoring of exposure and health surveillance. • Record keeping. • Consulting employees.
Codes of practice	<p><u>A Code of Practice is a practical guide on how to comply with something</u>, eg how to achieve a standard of health, safety and welfare required by a Work Health and Safety Act and its Regulations for a particular area of work.</p> <ul style="list-style-type: none"> • <u>Codes of practice</u> do not have the same legal force as a Regulation. Codes of practice may be issued by the Commonwealth and other organizations, many of these are later <u>drafted into legislation</u>. In the absence of legislation regulating these areas, codes should be adhered to. • <u>An approved code of practice</u> is designed to be used <i>in conjunction</i> with the Act and provide <i>practical guidance</i> to employers, self-employed persons and employees. • <u>An approved</u> (by government) industry code of practice <i>should be followed</i>, unless there is an alternative course of action which achieves the same or better standard of health, safety and welfare in the workplace. • <u>Approved codes of practice</u> may be used by a court as evidence of an employer's failure to implement their duty of care responsibility. A person or company cannot be prosecuted for failing to comply with an industry code of practice. However in proceedings under the Act or Regulations, <i>failure to observe</i> a relevant approved industry code of practice can be used as evidence that a person or company has contravened, or failed to comply with, the provisions or the act or Regulations. • <u>Examples include:</u> <ul style="list-style-type: none"> • <u>National Codes of Practice</u> are documents prepared for the purpose of advising employers and workers of acceptable preventative action for <i>averting</i> occupational deaths, injuries and diseases in relation to workplace hazards. Such documents are advisory except where a law makes them mandatory. <ul style="list-style-type: none"> • Code of Practice on Labeling for Agricultural & Veterinary Chemicals. • A National Code of Practice for the Preparation of SDSs. • A National Code of Practice for the Control of Workplace Hazardous Substances. • Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG Code). • Work Health and Safety Codes of Practice
Standards	<p><u>There are more than 7000 standards in Australia.</u></p> <ul style="list-style-type: none"> • <u>A standard is a published document</u> which sets out the <i>minimum requirements</i> to ensure that a material, product, or method will do the job it is intended to do. • <u>Australian Standards</u>, while not an express requirement under the Acts, do provide more technical details that explain clearly how to deal with chemicals, in particular hazardous and dangerous goods. Equipment, products and materials which meet the requirements of the relevant standard have the <i>'standards mark'</i> on them. • <u>Standards</u> may be issued by the Commonwealth and other organizations, many of these are later drafted into legislation. In the absence of legislation regulating these areas, standards should be adhered to. • <u>In accordance with Federal Government requirements</u>, Standards Australia policy is to align Australian standards as far as possible with <i>International Standards</i> and where there is a relevant <i>International Standard</i> it will generally be adopted. • <u>Many National standards are 'called up' by State / Territory legislation</u> which means that the provisions of these standards <i>must be complied with</i> and are legally binding, eg <ul style="list-style-type: none"> • <i>Australia New Zealand Food Standards Code (ANZRS Code)</i> includes setting maximum residue limits (MRLs) for pesticides in food. • Safe Work Australia, eg the National Occupational Health and Safety Commission (NOHSC), issues many standards.

CODES OF PRACTICE

AUSTRALIAN STANDARDS

Standards Association of Australia (SAA)



A minor storage standard, above a certain quantity there are additional specifications which must be met and complied with. Check what you need.

'Duty of Care'	<u>Persons transporting, storing, handling, selling or applying pesticides</u> , have a 'duty of care' , a responsibility to carry out their tasks in a safe and efficient manner so they do not cause harm or injury to themselves, other persons, their clients, other property, domestic and wild animals or the environment. This is in addition to their responsibilities under specific pesticide legislation . The following table (Table 17) is a brief summary of 3 ways in which a 'duty of care' may arise.
-----------------------	---

Table 17. A summary of the 3 ways in which a 'duty of care' may arise.

DUTY OF CARE	BRIEF SUMMARY
Operation of a statute (an Act)	<u>A 'duty of care' may be contained in legislation</u> , eg an Act, which does not specifically relate to pesticides. Work, Health and Safety (WHS) legislation usually provides for employer and employee responsibilities, eg employers are required to accept a duty of care for the health and safety of all people in the workplace.
Operation of a contract	<u>If a person is hired to do a job which involves the use of pesticides</u> , there will be a contract. Even if no specific term is included in the contract, the employer will have a responsibility to provide safe working conditions for the person using the pesticides. If a person has contracted to spray a crop, that person must do so with skill and care as he / she has been hired to act as a professional in that area.
Common law (court decisions)	<p><u>Court decisions - Duty of care</u> also arises out of common law, ie the law that is common to court decisions.</p> <p><u>Compensation</u> - Common law provides for compensation for a wrong or injury that a person suffers because of another's action.</p> <p><u>Negligence</u> - Negligence arises from 'not doing something a reasonable person would do, or doing something a reasonable person would not do'.</p> <p><u>Special skills</u> - A person involved in an occupation requiring special skills, is expected to exercise 'the ordinary skill of an ordinary competent person exercising these skills'.</p> <p><u>Persons storing, transporting, handling, selling or applying pesticides</u> have a 'duty of care' which includes:</p> <ul style="list-style-type: none"> • Taking reasonable care to prevent damage to other persons or property. • Being liable for defects developing during storage, eg the label becoming unreadable. • Transferring pesticides only to competent persons, who are given adequate warning of the danger unless they know already. If such persons do not know the danger then the person transferring them, eg the retailer, is liable for resulting damage. • Manufacturer's instructions must be passed on. • Only providing advice and information if trained to do so. • In some States / Territories it is permissible to give off-label advice, ie recommend a use not on the label. Manufacturers usually only accept responsibility for damage occurring as a result of a chemical being used according to the label. A person giving off-label advice may be accepting the responsibility should any damage occur. Permits should be obtained for off-label uses.

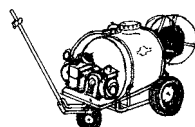
More than 100 Acts of Parliament regulate pesticides in Australia, eg

Aerial Spraying Control Acts
Dangerous Goods Acts
Environmental Protection Acts
Health Acts,
Noxious Weeds Act
Pesticides Acts, Poisons and Drugs Acts
Plant Diseases Acts
Plant Protection Acts and Vermin Control Acts
Work Health and Safety Acts

USER LICENSING

Anyone applying pesticides commercially or on another person's land should check minimum license and special insurance requirements.

Harmonizing licensing and training



The National Scheme for the assessment, registration and control-of-use of agvet chemicals aims to improve the efficiency and effectiveness of the regulation of agvet chemicals and requires:

- **Minimum licensing and training requirements** for businesses and individuals.
- The **training and licensing** will be **managed by the States and Territories** under their control-of-use responsibilities.
- **Legislation in each State and Territory** to give effect to proposed changes to record keeping, training and agvet chemical use arrangements as well as to enable cross-jurisdictional recognition of licences.

The key elements of the proposed national scheme in relation to licensing are:

- **All fee-for-service providers** are required to be licensed.
- **Both** fee-for-service businesses and individuals within those businesses are required to be licensed.
- **For business licences**, where the business is a company, one licence would be issued, otherwise for businesses which are not companies; the individual owners of the business will be licensed.
- **Licensing will not be required** for users of Restricted Chemical Products (RCPs) and Schedule 7 (S7) chemicals who are not operating a fee-for-service business (general users including farmers).
- **Licences will be issued** by the jurisdiction for registration of a business or for an individual, based on their primary location of business registration.
- **Fees and charges** will be set by each jurisdiction.
- **Automatic recognition** of any jurisdictional licence will exist in all other jurisdictions (similar to the current system for inter-jurisdictional recognition of drivers' licences).
- **Individual jurisdictions** will be responsible for auditing and compliance within their own state; and any suspension or cancellation of a licence or a right to operate in a particular jurisdiction will automatically apply in other jurisdictions.
- **The elements** of the proposed national scheme relating to licensing represent a minimum system of harmonisation that **does not preclude jurisdictions from doing more or retaining existing licence requirements to address regional risk**.

Licensing is included in State / Territory Environmental Acts, Pesticide Acts, etc.

Licenses may have different names, eg Environmental Authorizations.

Qualifications as a condition of license



Minimum licensing and training requirements for businesses and individuals include:

- **All fee-for-service providers** are required to hold a minimum **AQF level 3 competency** (or equivalent determined to be appropriate for the occupation) as a condition of licence.
- **All users of Restricted Chemical Products (RCPs) and Schedule 7 chemicals** (Dangerous Poisons) are required to hold minimum **AQF Level 3 competencies** (or equivalent determined to be appropriate for the use of that product) but with no licensing requirement. Users will be required to maintain records of **S7 product** and **RCPs** use.
- **Additional training** for the use of chemicals such as **1080** would require completion of an accredited course that aims to ensure that **1080** pest animal bait users have the knowledge, skills and appropriate competencies to use **1080**.
- **Again, these requirements reflect a minimum requirement**, individual States or Territories may choose to implement or retain additional licensing and competency requirements within their jurisdiction to allow for regional need.

Storage areas, transport and spray vehicles

Licensing the storage area.

- **Pesticide storage areas** which store more than **specified quantities** of **specified types** of agvet chemicals need to be licensed.

Licensing the transport or spray vehicle.

- **Vehicles** which transport more than **specified quantities** of **specified types** of agvet chemicals need to be licensed.

USER TRAINING

Pick the correct course for your particular circumstances



<p>Training packages</p> <p>Training is mandatory in some States and Territories</p>	<p>A Training Package is an integrated set of nationally endorsed competency standards, assessment guidelines and Australian Qualifications Framework (AQF) qualifications for a specific industry, industry sector or enterprise.</p> <ul style="list-style-type: none"> • A Training Package describes the skills and knowledge needed to perform effectively in the workplace. • Training Packages, respond to the evolving nature of job roles within the industry. • Registered Training Organizations (RTOs) develop learning strategies depending on learners' needs, abilities and circumstances. Training Packages complete a quality assurance process and are endorsed by the National Skills Standards Council (NSSC). <ul style="list-style-type: none"> • A complete list of RTOs is maintained at www.training.gov.au • RTOs include Secondary schools, TAFE colleges, private providers, industry associations, employers, community education providers and universities.
<p>Australian Qualifications framework (AQF)</p> <p>Accreditation</p>	<p>The Australian Qualifications Framework (AQF).</p> <ul style="list-style-type: none"> • A qualification formally recognizes the level and range of competency of an individual. Table 18 (page 275) illustrates the AQF and identifies the performance expectations of individuals within the industry at each of the levels. • The AQF levels define the relative complexity and depth of achievement and the autonomy required of graduates to demonstrate that achievement. There are 10 levels with Level 1 having the lowest complexity and Level 10 the highest complexity. The levels are defined by criteria expressed as learning outcomes. • Accreditation is a key link which enables all users of farm chemicals to continue to responsibly use these products to manage pests. It contributes to continuous improvement in the production of clean, safe and high quality food and natural fiber. This is an important contribution to product marketing, protection of the environment and the safety and sustainable development of Australian agriculture, horticulture industries and communities. <ul style="list-style-type: none"> • Accreditation starts at AQF Level 3, eg <ul style="list-style-type: none"> Level 3 – Operator performs routine tasks without supervision. Level 4 – Supervisor Level. Level 5 – Manager Level. • Operator Accreditation will only be awarded to those participants who have successfully demonstrated competence in least Level 3, eg <ul style="list-style-type: none"> Prepare and apply chemicals, Transport, handle and store chemicals and Control weeds
<p>A proposed national scheme</p> 	<p>The proposed national scheme includes the following elements:</p> <ul style="list-style-type: none"> • Harmonised minimum requirements for: <ul style="list-style-type: none"> • All fee-for-service providers to hold AQF Level 3 competencies or equivalent, determined appropriate for the occupation. • Users of Restricted Chemical Products (RCPs) or S7 chemicals to hold AQF Level 3 competencies or equivalent, determined to be appropriate for the use of that product. • A nationally consistent hierarchical model for access to and use of agvet chemicals providing for limited variations on approved label instructions under specified risk management control mechanisms. • Consistent monitoring, auditing and compliance: <ul style="list-style-type: none"> • Enhanced monitoring and auditing activities by States and Territories, including increased produce monitoring to be funded by the Australian Government. • A nationally consistent monitoring and auditing system for compliance with licencing and user competency obligations. • Increased, targeted produce monitoring and traceback activities providing a nationally consistent approach to residue monitoring and compliance. • Nationally consistent access conditions to private sector monitoring systems. • Compliance and enforcement systems, including industry responsibilities for co-regulation. • Record keeping: <ul style="list-style-type: none"> • Consistent record keeping for the use of agvet chemicals beyond the point of retail sale. • Consistent and accessible records will have been made at the point of sale (wholesale and retail). • Legislation in each State and Territory to give effect to proposed changes to record keeping, training and agvet chemical use arrangements as well as to enable cross-jurisdictional recognition of licences and training.

Table 18. Australian Qualifications Framework (AQF) Levels 1 to 10 July 2011. www.aqf.edu.au

AQF	Qualification type	Performance level
1	Certificate 1 (does <i>not</i> gain a qualification)	An awareness program only. It is suited to employees who require knowledge of chemical awareness but do not apply chemicals . Unit of competency Follow basic chemical safety rules (AQF 1) Course examples Chemical awareness
2	Certificate 11 (does <i>not</i> gain a qualification) Certificate of Attendance and Statement of Attainment	Pesticide users are not required to read or interpret a chemical label, is suitable for users who do not have extensive language, literacy or numeracy skills. Suitable for workers who are required to apply chemicals but only under close supervision of someone trained to AQF 3 . Units of competency Follow basic chemical safety rules (AQF 1) Apply chemicals under supervision (AQF 2) Course examples Chemical safety Vertebrate pest officer Weed control for Landcare Non-cropping situations, eg lawns, gardens, roadsides, bushland
3	Certificate 111 Operator level Operator performs routine tasks without supervision. Accreditation This course provides the required training for many Industry Quality Assurance Programs.	Workers perform routine tasks without supervision and have some input into decision making. Is suited to people who are using agvet chemicals as part of their normal work duties as an employee. Commercial users of pesticides must be re-accredited every 5 years . Units of competency Follow basic chemical safety rules (AQF 1) Apply chemicals under supervision (AQF 2) Prepare and apply chemicals (AQF 3) Transport, handle and store chemicals (AQF 3) Course examples Chemical application, eg Auschem, Chemcert, SMARTtrain, Farm Chemical User courses (FCUC) Weed control Senior vertebrate pest officer Conservation & land management Pesticide and rural training Natural resources On-farm fumigation
4	Certificate 1V Supervisor level	Workers have responsibility for managing and supervising the planning and implementing of chemical use programs, minimizing the risk involved in the use of agvet chemicals and developing and implementing pest management program. Pre-requisites The pre-requisite is a current AQF Level 3 Accreditation . Units of competency Implement and monitor the enterprise WHS program Minimize Risks in the Use of Chemicals Plan and Implement a Chemical Use Program Course examples Nursery Production Integrated Pest Management Vertebrate pest supervisor / enforcement officer Training in the Nursery & Garden Industry. Weed Risk management – Chemical risk management
5	Diploma Manager Level Course targeted at the person who needs to develop chemical management strategy planning techniques and develop WHS programs. This course is also designed for the trainer who intends to deliver chemical training at AQF 4 level.	Workers have responsibility of making management decisions based on information supplied by employees, consultants or other industry personnel. Course examples Chemical management, eg SMARTtrain AQF 5 Develop and manage a chemical use program Manager / vertebrate pest contractor Weed Risk management – Vegetation Survey & Assessment Planning for pest management
6	Advanced Diploma	
7	Bachelor Degree	
8	Bachelor Honours Degree Vocational Graduate Certificate Vocational Graduate Diploma Graduate Certificate Graduate Diploma	
9	Masters Degree	
10	Doctoral Degree Higher Doctoral Degree	

Course formats Flexible learning	<p>Courses are offered in several different formats, including:</p> <ul style="list-style-type: none"> • Traditional face-to-face delivery. Many students still seem to want some face-to-face format. • On-campus and flexible delivery courses which can be completed at work or at home at any time. A small amount of on-campus time is required to assess practical skills. • Self-paced learning with the resources being provided prior to assessment to enable clients to learn at their own pace. • Workplace learning and assessment. • Online and interactive, on-demand. • Recognition of prior learning; fast track programs for those with existing skills. • Workshop based training, assessment, weed control. • Webinars are great for short courses, eg recent changes to the WHS Act. • Open Universities Australia. • Option to complete the qualification early.
Topics	<p>Accredited courses aim to teach the regulatory and safety responsibilities relating to farm chemicals, including:</p> <ul style="list-style-type: none"> • Introduction to Pests and Pest Management. • The Product Label and Safety data sheets. • Safe Transport and Storage of Farm Chemicals. • Safe Handling and Application of Agricultural and Veterinary Chemicals. • Toxicity, Health and First Aid. • Fire, Spill and Transport Emergencies. • Farm Chemicals and the Environment. • Work, Health and Safety.
Resources Websites	<p>Participants receive the following resources:</p> <ul style="list-style-type: none"> • Training material and extension publications should address current knowledge gaps. Find out how much growers know. • A reference manual, study guides. • An assessment guide. • Legislation supplements relevant to their State / Territory. • Optional extras include Weed Control learning and Assessment Guide. On-farm Fumigation Learning and Assessment guides. • Online learning resources and support material. • Best Practice manuals, eg Guide to Using Agricultural Chemicals in Victoria, Ground-based spray application, Nursery accreditation schemes, Nursery Pesticide Application Best Practice Manual. • Pesticides. • Relevant management systems and control methods. • Training required for new laws, etc, eg updating Organic Standards. • Legislation - new pesticides, active constituents, formulations.
Assessment Open book	<p>The national procedures for assessment have not been adopted by all States. In brief, the national assessment procedures (for AQF 3) usually consists of 3 parts:</p> <ul style="list-style-type: none"> • Label reading assignment – pass mark is 100% reflecting the importance of being able to read and interpret labels correctly. The clarity of the information presented on labels in plain English is continually improving. • A calibration assessment chosen from a bank of assessments that covers a wide range of chemical application equipment. The pass mark for this assessment is 100% reflecting the importance of being able to correctly calibrate equipment. • A general knowledge quiz covering each of the 16 learning outcomes in the curriculum. <p>Other assessment procedures to demonstrate competent use of farm chemicals include:</p> <ul style="list-style-type: none"> • Competency record book. • Documentation such as storage manifests, spray diaries • Questions asked of the candidate; generally print-based and require written answers. • A worksite visit or practical application • A written requirement is likely in AusChem / Smarttrain assessments (returned to trainer assessor when completed).
Records 	<p>Records must be kept of:</p> <ul style="list-style-type: none"> • Accreditation and re-accreditation. • Licensing of applicators. • Licenses for storage areas, spray application vehicles, etc. • Licenses for Poisons. Special training, eg 1080.

Courses for specific industries	<p>Accreditation is necessary for people involved in:</p> <ul style="list-style-type: none"> • Amenity horticulture, nursery industry. • Production horticulture. • Turf industry. • Fruit and vegetable growers. • Forestry, park authorities, conservation and land management, landcare. • Weed control. • Farmers, graziers, field cropping. • Vertebrate pest control officers, eg fox, wild dog and rabbit control. • Agribusiness professionals, eg consultants. • Train the trainers. • Wholesale and retail outlets (page 281). • Fumigators. • Sugarcane and cotton industries, etc. • Local government, eg pest control staff. • Viticulture, viticulture advanced spray application. • Cotton crops. • School and childcare grounds. • Government employees. • Biosecurity, Plant Health Australia and AQIS. • Courses can be customized to suit the needs and requirements of large groups, eg the trainer / assessor is able to customize the examples used at the course.
All fee-for-service providers are required to be licensed	
Licensing and accreditation enables users to sign of on Quality Assurance	
Courses for specific weeds, pests and diseases	<p>Mostly for:</p> <ul style="list-style-type: none"> • Weed management, eg herbicide operators in non-crop, aquatic and bushland situations. • Vertebrate pest management, eg operators requiring special training for the application of pesticides to control foxes, wild dogs and rabbits, etc. • Using fungicides in grain crops. The use of fungicides on grain crops to control rusts and other leaf diseases can present new challenges to farmers. Farmers who for years have been using herbicides to control weeds in broadacre crops suddenly find they need fresh skills to effectively apply fungicides or insecticides. • Chemcert 2010 Locusts. Training topics include: <ul style="list-style-type: none"> • Labels and Safety Data Sheets. Permits. • Forecasting hatching dates. • Locust management for different crops. • Spray drift management, residues, and pesticide effects on honeybees.
Compliance Training, evaluation	<p>Management needs to provide compliance training for employees to indicate how the business must comply with the relevant legislation.</p> <ul style="list-style-type: none"> • This may involve a self-audit and an external audit against checklists. • The training itself must be evaluated, eg is the training and evaluation carried out by appropriately qualified people? • How effective is the training?
Re-accreditation 'Use by' dates	<p>Re-accreditation is an ongoing process due to changes in pesticide use and policies, eg promotion of IPM, BMPs. All licenses should be for a limited and defined period. Examples of 'use by' dates include:</p> <ul style="list-style-type: none"> • Chemcert, Auschem, SMARTTrain participants for a period of 5 years in NSW. • Agsafe accreditation has a 'use by' date of 3 years. • All businesses should have re-training programs in place. • Various courses are available for re-accreditation. • Recommended / Voluntary other using GM crops, IPM etc. • Also train the trainer and advisors and consultants, for extension officers, researchers, and agronomist should be re-accredited as well.
Quality Assurance (QA) Purchase & use of, Trade	<p>It is likely that accredited training will be a mandatory / essential requirement for:</p> <ul style="list-style-type: none"> • The purchase and use of a wider range of agvet chemicals and be a key component of industry quality assurance (QA) schemes. • Export and other markets. Some groups of users, eg grain farmers will be required to have recognized chemical user training and accreditation qualifications like Chemcert to be able to sign off on a QA program to demonstrate that they have produced grain of high quality in a way that safeguards the environment and meets trade requirements. • For all commercial users of agvet chemicals in Australia. • See also pages 320, 444.
In-house training	<p>Local Shires / Administrations/businesses may provide additional in-house short training courses for their own accredited operators and inspectors in their specific work situation. This may include having the required health tests.</p> <ul style="list-style-type: none"> • Ronstar granular applicators training course in nurseries. • Pest Management Manual for Parks. • Safe Use and Handling of Glyphosate in Maintenance Depots. • Pest Control Manuals for individual businesses.

Nationally Accredited User Training Courses

State / Territory governments regulate control of use, including basic training requirements for user training and licensing of commercial operators

Some examples	<p>Accredited courses are numerous and include:</p> <ul style="list-style-type: none"> • AusChem / Chemcert with add-ons for viticulture, the nursery industry, etc. • SMARTtrain offers a range of chemical training courses. • AgVET Farm Chemical Users Courses. • The Centre for Pesticide Application and Safety (C-PAS), Gatton College, University of Qld, provides training for agriculturists and horticulturists. • Domestic pest control operators (buildings), fumigators. • See also page 312.
----------------------	--

AusChem / ChemCert

AusChem www.auschem.org.au	<p>Auschem Australia is a non-profit, industry organization managed nationally by a Board comprising representatives of various organizations. eg</p> <ul style="list-style-type: none"> • State AusChem organizations. • The National Registration Authority for Agricultural and Veterinary Chemicals. • Agsafe (the National Association for Crop Production and Animal Health). • The National Farmers' Federation (NFF). • The Rural Training Council of Australia (RTCA). <p>Training and assessment is conducted by a national network of trained and accredited Registered Training Organizations (RTOs). The certificate is valid across Australia.</p> <ul style="list-style-type: none"> • Training at basic, advanced and industry specialist levels is tailored to the needs of participants. • The national structure has been developed to ensure common policies and coordination of course content, resources, quality assurance and delivery. • Based on endorsed national competencies and on accredited training and assessment. • AusChem Accreditation is designed to enable chemical users to meet all regulatory requirements for access to chemicals and comply with chemical use legislation as well as to meet obligations under industry quality assurance programs, and food safety standards for both national and international markets. • Guidelines and materials have been developed for training workshops, eg <ul style="list-style-type: none"> • Integrated Pest Management • Legislation and the Product label • Personal and Environmental Safety and Risk Assessment • Farm chemical formulations and application of crop protection products • Record keeping. • The main aim of AusChem is to train and accredit farm chemical users in the safe storage, handling and use of farm chemicals. • Provision of AusChem courses in the States is on a fee-paying basis.
AusChem Accreditation	<p>After successfully completing the AusChem Australia program (Level 3), you will be eligible to receive an accreditation card issued by AusChem Australia. The AusChem card is nationally recognized and shows that the necessary competencies have been completed for AusChem Australia Accreditation.</p>
Levels of training	<p>Involvement and extension of AusChem in other training programs.</p> <ul style="list-style-type: none"> • There is potential for advanced level training via industry-specific training modules, eg viticulture, nursery and grains industries, weed control. These courses address additional pesticide issues relevant in that particular industry, including: <ul style="list-style-type: none"> • Application equipment. • Pesticides registered for use. • Personal protective equipment (PPE). • Record keeping. • The AusChem certificate is also a pre-requisite for Quality Assurance programs (QA) programs such as Cattlecare and SQF 2000.
Use-by date, re-accreditation	<p>The AusChem certificate is valid for 5 years and must be updated by either:</p> <ul style="list-style-type: none"> • Undertaking a refresher or industry specialist course, or by • Taking a challenge test. • A range of reaccreditation options are available including a 1-day reaccreditation course or a specialist course.

Table 19. Some AusChem / ChemCert courses

AQF Level 1	AQF 1 Chemical awareness for employees who require knowledge of chemical awareness but do not apply chemicals .
AQF Level 2	AQF 2 Using chemicals safely is an entry level program designed for students, apprentices and people who use chemicals only under close supervision . The course is designed to provide the basic information necessary for people to make sure they can understand the information on chemical product labels.
AQF Level 3 Accreditation	AQF 3 Agvet chemical users' course accreditation provides the required training for many industry quality assurance programs. AQF 3 Agvet chemical user re-accreditation course which enables users of agvet chemicals to keep up to date with changes in chemical use, new legislation, new labels and to have a reminder about safety and best practice.
AQF Level 4 Accreditation	AQF 4 Chemical risk management accreditation . This course designed for workers who spray without supervision . This course provides the required information and all the tools necessary to comply with the regulations and to make sure the workplace is safe. Essential chemical-use training for owner-managers and workers. AQF 4 Chemical risk management re-accreditation course . Course for those requiring a refresher course at AQF 4 level.
Others	<p>AusChem Training supports a number of courses which provide specially designed training for people at all levels of involvement in the use of agvet Chemicals.</p> <p>Specialist advanced one-day course in spray application for specific industries.</p> <p>Advanced spray application - viticulture. This one day course is designed to build the skills of spray applicators so that they will fully understand the principles behind good decision making and how to maximize the effectiveness of their spray application equipment.</p> <p>Advanced spray application - grain. This course covers application technology and loss management; spraying quality and nozzles; droplet behavior and conditions which influence it; targets, products, volume of spray and spray quality; water, adjuvants and formulations; nozzle selection.</p> <p>Fumigation of grain with phosphine. The phosphine course is run over one day, and involves insect identification, how to ensure grain storage is gas tight, calculation of dose rates, and how to comply with the WHS requirements when applying the chemical.</p> <p>K-obiol training program. This short course enables people who wish to use k-obiol grain protectant in NSW, Qld, VIC & SA on cereal grains, to access the product from a limited range of resellers (as approved by Bayer). It will cover concerns with residues in domestic and export markets, calibration, application equipment set up, and the use of a QA program as required by Bayer. Course dates are set and can also be run according to demand, by contacting the trainers in the k-obiol database.</p> <p>1080 pest control course. This course aims to ensure that 1080 pest animal bait users have the knowledge, skills and appropriate competencies to use 1080 pest animal bait products in a manner which is both safe for themselves and the environment. It is a pre-requisite to this course to have successfully completed an agvet farm chemical user's course.</p> <p>Spray Application and Risk Management in Grain Production is a specialist course to broaden chemical management skills of people spraying in broad hectare grain situations, with optional additional livestock module. This course meets the requirements for renewal of accreditation. Get up to date with latest label instructions requiring that applicators perform legal applications.</p> <p>Others include:</p> <ul style="list-style-type: none"> Customized mouse plague courses. Chemcert Guide to Using APVMA Approved Phenoxy Herbicides ChemCert Selecta Spray Guide Fungicide application WHS risk assessment for pesticide use, spray drift management, pesticide volatility concern. Integrated pest management. Environmental management standards Application of certain chemicals Spray drift workshops <p>Updates for consultants. Workshops or short courses and reaccreditation help growers and others implicate new ideas, eg new Work Health & Safety legislation, new crops, new pests, diseases or weeds and new application techniques.</p>

Examples

SMARTtrain


SMARTtrain Accreditation www.smarttrain.com.au	<p>SMARTtrain is a non-profit, incorporated national association funded by sponsorship from industry organisations, government grants and a proportion of course fees.</p> <ul style="list-style-type: none"> • The main aim of SMARTtrain is to train and accredit farm chemical users via the SMARTtrain course (previously the Farm Chemical Users Course) in the safe storage, handling and use of farm chemicals. • SMARTtrain provides nationally recognized training in the areas of agvet pesticide use and WHS risk management. • Courses are delivered throughout Australia by RTOs. • Chemical accreditation courses provide training in the safe and effective use of agvet chemicals. • Provides flexible accreditation options with courses tailored to industry requirements. • Provision of SMARTtrain courses in the States is on a fee paying basis. • SMARTtrain is taught by accredited providers in each State / Territory and the certificate is valid across Australia.
Levels of training	<p>The course is aimed at:</p> <ul style="list-style-type: none"> • Farmers. • Graziers. • Government employees. • Anyone responsible for, or involved in, the use of farm chemicals. <div style="text-align: right; margin-right: 50px;">  </div> <p>Involvement and extension of SMARTtrain in other training programs.</p> <ul style="list-style-type: none"> • There is potential for advanced level training via industry-specific training modules and some have been, or are being, developed, eg viticulture and nursery industries. These add-on courses address additional pesticide issues relevant in that particular industry, including: <ul style="list-style-type: none"> • Application equipment. • Pesticides registered for use. • Personal protective equipment (PPE). • Record keeping. • The SMARTtrain certificate is also a pre-requisite for Quality Assurance (QA) programs such as Cattlecare and SQF 2000. • A number of universities and tertiary colleges have included SMARTtrain in undergraduate courses.
Use-by date, re-accreditation	<p>Please contact the SMARTtrain hotline (1800 138 351) to see if this course applies to you or you need to undertake a refresher course.</p>

Table 20. Some SMARTtrain courses

AQF Level 2	<p>Chemical Safety. Are you an employee who will be applying chemicals under supervision?</p> <p>Safe use of hazardous substances. Will you be using or be exposed to hazardous substances in your workplace?</p>
AQF Level 3 Accreditation	<p>AQF 3 Chemical application accreditation. Course for those that apply agvet chemicals without supervision.</p> <p>AQF 3 Chemical Application Re-accreditation. Course for those requiring a refresher course at AQF 3 level.</p>
AQF Level 4 Accreditation	<p>AQF 4 Chemical Risk Management accreditation. For people who supervise other people applying agvet chemicals or wish to progress towards Diploma level credits. AQF 3 level is a pre-requisite for this course.</p> <p>AQF 4 Chemical Risk Management Re-accreditation. Course for those requiring a refresher course at AQF 4 level.</p>
AQF Level 5 Accreditation	<p>AQF 5 Chemical Management accreditation. Course targeted at the person who needs to develop chemical management strategy planning techniques and develop workplace WHS programs. This course is also designed for the trainer who intends to deliver chemical training at AQF 4 level.</p> <p>AQF 5 Chemical Management Re-accreditation Course. The refresher course for Level 5. Trainers that intend to continue to deliver AQF 4 training will need to undertake this course every five years. On successful completion of the refresher course automatic reaccreditation at AQF 4 is also awarded.</p>
Examples	<p>Weeds and their control. Learn how to successfully plan, implement and monitor weed control activities according to national guidelines and industry best practice. This course is a requirement in some States.</p> <p>Integrated Pest Management Course. This supplement is only available on CD. Developed to customize the standard AQF3 Chemical Application course for growers practicing or interested in IPM.</p> <p>Developing a Pesticide Use Notification Plan This course will guide the participant to understand the process of developing a notification plan for public places where pesticides are applied.</p> <p>AQF 4 On-Farm Fumigation. Provides pest management techniques for insects of stored grain and vertebrate pests.</p> <p>AQF 4 OHS risk management on farms. Provides a step-by-step approach to documenting a risk management system for the farm or workplace.</p>

MANUFACTURERS AND RETAILERS

Agsafe

All those who **manufacture, sell (wholesale and retail) and give advice or recommend on the use of agvet chemicals** are **required** by the industry to undertake an accreditation training program.



www.agsafe.com.au/

Agsafe is a non-profit independent subsidiary of CropLife Australia. It implements an agvet chemical industry co-regulatory compliance program which aims to:

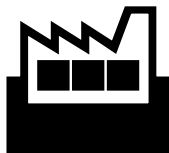
- **Have professional trained and accredited staff** with a commitment to the Agsafe Code of Conduct, throughout the distribution chain at all locations where agvet chemicals are commercially sold.
- **Have all premises** in the distribution chain where agvet chemicals are stored, handled, dispatched and sold meeting their accreditation obligations.
- **Not trade** with individuals or organisations which do not meet their accreditation obligations.
- **Have regulatory authorities endorse the Agsafe Accreditation program** and the credibility of the program reflected by regulatory recognition in licensing and in the provision of general and individual exemptions to Agsafe accredited premises.

Accreditation and Training



Agsafe courses

- Basic Training
- Work Health & Safety
- Pest Management
- Emergency Planning & Response
- Chemical Handling, Storage & Transport
- AgSAFER Risk Management
- Agvet Industry Update



Agsafe Accreditation and Training is a co-regulatory scheme, which ensures **all premises and personnel** involved in the transportation, storage, distribution and sale of agricultural and veterinary chemicals, such as distributor's outlets and manufacturers' warehouses, comply with the many Commonwealth and State / Territory Acts and regulations that apply to them.

Personnel Accreditation may be achieved by successfully completing:

- **The Personal Accreditation and Training Course**
 - This training course is an introductory course which aims to teach the regulatory and safety responsibilities relating to agvet chemicals.
 - **Pre-course requirements include having at least one year of industry experience.** Students are given a Certificate of Attainment until they have twelve months industry experience. They may then apply for full accreditation.
 - **Making a formal commitment to comply** with the standards of professional conduct outlined in the Agsafe Code of Conduct.
 - **Accreditation has a 'use by' date (3 years)** from which time the holder must have undertaken a unit of approved training to maintain accreditation status. Personnel can choose from the various modules depending on their business and professional interests.
 - **Re-accreditation training** ensures that personnel are kept abreast of industry programs, best practice and regulatory changes.
- **The Agsafe Guardian program** provides more job specific training in an **online format** (see also page 282) In conjunction with the online training modules, each individual that completes online training **must undertake a workplace assessment** to confirm that competencies learnt online are being effectively carried out in the workplace. It ensures that agvet chemicals in the distribution chain - from manufacture, through to sale to the end user - are handled by industry personnel who:
 - Understand all relevant safety and regulatory obligations;
 - Can fulfil appropriate 'duty of care' obligations; and
 - Can deliver to the end-user appropriate advice on chemical use, consistent with legal obligations and with advice from Departments of Agriculture or Primary Industries, which is increasingly disseminated via retail outlets.

Premises accreditation is attained through:

- **Initial self-assessment** against the criteria outlined in the Agsafe Industry Standard for the Safe Transport, Handling and Storage of Agricultural and Veterinary Chemicals.
- **Premises are then inspected** by external assessors every **2 years** for compliance against the **Agsafe Industry Standard**. Premises with items of non-compliance are normally given one month to address these before risking trading sanctions.
- **Agsafe Advanced**. Premises meeting a high standard of compliance criteria can move to 4 year accreditation.
- **Agsafe's ACCC Authorization** allows the agvet chemical industry to levy joint trading sanctions on stores and retail outlets which do not have all eligible staff accredited and if the store is not accredited.
- **Complying with the threshold level of dangerous goods** for obligatory premises accreditation which requires emergency services placarding as recommended by the National Occupational Health and Safety Commission (**NOHSC**).
- **Have all premises in the distribution chain** where agvet chemicals are stored, handled, dispatched and sold meeting their accreditation obligations by:
 - Having all eligible staff accredited.
 - Meeting all relevant regulations, standards and codes.
 - Demonstrating their Duty of Care.

Industry Waste Reduction Scheme (IWRs)



drumMUSTER collects empty, triple-rinsed agricultural chemical containers for recycling, providing an important tool to ensure containers are not stored on-farm, sent to landfill, buried or burnt.

- **Recently drumMUSTER** reached an important milestone collecting more than 23 million drums. [drumMUSTER website](#)
- **The program is funded** via a 4 cent per Litre or Kg levy, applied at the point of sale, for all chemical manufacturers that are signed up with the **drumMUSTER** program.
- **Agsafe standards for Effective Rinsing of Farm Chemical Containers** apply.
- **Participating manufacturers are identified** by the inclusion of the eligible **drumMUSTER** container logo on their eligible containers. The logo can be displayed on the chemical label, embossed into the container wall or applied as a sticker to the container. Containers not displaying this logo may be from non-participating manufacturers and will not be accepted into the program.
- See also page 309.

ChemClear® is the national program dedicated to collecting and safely disposing of obsolete agricultural chemicals. The program has collected and disposed of 397 tonnes since its inception in 2003.

Home Garden Chemical Awareness for Resellers 2003

This course was developed with input from industry.

- **Agsafe has recently trained 15 trainers** from around Australia who are now able to deliver this course.
- **The course can also help retailers with accreditation** under the **Australian Garden Centre Accreditation Scheme (AGCAS)**. The course includes:
 - Introduction to domestic home and garden products.
 - Pest control products legislation - General.
 - Pest control products legislation – Labeling.
 - Retail storage and safety of pesticides.
 - Giving advice on home and garden chemicals.
- **Retailers undertaking the workshop will gain hands-on experience in:**
 - Responsibly selling home garden chemical products by understanding and interpreting the product label.
 - Understanding and complying with relevant national and state-specific legislation.
 - Advising on safe transport.
 - Answering frequently asked questions regarding safe handling, storing and transport and disposal of home garden chemicals.
 - Safely manage retail and warehouse operations by following guidelines.
 - Being aware of and understanding the importance of emergency procedures.

Agsafe Nationally Recognised Training (NRT) courses

These include:

- Personnel and Premised Accreditation.
- Chemical Handling Storage and Transport.
- Emergency Planning and Response.
- Home Garden Chemical Awareness for Resellers (ChemWise).

Agsafe also recognizes other courses, eg

- User chemical training programs, eg AusChem.
- The Fertcare training program which is a joint initiative of the Fertilizer Industry Federation of Australia (FIFA) www.fifa.asn.au and Australian Fertilizer Services Association (AFSA) www.afsa.net.au/.

Online e-learning



Agsafe has entered into an agreement with **VOCAM Worldwide Publishing** to provide its training courses to Agsafe members.

- **VOCAM** are providers of multimedia online e-learning within the field of workplace health and safety.
- Under the points system, Agsafe members can enrol in **VOCAM** training courses to assist with maintaining Agsafe accreditation.
- **VOCAM** training will provide Agsafe members with the ability to complete short and relevant training courses in a timeframe that suits you and your workplace, ensuring that you continue to meet your legal requirements under **WHS** regulations.

Vocam Australia is the parent company of Safety-TV and TrainNOW.

PESTICIDE CHEMICAL LABELS

Always refer to the label attached to the product

<p>What is a label?</p> 	<p><u>The wording and layout of labels</u> is dictated by <u>legislation</u>.</p> <ul style="list-style-type: none"> • A label is defined as the written, printed and related graphic matter on, or attached to, the container in which the product is directly packed and the outside container or wrapper of the retail package, if there be any. A label includes a tag leaflet, sticker, brand, stamp, mark, stencil or written statement. <ul style="list-style-type: none"> • Label leaflets are a legal part of the label and are used when there is insufficient space on the container for all the required information. Label leaflets may be available in booklet form and inserted into an envelope or pocket on the container. • The purpose of labeling is to ensure that the chemicals can be readily identified, handled, transported, stored, used and disposed of correctly. • Trade issues are considered when establishing whether label instructions are adequate; ensuring that APVMA can act promptly to update label instructions to meet the requirements of trading partners (export withholding periods, etc).
<p>Regulation</p>	<p><u>The APVMA Ag Labelling Code</u> sets out requirements and best practice for commercial and home garden and domestic pest control product labels.</p>
<p>RPLs and MPLSs Assessing labels</p> <p>Relevant Label Particulars (RPLs) (only essential elements of a label in plain text in PUBCRIS)</p> <p>Market Product Labels (MPLs) (company logos, etc, NOT in PUBCRIS)</p>	<p><u>The way the APVMA approves labels has changed</u>. When assessing labels APVMA only considers those matters prescribed in the legislation and regulations, eg adequate instructions for the safe and effective handling and use of a product. It does not assess elements such as color, logos, etc which is done by the marketing company.</p> <ul style="list-style-type: none"> • Relevant Label Particulars (RPLs) relate to APVMA's assessment of whether labels have adequate instructions for safe and effective handling and use of a product. Legislation limits the APVMA's consideration to only those matters prescribed in legislation and RPLs. An APVMA-approved label refers to and means only the approved instructions and particulars that comprise the RPL. The APVMA will publish the RPL through PUBCRIS and Growcom. • Marketed Product Labels (MPLs) refer to the label affixed to containers in the market place which includes elements of an agvet product label such as color, logos, presentation, marketing information, warranty and other company information. APVMA is no longer required to assess these elements of an agvet product label. <ul style="list-style-type: none"> • The applicant must ensure that the MPLs placed on containers for the product contain the approved RPLs and comply with any conditions of label approval. • MPLs for products registered under the new conditions will no longer be available through PUBCRIS.
<p>Legal obligation to read the label</p> 	<p><u>It is a legal requirement to read all of the label or have it read to you</u>.</p> <ul style="list-style-type: none"> • Failure to follow the instructions on a label can result in adverse consequences and may constitute a legal violation, subject to civil and criminal prosecution. <div style="border: 2px solid black; padding: 10px; text-align: center; margin: 10px auto; width: fit-content;"> <p>Read, understand and follow all of the instructions on the pesticide label attached to the container.</p> </div>
<p>Damaged labels, unlabeled containers</p>	<p><u>A pesticide must not be used from a container</u> that does not have an original, currently registered label fixed to it.</p> <ul style="list-style-type: none"> • If the label is not fixed to the container, is damaged or illegible, or if there is any doubt about the identity of the product, it must not be used. • If the contents cannot be identified, they should be disposed of in consultation with a relevant waste management authority. • A decanted substance (eg a substance poured from one container to another) which is not used immediately must be properly labeled. These containers must remain labeled until cleaned to remove the residue of the hazardous substance. If a container is not labeled and the product name not known, then it should be clearly marked as: <p style="text-align: center;">CAUTION DO NOT USE. UNKNOWN SUBSTANCE</p>
<p>Labels change</p>	<p><u>Purchase only enough pesticide for 1-2 years</u> at the most. The pesticide may:</p> <ul style="list-style-type: none"> • Be provided with a more up-to-date label, eg spray drift instructions. • Have special restrictions placed on its use. • Be subject to a special review process. • Be de-registered. • Deteriorate in quality.

When should you read the label?

Before purchasing, check:

- If it is the **correct product for the job**, eg
 - To which **crops or sites** can it be applied?
 - Which **diseases, pests or weeds** is it registered to control.
 - In which **States / Territories is it registered for use?**
 - Is the material **too toxic or hazardous** to be **stored and used** safely under your conditions (signal heading, dangerous goods class label, etc).
- The correct concentration of the **active constituent**.
- If the product and its formulation are suitable for the **available application equipment**.
- If the chemical can be safely used under the **application conditions**.
- If the necessary **personal protective equipment (PPE)** is available for **measuring, mixing and application**.
- The **quantity** required (calibration, application rate).
- Safety Directions and **FIRST AID**.
- Withholding, re-entry and plant back periods.
- **Restrictions, Restraints, Limitations and Prohibitions, Precautionary and Protection** statements.
- **Need to obtain and read the SDS** for the current product.
- **Environmental precautions** in relation to livestock, wildlife, fish, birds, etc.
- That there are facilities to **wash the application equipment** (washdown area).
- That there are facilities to **wash PPE and have a shower**.
- Emergency responses for **spills**.

Before opening the container, measuring and mixing, check:

- The **personal protective equipment (PPE)** required during measuring and mixing and later, application.
- **What** you can mix it with (compatibility) and **how to mix** it.
- **How to apply**, safety directions necessary when using it.
- Any **Restrictions** and special **Restraints** which affect its use.
- How much of the product is required and the rate of application.
- **Remember when opening the container, measuring and mixing you are handling concentrated pesticide which is the most hazardous.**

Before application, check:

- The **personal protective equipment (PPE)** required for application.
- **When** it can be applied, eg withholding, re-entry and / or plant-back periods.
- **How** it can be applied, eg type of application equipment required.
- **Suitable weather conditions** for the application (before, during and after spraying).
- **Safety measures** to be followed, where the product can be used.
- Any **Restrictions** or other **Limitations** on the product.

Before storing or disposing of dilute or concentrated pesticide and before disposing of the container, check:

- Where and how to **store** the chemical, **with what** it should **not be stored**.
- Where and how to **dispose of left-over dilute pesticide** and **washings**.
- Correct disposal of **surplus concentrate**.
- How to **decontaminate** and **dispose of, re-use or recycle** the **empty container**.

Only buy the product if the information on the label indicates it is suitable for your needs.



Off-label use, unregistered products, permits

The use of off-label chemicals is illegal. How wide spread is this practice?

- **The reality is** that many chemicals are being applied off-label, a practice that is both illegal and potentially counterproductive.
- **Growers with concerns** about pesticide issues should take steps to ensure they are better informed.
- **Using an unapproved off-label spray is illegal**, subject to prosecution and may result in the following:
 - Damage to the crop and reduced yield.
 - Pose a health hazard.
 - Damage to the environment.
 - Lose markets if chemical residues are over legal limits.
- **Variations to approved uses** (also known as off-label use) will be harmonised to some extent (page 268). Chemical users will be allowed to apply any registered chemical to an approved crop (unless such practices are specifically prohibited on the label / permit).

Off-label permits may be required to achieve the following:

- **Vary** the rate or application frequency.
- **Control** a different pest or disease or to use a chemical on a different crop.
- **To alter particular label instructions**, eg the withholding period.
- **Off-label use.** Many new crops, especially Asian vegetables, tropical and subtropical fruits have presented major problems with off-label use. Many of the crops do not have products registered or permits for that specific crop even though there may be a registered product for a similar crop. This is further exasperated when a new pest or disease appears, when again there is no registered chemical. Evidence of the problem is shown in the residue monitoring program undertaken at Sydney Markets by NSW DPI and Sydney Markets Ltd, which showed that over a 16 year period, approximately **18% of Maximum Residue Limit (MRL) violations were the result of off-label use.**

Labels are updated and improved

Labels slowly but surely improve over time. both in the case of information available and in the layout of the labels themselves, making them easier to understand. Always check the product is still registered or that its use is not restricted or suspended before using. Recent examples include:

Compliance. To ensure that **APVMA** assessed information on labels is correct; **labels are policed** by the **APVMA**.

Toxicity of pesticides to biocontrol agents. Some pesticides are relatively non-toxic to natural enemies at low rates but not at recommended rates. Pesticide registration could require the toxicity of the pesticide to a selected list of biocontrol agents for each cropping system be provided on the label or on readily available computerized databases. Some labels do indicate which biocontrol agents might be sensitive.

Environmental labeling. Under current arrangement labels for industrial chemicals used in both the workplace and in domestic situations do not require information on environmental hazards. The costs and benefits of **mandatory environmental labeling** of chemicals to determine whether this would result in a net benefit to the community, has been examined. A consultation **Regulation Impact Statement** on options for developing and implementing nationally consistent decisions to manage the environmental risks of industrial chemicals is currently underway.

Spray drift conditions. The requirement to avoid spray drift has always been the responsibility of pesticide users. Application of best practice to avoid spray drift is still required (see also next page and page 307).

- **New labeling is more prescriptive** about the use of Drift-Reduction Strategies (Leonard 2011).
- **Product labels may include new stipulations** about droplet size, weather conditions during spraying and no-spray buffer zones.
- **In 2010 the APVMA implemented a new policy** that requires pesticides to be assessed for the **potential of spray drift**. Label instructions for all recently registered products now contain new spray-drift statements, including quantification of mandatory no-spray zones downwind from the point of application. Other data can relate to droplet size, weather conditions and record-keeping requirements.
- **Labels of currently registered pesticides are also being reviewed.** It is anticipated that in time the majority of products will include detailed restraints information on the label.

Product registration

Potential to drift, Drift Reduction Technologies (DRTs)

Mandatory label statements

AgDRIFT can evaluate the downwind deposition or "drift" and provide empirical solutions of ground & orchard applications

Delta T is the relationship between temperature and relative humidity that gives a score for deciding when best to apply sprays on crop
It is used by applicators, growers and agronomists to help decide the most suitable spraying conditions when applying pesticides, particularly during the warmer summer months. Conventional wisdom is that Delta T of 2-10 is the ideal for spraying.

Off-target pesticide spray drift must not harm human health, the environment or Australia's international trade. Policy now requires that when **assessing applications for product registration**, pesticides will be assessed for the **potential to drift**. The APVMA will undertake spray drift assessment of agvet chemical products and biological chemical products labeled for **outdoor use** that can be applied as sprays or dusts (some exceptions). See also page 307.

The APVMA has committed to assessing and updating the labels of all currently registered products subject to spray drift regulation to include comprehensive instructions for managing spray drift risk ([APVMA's Operational Notice dated 1 March 2010](#)). It is possible that this may not proceed. The first pesticides reviewed under new regulations are phenoxy herbicides including MCPA and 2,4-D.

New labeling is more prescriptive about the use of **drift-reduction practices**. There are mandatory label statements. Labels (below) for all recently registered products contain new spray-drift statements, eg

- **Droplet size.** Spray quality is regulated and requires the use of the **largest spray droplet size compatible with efficacy**.
 - Coarser sprays are the most effective way to reduce the risk of chemical drift.
 - Spray droplet size is a more significant contributor than wind speed.
 - Use drift reduction nozzles, eg **low drift nozzles**, particularly **air-induced technologies**.
- **Weather conditions** before, during and after spraying (wind speed and other weather conditions limit spraying).
- **Record-keeping** is a Federal and State or Territory requirement but requirements vary. Some spray diaries include the information required by Federal legislation, eg information must be recorded within 24 hours of application and kept for a minimum of 2 years. Recordings of wind speeds and so on should be taken at least at the start and end of the operation.
- **Quantification of mandatory no-spray zones downwind** from the point of application. No-spray zones are the protective buffer zones that the APVMA requires between the **application areas and an area downwind that needs to be protected**.
 - **The size of the no-spray zone** depends in the inherent hazard characteristic of the pesticide and on an assessment of the specific risk. Protective **DOWNWIND** no-spray zones (buffer zones) are imposed when necessary. Labels may have different no-spray zones for each of the 3 major risk categories:
 - Human health,
 - Environmental health and
 - International trade.
 - **AqDRIFT® (ground applications) and AqDISP® (aerial applications)** are used to establish no-spray zones. There are different ones for aquatic protection and for terrestrial vegetation protection.
 - **New minimum UPWIND buffer zones** regulations are being implemented for ground-based and aerial spray applications to protect public and sensitive areas.
 - **No spray zones (metres) will also depend** on whether it is applied by air or by ground application:
 - **Aerial** will depend on whether spray is applied by fixed wing aircraft or by helicopter and wind speed at the time of application.
 - **Ground** on the wind speed at time of application.
 - Other specific drift warnings, depending on the product.

PROTECTION OF CROPS, NATIVE AND OTHER NON-TARGET PLANTS
DO NOT spray in high winds. DO NOT spray cereals if Lucerne is present. DO NOT spray crops or weeds outside the stages indicated by the "Critical Comments" as damage, loss of yields or inadequate weed control may result.

Drift warning
DO NOT apply under weather conditions or from spraying equipment, that may cause spray drift onto nearby susceptible plants/crops, cropping lands or pastures such as cotton, tobacco, vines, fruit trees, vegetables, ornamentals, oil seed and legume crops and pastures and other susceptible plants and trees (eg Kurrajongs & Belahs).
DO NOT use unless wind speed is more than 3 kilometers per hour and less than 15 kilometres per hours as measured at the application site.
DO NOT apply with smaller than coarse to very coarse spray droplets according to ASAE S572 definition for standard nozzles.

Example only


**Guidelines and restrictions can reduce drift potential,
BUT THEY DO NOT ELIMINATE IT**
Spray set-up and equipment use is a central part of accurate spray application.
Weather conditions before, during and after spraying is also vital.

Understanding pesticide chemical labels

You must read the label and understand the information in it before you use a chemical. Some chemical containers also have a small booklet of information. The booklet is part of the label and it must also be read before using a chemical. The numbers in this document refer to the numbers on the attached model label. The following information explains what the different sections of the label mean. Not all chemical labels have all the information as provided here.

Source: *The following has been licensed from the Australian Pesticides and Veterinary Medicines Authority (APVMA) under a Creative Commons Attribution 3.0 Australia Licence. This material is an extract from Understanding pesticide chemical labels, first published by the APVMA in 2011. Further information is available at www.apvma.gov.au/use_safely/understanding_labels/index.php. To further elaborate, some illustrations and explanations in italics have been added to the material provided.*

Table 21. Model Pesticide Chemical labels (APVMA 2011). In addition find the information on a commercial pesticide label.

A WARNINGS AND PRODUCT DESCRIPTION	<p style="text-align: center;">1. CAUTION</p> <p style="text-align: center;">KEEP OUT OF REACH OF CHILDREN. READ SAFETY DIRECTIONS BEFORE OPENING OR USING.</p> <p style="text-align: center;">2. JO BLOGGS 500</p> <p style="text-align: center;">3. SELECTIVE HERBICIDE</p> <p style="text-align: center;">4. ACTIVE CONSTITUENT: 500g/L 2,4-DB presents as dimethylamine salt</p> <p style="text-align: center;">5. GROUP 1 HERBICIDE</p> <p>6. For selective control of certain broadleaf weeds in various crops as per directions for use table.</p> <p>7. Jo Bloggs Pty Ltd, 80 Ryde St, Tindale, NSW 2000 EMERGENCY CONTACT NO. 1800 ETC Contents 20 L</p>												
B DIRECTIONS FOR USE	<p style="text-align: center;">8. DIRECTIONS FOR USE</p> <p>RESTRAINTS: DO NOT apply when rain is expected within 4 hours. DO NOT apply to crops stressed by drought or cold, frosty conditions</p> <p>SPRAY-DRIFT RESTRAINTS: DO NOT apply with spray droplets smaller than a coarse spray droplet size category according to 'APVMA Compliance Instructions...' etc</p> <table border="1" style="width: 100%; border-collapse: collapse; margin: 10px 0;"> <thead> <tr> <th style="width: 15%;">CROP</th> <th style="width: 20%;">WEEDS</th> <th style="width: 15%;">STATE</th> <th style="width: 20%;">APPLICATION RATE</th> <th style="width: 10%;">WHP</th> <th style="width: 20%;">CRITICAL COMMENTS</th> </tr> </thead> <tbody> <tr> <td>9. Barley, oats</td> <td>Clovers, mallow</td> <td>SA, Vic, NSW</td> <td>1L in 40L water</td> <td>7 days</td> <td>DO NOT use on buffalo grass</td> </tr> </tbody> </table> <p>10 NOT TO BE USED FOR ANY PURPOSE OR IN ANY MANNER CONTRARY TO THIS LABEL UNLESS AUTHORIZED UNDER APPROPRIATE LEGISLATION</p> <p>11 WITHHOLDING PERIOD: DO NOT GRAZE OR CUT FOR STOCK FOOD FOR 7 DAYS AFTER APPLICATION</p>	CROP	WEEDS	STATE	APPLICATION RATE	WHP	CRITICAL COMMENTS	9. Barley, oats	Clovers, mallow	SA, Vic, NSW	1L in 40L water	7 days	DO NOT use on buffalo grass
CROP	WEEDS	STATE	APPLICATION RATE	WHP	CRITICAL COMMENTS								
9. Barley, oats	Clovers, mallow	SA, Vic, NSW	1L in 40L water	7 days	DO NOT use on buffalo grass								
C GENERAL INSTRUCTIONS	<p style="text-align: center;">GENERAL INSTRUCTIONS</p> <p>12 RESISTANCE WARNING: Jo Bloggs 500 is a member of the phenoxy group of herbicides. Its mode of action is to etc.</p> <p>13 COMPATIBILITY: this product is compatible with most water-based insecticides</p> <p>14 MIXING: half fill spray tank with water. Slowly add chemical and then fill tank with water</p> <p>15 MANDATORY INSTRUCTIONS FOR GROUND APPLICATIONS: USE ONLY nozzles that the nozzles' manufacturer has rated to deliver a COARSE etc.</p>												
D PRECAUTIONS	<p style="text-align: center;">PRECAUTIONS</p> <p>16 RE-ENTRY PERIOD: Do not enter treated area for 3 days, unless wearing appropriate PPE.</p> <p>17 PLANT-BACK PERIOD: DO NOT plant sensitive crops (eg tomatoes) in treated soil for at least 12 days.</p> <p>18 PROTECTION OF CROPS, NATIVE & NON-TARGET PLANTS: DO NOT apply under weather conditions or from spraying equipment that may cause spray drift onto nearby susceptible plants/crops, cropping lands or pastures.</p> <p>19 PROTECTION OF LIVESTOCK: Dangerous to bees. DO NOT spray any plants in flower while bees are foraging.</p> <p>20 PROTECTION OF WILDLIFE, FISH, CRUSTACEANS & ENVIRONMENT: DO NOT allow chemical or used containers to contaminate streams or waterways.</p>												
E FIRST AID, STORAGE AND DISPOSAL	<p>21 STORAGE AND DISPOSAL: Store in the closed original container in a cool, well-ventilated area. DO NOT store for prolonged periods in direct sunlight This container can be recycled if it is clean, dry and free of visible residues and has the DrumMuster logo visible. Triple or pressure rinse container for disposal. Dispose of rinsate by adding to the spray tank.</p> <p>22 SAFETY DIRECTIONS: Will irritate eyes. When opening the container and preparing the spray, wear face shield or goggles. Wash hands after use.</p> <p>23 FIRST AID: If poisoning occurs, contact a doctor or Poisons Information Centre on 131 126</p> <p style="text-align: center;">24 APVMA APPROVAL NO. XXX</p> <p style="text-align: center;">25 Batch" A76932 DOM: 10062011</p> <div style="text-align: right; margin-top: 10px;">  </div>												

A. WARNINGS AND PRODUCT DESCRIPTION

A.1	The signal heading	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%;">SIGNAL HEADING</th> <th>WHAT IT MEANS THE CHEMICAL IS KNOWN TO BE:</th> </tr> </thead> <tbody> <tr> <td>No signal heading</td> <td>The chemical is "unscheduled" and it is <i>relatively safe</i> to the person using the chemical. However, never treat any chemical lightly as it may still affect your health, either in the short term or the long term.</td> </tr> <tr> <td>CAUTION</td> <td>The chemical is <i>low to moderately hazardous</i> to the person using the chemical. Often it can irritate the skin or eyes.</td> </tr> <tr> <td>POISON</td> <td>The chemical is <i>very hazardous</i> to the person using the chemical. It can cause poisoning if it enters a person's body.</td> </tr> <tr> <td>DANGEROUS POISON <i>Not available to home gardeners</i></td> <td>The chemical is <i>extremely dangerous</i> to the person using the chemical. Just a small amount of the chemical can cause poisoning and even death if it enters a person's body. For these poisons there are usually restrictions on the purchase and use that are imposed by State or Territory governments such as training and accreditation requirements. Check with your State or Territory coordinator.</td> </tr> </tbody> </table> <p>The signal heading also includes instructions to keep the product out of reach of children, and to read the safety directions before opening or using the product.</p> <div style="text-align: center; border: 1px solid black; padding: 2px; margin: 10px auto; width: fit-content;"> KEEP OUT OF REACH OF CHILDREN READ SAFETY DIRECTIONS BEFORE OPENING OR USING </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="border: 1px solid black; padding: 2px; text-align: center; width: 30%;"> CAUTION <small>KEEP OUT OF REACH OF CHILDREN READ SAFETY DIRECTIONS BEFORE OPENING OR USING</small> </div> <div style="border: 1px solid black; padding: 2px; text-align: center; width: 30%;"> POISON <small>KEEP OUT OF REACH OF CHILDREN READ DIRECTIONS BEFORE OPENING OR USING</small> </div> <div style="border: 1px solid black; padding: 2px; text-align: center; width: 30%;"> DANGEROUS POISON <small>KEEP OUT OF REACH OF CHILDREN READ SAFETY DIRECTIONS BEFORE OPENING OR USING</small> </div> </div>	SIGNAL HEADING	WHAT IT MEANS THE CHEMICAL IS KNOWN TO BE:	No signal heading	The chemical is "unscheduled" and it is <i>relatively safe</i> to the person using the chemical. However, never treat any chemical lightly as it may still affect your health, either in the short term or the long term.	CAUTION	The chemical is <i>low to moderately hazardous</i> to the person using the chemical. Often it can irritate the skin or eyes.	POISON	The chemical is <i>very hazardous</i> to the person using the chemical. It can cause poisoning if it enters a person's body.	DANGEROUS POISON <i>Not available to home gardeners</i>	The chemical is <i>extremely dangerous</i> to the person using the chemical. Just a small amount of the chemical can cause poisoning and even death if it enters a person's body. For these poisons there are usually restrictions on the purchase and use that are imposed by State or Territory governments such as training and accreditation requirements. Check with your State or Territory coordinator.
SIGNAL HEADING	WHAT IT MEANS THE CHEMICAL IS KNOWN TO BE:											
No signal heading	The chemical is "unscheduled" and it is <i>relatively safe</i> to the person using the chemical. However, never treat any chemical lightly as it may still affect your health, either in the short term or the long term.											
CAUTION	The chemical is <i>low to moderately hazardous</i> to the person using the chemical. Often it can irritate the skin or eyes.											
POISON	The chemical is <i>very hazardous</i> to the person using the chemical. It can cause poisoning if it enters a person's body.											
DANGEROUS POISON <i>Not available to home gardeners</i>	The chemical is <i>extremely dangerous</i> to the person using the chemical. Just a small amount of the chemical can cause poisoning and even death if it enters a person's body. For these poisons there are usually restrictions on the purchase and use that are imposed by State or Territory governments such as training and accreditation requirements. Check with your State or Territory coordinator.											
A.2	Brand name (or trade name)	The common name of the chemical product.										
A.3	Type of chemical	<p><u>The broad description of what the chemical does. Common terms are:</u></p> <ul style="list-style-type: none"> • Herbicide = kills plants • Insecticide = kills insects • Fungicide = kills fungus diseases • Nematicide = kills nematodes (tiny worm-like creatures, that usually live in soil) • Molluscicide = kills molluscs (slugs and snails) 										
A.4	Active constituent	<p>This is the name of the actual part of the chemical that does the work. That is the part that kills the weeds, insects or other pests. The concentration of the active constituent(s) is also given.</p> <ul style="list-style-type: none"> • Some products contain a solvent to dissolves the active constituent. These solvents can sometimes be poisonous, and in such cases the amount and name of the solvent is shown on the label under the heading "Solvent". 										
A.5	Resistance group	<p>To prevent the pest from building up resistance to the chemical, you should not use chemicals from the same resistance group over and over. Swap between chemicals from different resistance groups. Also see the information in section 12 below. <i>Here is one example of a resistant group on a label.</i></p> <div style="text-align: center; border: 1px solid black; padding: 5px; margin: 10px auto; width: fit-content;"> GROUP M HERBICIDE </div>										
A.6	What the chemical does	This lists the things that the chemical is registered to do. It includes which crops the chemical can be used on and which insects, weeds and diseases , etc that it is registered to control.										
A.7	Name, address & phone number of the business that made the chemical	Contact the business if you need advice on how to use the chemical and if you need other information about the chemical (for example, how to clean up spilled chemical).										

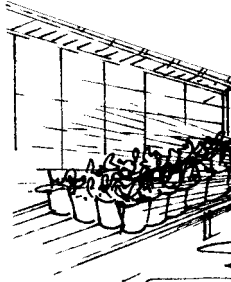



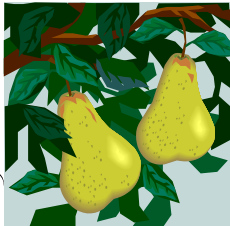


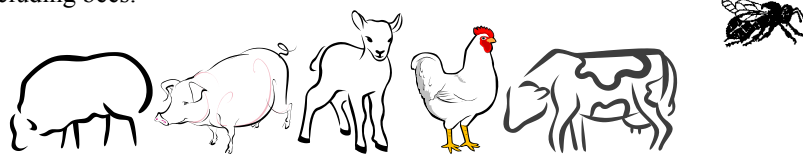
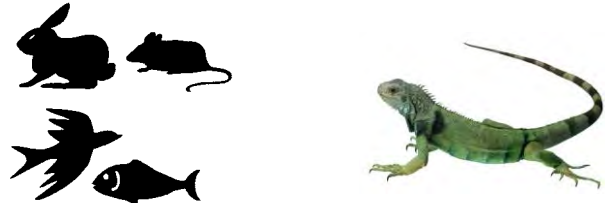
B. DIRECTIONS FOR USE

B.8 Restraints	<p>This is a list of situations where the chemical MUST NOT be used, either because the chemical will not work in these situations or because it is too dangerous to use the chemical in these situations. Some chemicals do not have restraints.</p> <p>If spray drift restraints apply, including mandatory no-spray zones, they will be listed here. Drift margin instructions may include mandatory, legally enforceable instructions such as:</p> <ul style="list-style-type: none"> • Droplet size • Wind speed when spraying • Surface inversion conditions • Record keeping • Downwind no-spray 												
B.9 Directions for use Table	<p>Information on how to use the chemical against specific pests on specific crops. Read the information in the table from left to right making sure you read the information in all of the columns.</p> <table border="1" style="width: 100%; border-collapse: collapse; margin: 10px 0;"> <thead> <tr> <th style="text-align: left;">Crop/situation</th> <th style="text-align: left;">Pest/weed</th> <th style="text-align: left;">State</th> <th style="text-align: left;">Application rate</th> <th style="text-align: left;">WHP (see B.11)</th> <th style="text-align: left;">Critical comments</th> </tr> </thead> <tbody> <tr> <td style="font-size: small;">Lists the crops or situation where the product can be used</td> <td style="font-size: small;">Lists the pests or weeds that the product can control</td> <td style="font-size: small;">Lists the states where the product can be used</td> <td style="font-size: small;">Shows the rate or range of rates that should be used to apply the chemical</td> <td style="font-size: small;">Lists the withholding periods (WHP) for each crop</td> <td style="font-size: small;">Lists important application details for each crop</td> </tr> </tbody> </table> <p style="text-align: center; margin: 0;">Information is most frequently presented in tabular form</p>	Crop/situation	Pest/weed	State	Application rate	WHP (see B.11)	Critical comments	Lists the crops or situation where the product can be used	Lists the pests or weeds that the product can control	Lists the states where the product can be used	Shows the rate or range of rates that should be used to apply the chemical	Lists the withholding periods (WHP) for each crop	Lists important application details for each crop
Crop/situation	Pest/weed	State	Application rate	WHP (see B.11)	Critical comments								
Lists the crops or situation where the product can be used	Lists the pests or weeds that the product can control	Lists the states where the product can be used	Shows the rate or range of rates that should be used to apply the chemical	Lists the withholding periods (WHP) for each crop	Lists important application details for each crop								
B.10 NOT TO BE USED FOR ANY PURPOSE... statement	<p>This statement is intended to limit the use of a product to purposes that have been assessed and approved by the APVMA. If you want to use a chemical in any way other than according to the label instructions, you may need to get a permit from the APVMA.</p> <div style="border: 1px solid black; padding: 10px; text-align: center; margin: 10px 0;"> <p>NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION.</p> </div>												
B.11 Withholding Period (WHP) <i>Protects the consumer and the public</i> Withholding Period (WHP) Maximum Residue Limits (MRLs)	<p>The time from when you apply the chemical until you can pick the crop. You MUST NOT harvest a crop before the withholding period has expired. Some withholding periods may also apply to grazing livestock on treated areas or cutting for stock feed.</p> <div style="border: 1px solid black; padding: 10px; text-align: center; margin: 10px 0;"> <p>DO NOT APPLY LATER THAN [] DAYS BEFORE HARVEST DO NOT GRAZE OR CUT FOR STOCK FEED FOR [] DAYS AFTER APPLICATION</p> </div> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p><i>The Withholding Period (WHP) allows sufficient time for residue levels to fall below the Maximum Residue Limit (MRL), and so avoid unacceptable residues of chemicals and their metabolites in raw agricultural commodities and food for human consumption.</i></p> </div> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p><i>The Maximum Residue Limit (MRL) is the maximum concentration of a residue, resulting from the officially authorized safe use of a pesticide that is recommended to be legally permitted or recognized as acceptable in, or on, a food, agricultural commodity, or animal feed.</i></p> <p>MRLs are <u>not printed on the label</u> but the strict observance of <u>rates, intervals between applications</u> and of <u>WHPs</u> that must be followed <u>are printed</u> on the label to ensure MRLs of pesticides are not exceeded in food and animal feed.</p> </div>												


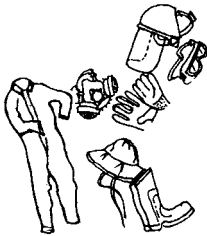


C. GENERAL INSTRUCTIONS

C.12 Resistance warning	<p>These instructions should be followed, so that the insect, disease or weed does not become resistant to the chemical you are using (also see information in section A 5 above).</p> <div style="text-align: center; margin-top: 20px;"> <div style="border: 1px solid black; padding: 5px; display: inline-block; transform: rotate(-2deg); margin-bottom: 10px;">Insecticide Resistance Warning</div> <div style="border: 1px solid black; padding: 5px; display: inline-block; transform: rotate(-5deg); margin-bottom: 10px;">RESISTANT WEEDS WARNING</div> <div style="border: 1px solid black; padding: 5px; display: inline-block; transform: rotate(-3deg); margin-bottom: 10px;">Fungicide Resistance Warning</div> </div>
C.13 Compatibility	<p>This tells you if it is safe to mix this chemical with other chemicals. If chemicals are not compatible, they should not be mixed together. More information about compatibility can be obtained from agronomists and consultants.</p> <div style="text-align: center; margin-top: 20px;"> <div style="border: 1px solid black; padding: 10px; width: 80%; margin: 0 auto;">[] is compatible in tank mixes with []</div> <div style="border: 1px solid black; padding: 10px; width: 80%; margin: 10px auto;">[] is not compatible with []</div> </div>
C.14 Mixing instructions	<p>This is important information on how to mix the chemical with water. You must follow these instructions otherwise the chemical may not work.</p> <div style="text-align: center; margin-top: 20px;"> <div style="border: 1px solid black; padding: 10px; width: 80%; margin: 0 auto;"><i>Ensure the spray tank is free of any residue of previous spray materials</i></div> </div>
C.15 APVMA compliance instructions for mandatory droplet size categories	<p>Any products that require application using mandatory droplet sizes will also include further mandatory instructions here.</p>

D. PRECAUTIONS

<p>D.16 <i>Re-entry period</i></p>	<p>The time when you apply the chemical, until it is safe to go back into the treated area. If you want to go back into the treated area before this time, you must wear the safety equipment that is listed here.</p> <div style="text-align: center; margin: 10px 0;"> <div style="background-color: black; color: white; padding: 5px; display: inline-block;">KEEP OUT PESTICIDES APPLIED</div> <p>Do not allow entry into treated areas for [...] hours/days after treatment</p>  </div>
<p>D.17 <i>Plant-back period</i></p>	<p>The time when you apply the chemical, until it is safe to plant seedlings or sow seeds into the treated soil. This applies to soil fumigants and to some herbicides.</p> <div style="text-align: center; margin: 10px 0;">  </div>
<p>D.18 <i>Protection of crops, native and other non-target plants</i></p>	<p>Describes the things you need to do (or not do) so that the chemical doesn't damage crops or other desirable plants.</p> <div style="display: flex; justify-content: space-around; align-items: center; margin: 10px 0;">      </div>
<p>D.19 <i>Protection of livestock</i></p>	<p>Describes the things you need to do (or not do) so that the chemical doesn't injure livestock, including bees.</p> <div style="text-align: center; margin: 10px 0;">  </div>
<p>D.20 <i>Protection of wildlife, fish, crustaceans and the environment</i></p>	<p>Describes the things you need to do (or not do) so that your chemical doesn't damage the environment (damage to these is known as off-target damage).</p> <div style="text-align: center; margin: 10px 0;">  </div>

E. FIRST AID, STORAGE AND DISPOSAL

E.21 Storage & Disposal	<p>Information on how to safely store the chemical and how to safely get rid of empty containers. Note that chemicals must NEVER be kept in food and drink containers.</p> <div style="text-align: center;">  </div>
E.22 Safety Directions Safety Data Sheet (SDS)	<p>Information on how the chemical can affect your health, and what you should do to protect yourself from exposure to the chemical. It lists the safety equipment that you should wear when handling the chemical. You should read the safety directions before opening the container or using the product.</p> <p>More detailed safety information can often be found in the Safety Data Sheet (SDS), which can be obtained from the company that made the chemical. Most SDS can be downloaded from company websites. There are also other websites that provide this information.</p> <div style="display: flex; align-items: center; justify-content: space-between;"> <div style="border: 1px solid black; padding: 5px; width: 60%;"> <p style="text-align: center; margin: 0;">Safety Data Sheet</p> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;"> <p style="margin: 0;">1. PRODUCT IDENTIFIER AND IDENTIFY FOR THE CHEMICAL</p> <p style="margin: 0;">Product Name: YATES ZERO WEEDSPRAY 490</p> <p style="margin: 0;">Recommended Use: Non-selective herbicide for the home garden etc</p> </div> <div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;"> <p style="margin: 0;">2. HAZARD IDENTIFICATION</p> <p style="margin: 0;">etc</p> </div> </div> <div style="text-align: center;">  </div> </div>
E.23 First Aid 	<p>You should read and understand the first aid instructions on the label before you use the chemical, so that you know exactly what to do if there is an emergency.</p> <p>The Safety Data Sheet (SDS) has much more detailed first aid instructions than the label, and often has advice for doctors. You should have an SDS on hand and take it with you to the doctor or hospital if you believe you have been poisoned.</p>
E.24 APVMA Approval Number	<p>In Australia, all farm chemicals MUST be approved by the AVPMA before they can be legally sold. All registered products will either have an AVPMA or NRS Approval Number on them. The AVPMA approval number on a chemical label is our assurance that the product has been checked as safe and effective if you follow label instructions.</p>
E.25 Batch number, Date of Manufacture (DOM) & Expiry Date	<p>It is good to write down the batch number of all chemicals used, in case something goes wrong and the chemical doesn't work properly.</p> <p>Chemical should not be used after the expiry date.</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p><i>Product expiry dates are updated during the renewal period in July each year. Active constituent approvals do not have expiry dates. Expiry dates are under review.</i></p> </div>
E.26 Dangerous Good and/or a Hazardous Chemical Main type of risk	<p>If a chemical container has a diamond shaped symbol on it [], the chemical is classified as a <i>Dangerous Good</i> and / or a <i>Hazardous Chemical</i>. If a product is classed as a <i>Dangerous Good</i> there are specific laws about how to transport and store it. Check with your chemical supplier to find out if you need to take special precautions when carrying <i>Dangerous Goods</i> on your vehicle when driving on public roads. If the product is classified as a <i>Hazardous Chemical</i> you must comply with specific laws in relation to workplace health and safety aspects.</p> <div style="text-align: center; margin-top: 20px;">  </div>

SAFETY DATA SHEETS (SDSs)

<p>What does the SDS tell you? Safe Work Australia 2014</p>	<p>A Safety Data Sheet (SDS), previously called a Material Safety Data Sheet (MSDS), is a document that provides information on the properties of hazardous chemicals, how they affect health and safety in the workplace and how to manage the hazardous chemicals in the workplace, eg</p> <ul style="list-style-type: none"> Section 1. Product identifier and identity for the chemical Section 2. Hazard identification Section 3. Composition / information on ingredients Section 4. First Aid Measures Section 5. Fire Fighting Measures Section 6. Accidental Release Measures Section 7. Handling and Storage Section 8. Exposure control / personal protection Section 9. Physical and chemical properties Section 10. Stability and reactivity Section 11. Toxicological information Section 12. Ecological information Section 13. Disposal considerations Section 14. Transport information Section 15. Regulatory information Section 16. Other information
<p>The SDS must apply to the specific pesticide to be used and should always be referred to when assessing risks in the workplace.</p>	
<p>WHS regulations</p>	<p>Work and Safety Regulations (WHS Regulations) require the manufacturer or importer of a hazardous chemical to prepare an SDS for the chemical. Additionally, a supplier must provide the manufacturer's or supplier's current SDS for the hazardous chemical when first supplied to a workplace and upon request.</p>
<p>Codes of Practice</p>	<p>Codes of practice provide guidance on preparing an SDS for workplace chemicals.</p> <ul style="list-style-type: none"> • National Code of Practice for the Preparation of Material Safety Data Sheets (until 31/12/2016). • Code of Practice for the Preparation of Safety Data Sheets for Hazardous Chemicals (from 1/1/2012 and mandatory after 31/12/2015). This code of practice is used where the chemical has been classified according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).
<p>Who prepares the SDS?</p>	<p>Manufacturers and importers of hazardous substances for use in the workplace are required to produce a SDS and supply it to purchasers and persons handling and using the product in the workplace.</p> <ul style="list-style-type: none"> • Manufacturers and importers must send a copy of each SDS they produce to the Australian National MSDS Repository (ANMSDS Repository) which is maintained by Safe Work Australia. • Guidance regarding the recommended format and contents for SDS used in Australia is available for manufacturers and importers. • The preparation of a SDS for a substance not determined to be hazardous is not mandatory. However, some manufacturers and importers may prepare SDS for these substances as good practice. • Users should have an SDS for every chemical on hand. Manufacturers must supply an SDS on demand. Photocopies have no legal status.
<p>Where do I get an SDS from? Manufacturer Distributor Product reseller</p>	<p>Many workplaces request that an SDS accompany delivery of any hazardous substance.</p> <ul style="list-style-type: none"> • If not supplied, contact the manufacturer / importer / distributor of the product to post / fax / email the required SDS. • Access on the web. Most of the larger companies also have websites which allow users to access SDSs for their products. • Generic SDSs and additional information on hazardous substances may be accessed through various online chemical management systems including: <ul style="list-style-type: none"> • CHEMWATCH - chemical management, risk assessment, SDSs and chemical regulations. • InfINDER - a commercial database that contains information on all the registered agvet chemicals in Australia. • GROWCOM - the peak representative body for Qld horticulture and provides information on issues relating to horticulture at a State and National level. • HerbiGuide - provides information on weeds, pests and diseases in crops, pastures, horticulture and environmental situations to help you with crop protection decisions.
<p>SDS and the product label</p>	<p>The SDS provides supplementary and different information to that provided on the label.</p> <ul style="list-style-type: none"> • The SDS is not part of, or a substitute for, reading the label. • The SDS is mentioned on some chemical labels to remind the user of its availability, and of the further and different information that it contains. If an SDS is required under relevant Work Health and Safety (WHS) legislation the following statement is included on the label: <p style="text-align: center;">“Additional information is in the Safety Data Sheet”.</p> • While the SDS provides adequate information for most users, the SDS is not a substitute for expert advice.

<p>What are the WHS requirements?</p>	<p><u>It is the requirement of WHS regulations</u> in most States / Territories that an appropriate SDS of a hazardous substance be made available during the sale of the product or upon request.</p> <ul style="list-style-type: none"> • The SDS must be obtained by the employer, from the manufacturer / importer of a hazardous substance either before, or on the first occasion, on which the hazardous substance is supplied. • Where an SDS has <u>not</u> been supplied, it must be requested from the manufacturer or importer. • Employers are required by the Hazardous Substances Regulations to ensure that all employees have ready access to SDSs and can get information about health hazards in addition to that provided on the label. 										
<p>Using SDSs in the workplace</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>SDSs are being updated all the time. Make sure you have the current one for your product. Date it on receipt.</p> </div>	<p><u>Employers must ensure that:</u></p> <ul style="list-style-type: none"> • Current SDSs are available. They must be checked for currency at least every 12 months. Date the SDS when it is received from the supplier. • An SDS file should be maintained for all pesticides at all premises where hazardous substances are stored, manufactured or handled. • Keep copies of the SDS of each product used and place in a register. • Ensure everyone can access SDS and is familiar with their contents and that they are trained in their correct use. • Any storage or retrieval system for SDSs is kept in good working order. • Employers and employees must be familiar with the contents of the SDS for products in their area. • Where information is displayed on a screen, there should be a means of obtaining a paper copy of that information. • The SDS allows risk assessment of the use of the hazardous substance and any necessary controls to be established in the workplace. • If environmental monitoring or health surveillance is required, ensure that it is carried out. • The personal protective equipment (PPE) and emergency planning and response procedures are audited and adequate. • All equipment and procedures are audited for their correct use. • The WHS committee, or officers, can use the SDS to monitor and improve health and safety at the workplace, ie to decide whether any improvements should be made to equipment or procedures. 										
<p>Have I got the correct SDS?</p> <p style="text-align: center;"><i>Roundup Glyphosate</i></p> <p style="text-align: center;"><i>Omethoate</i></p> <p style="text-align: center;"><i>Imidacloprid</i></p>	<p><u>Ensure that you have the correct SDS.</u> The SDS obtained must be for the particular formulation of the pesticide, pack size, etc being purchased, stored or used.</p> <ul style="list-style-type: none"> • Glyphosate, is formulated in more than 500 pesticide products. You need a different SDS for each product, eg <ul style="list-style-type: none"> Roundup® Ready Herbicide (690g/L GLYPHOSATE) Roundup® BIACTIVE (360g/L GLYPHOSATE) Forward® Glyphosate Herbicide (450 g/L GLYPHOSATE) Nufarm Glyphosate 360 Herbicide (360 g/L GLYPHOSATE) • Omethoate is manufactured in two different formulations each of which has a different concentration of active constituent and have different signal headings and so vary widely in their potential hazard. You need a different SDS for each of the following products: <table style="margin-left: 40px; border: none;"> <tr> <td style="padding-right: 20px;">Folimat® 800 Insecticide Spray (800 g/L OMETHOATE)</td> <td>Signal heading DANGEROUS POISON</td> </tr> <tr> <td>Folimat® Garden Insecticide (2 g/kg OMETHOATE)</td> <td>CAUTION (aerosol)</td> </tr> </table> • Imidacloprid is also manufactured in different formulations, eg <table style="margin-left: 40px; border: none;"> <tr> <td style="padding-right: 20px;">Nuprid® 350SC Insecticide (350g/L IMIDACLOPRID)</td> <td>POISON</td> </tr> <tr> <td>Confidor® Concentrate Insecticide (200g/L IMIDACLOPRID)</td> <td>CAUTION</td> </tr> <tr> <td>Yates Confidor® Ready to Use Insecticide (0.125g/L IMIDACLOPRID)</td> <td>Not scheduled</td> </tr> </table> 	Folimat® 800 Insecticide Spray (800 g/L OMETHOATE)	Signal heading DANGEROUS POISON	Folimat® Garden Insecticide (2 g/kg OMETHOATE)	CAUTION (aerosol)	Nuprid® 350SC Insecticide (350g/L IMIDACLOPRID)	POISON	Confidor® Concentrate Insecticide (200g/L IMIDACLOPRID)	CAUTION	Yates Confidor® Ready to Use Insecticide (0.125g/L IMIDACLOPRID)	Not scheduled
Folimat® 800 Insecticide Spray (800 g/L OMETHOATE)	Signal heading DANGEROUS POISON										
Folimat® Garden Insecticide (2 g/kg OMETHOATE)	CAUTION (aerosol)										
Nuprid® 350SC Insecticide (350g/L IMIDACLOPRID)	POISON										
Confidor® Concentrate Insecticide (200g/L IMIDACLOPRID)	CAUTION										
Yates Confidor® Ready to Use Insecticide (0.125g/L IMIDACLOPRID)	Not scheduled										
<p>If you need to know more</p>	<p><u>If you have any doubts about information:</u></p> <ul style="list-style-type: none"> • Get in touch with the contact person listed on the SDS or • Contact the local WHS Office. 										

Table 22. A checklist of the information required in an SDS (Safe Work Australia).

SECTION 1 – PRODUCT IDENTIFIER AND IDENTIFY FOR THE CHEMICAL	
Product identifier	Suppliers name, address and phone number
Other means of identification	Emergency phone Number
Recommended use of the chemical and restrictions on use	
SECTION 2 - HAZARD IDENTIFICATION	
Classification of the hazardous chemical	Other hazards which do not result in classification
Label elements, including precautionary statements	
SECTION 3 – COMPOSITION / INFORMATION ON INGREDIENTS	
Identity of chemical ingredients	Concentration of ingredients
CAS number and other unique identifiers	
SECTION 4 - FIRST AID MEASURES-	
Description of necessary First Aid measures	Medical Attention and Special Treatments
Symptoms caused by exposure	
SECTION 5 – FIRE FIGHTING MEASURES	
Suitable extinguishing media	Special protective equipment and precautions for fire fighters
Specific hazards arising from the chemical	
SECTION 6 – ACCIDENTAL RELEASE MEASURES	
Personal precautions, protective equipment and emergency procedures	
Environmental precautions	
Methods & material for containment and cleanup	
SECTION 7 – HANDLING AND STORAGE	
Precautions for safe handling	
Conditions for safe storage, including any incompatibilities	
SECTION 8 – EXPOSURE CONTROLS / PERSONAL PROTECTION	
Control parameters - exposure standards, biological monitoring	
Appropriate engineering controls	
Personal protective equipment (PPE)	
SECTION 9 – PHYSICAL AND CHEMICAL PROPERTIES	
Appearance	Decomposition temperature
Odour	Viscosity
Odour threshold	Specific heat value
pH	Particle size,
Melting point / freezing point	Volatile organic compounds content
Boiling point and boiling range	% volatile
Flash point	Saturated vapour concentration
Evaporation rate	Release of invisible flammable vapours and gases
Flammability	Additional parameters
Upper / lower flammability or exposure limits	Shape and aspect ratio
Vapour pressure	Crystallinity
Vapour density	Dustiness
Relative density	Surface area
Solubility(ies)	Degree of aggregation or agglomeration
Partition coefficient: n-octanol / water	Ionisation (redox potential)
Auto-ignition temperature	Biodurability or biopersistence
SECTION 10 – STABILITY AND REACTIVITY	
Reactivity	Incompatible materials and possibly hazardous reactions
Chemical stability	Hazardous decomposition products
Conditions to avoid	
SECTION 11 – TOXICOLOGICAL INFORMATION	
Information on routes of exposure	Exposure levels
Symptoms related to exposure	Interactive effects
Numerical measures of toxicity	Data limitations
Immediate, delayed and chronic health effects from exposure	
SECTION 12 – ECOLOGICAL INFORMATION	
Ecotoxicity	Mobility in soil
Persistence and degradability	Other adverse effects
Bioaccumulative potential	
SECTION 13 – DISPOSAL CONSIDERATIONS	
Safe handling and disposal methods	Environmental regulations
Disposal of any contaminated packaging	
SECTION 14 – TRANSPORT INFORMATION	
UN number	Environmental hazards
Proper shipping name	Special precautions during transport
Transport hazards class(es)	Hazchem Code
Packing group	
SECTION 15 - REGULATORY INFORMATION	
Safety, health and environmental regulations specific for the product in question	
Poison schedule number	
SECTION 16 - OTHER INFORMATION	
Date of preparation or review	
Key abbreviations or acronyms used	


SAFETY DATA SHEET

Section 1: IDENTIFICATION OF THE MATERIAL AND SUPPLIER

Product Name: AMISTAR® XTRA Fungicide
Other Names: Proper shipping name: Environmentally Hazardous Substance, Liquid, N.O.S. (Azoxystrobin)
Applicable only for marine and air transport
Product code: A12910C
Recommended Use: Fungicide for control of certain fungal diseases in barley, wheat and peanuts
Company Details: Syngenta Crop Protection Pty Limited
ABN 33 002 933 717
Address: Level 1, 2-4 Lyonnark Road

MATERIAL SAFETY DATA SHEET

Date of Issue: August 25th 2010



1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

Product name Bayer Glyphosate 450 Herbicide
Other names None
Product code and pack sizes 79461119 (1000 L), 79494874 (110 L), 79395841 (20 L)
Chemical class Glycine derivative

eco oil

Material Safety Data Sheet


Issue Date: January 2011

Statement of Hazardous Nature:
"Not classified as hazardous according to criteria of the National Occupational Health and Safety Commission"

Company Details

Issued by: Organic Crop Protectants Pty Ltd

Safety Data Sheet



1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

Product Name: YATES ZERO WEEDSPRAY 490
Recommended Use: Non selective herbicide for the home garden.
Supplier: Yates Australia, a division of DuluxGroup (Australia) Pty Ltd
ABN: 67 000 049 427
Street Address: 1 Gow Street,
Padstow, NSW 2211
Australia
Telephone Number: +61 2 9781 8777
Facsimile: +61 2 9781 8825
Emergency Telephone: 1 800 033 111 (ALL HOURS)

2. HAZARDS IDENTIFICATION

Based on available information, not classified as hazardous according to criteria of Safe Work Australia; NON-HAZARDOUS SUBSTANCE.
Not classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Road and Rail; NON-DANGEROUS GOODS.

Fig. 26. Examples of Safety Data Sheets (SDSs). You need a different SDS for each formulation of the same active constituent. Safety Data Sheets were previously called Material Safety Data Sheets.

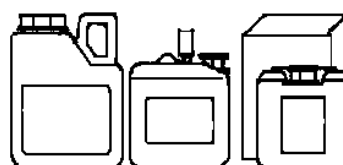
ISSUES OF CONCERN AND OPPORTUNITES

Australia has an efficient and effective system for managing agvet chemicals, eg **training courses and licensing** of commercial operators and those applying pesticides on government land and the chemical industry is developing its own schemes to deal with **chemical containers and waste minimization**. However, because of the danger involved with the use of many pesticides, there are domestic and international pressures for higher standards of agvet chemical management. The responsibility for managing of agvet chemical products in Australia:

- Policy and legislation by governments (International, Commonwealth, State / Territory and Local).
- Manufacturers and retailers of agvet chemical products.
- Users, eg individuals, businesses, grower associations.

This section is a discussion of the problems and opportunities ahead:

- Policy and regulation.
- Community health and safety.
- Work health and safety (WHS).
- Quality assurance (QA) and trade, records.
- Risk assessment and management.
- Pesticide resistance.
- Pesticide selection.
- Why pesticides “fail” – Errors cost \$\$\$.
- Phasing out pesticides, restricting use.
- Spray drift remains a problem.
- Residues, pesticides in food and the environment.
- Industry waste reduction scheme (IWRS).
- Minimizing use of (hazardous) pesticides.
- Still incidents and mishaps.
- User training.



Policy and regulation

Legislation



There is a trend away from regulation towards identifying what the outcome must be, allowing users work to out what has to be done, often via a Code of Practice or Standard.

- **Industry wants the regulatory burden on business reduced** and efficiency increased; this is a good idea but business needs to be audited for compliance.
- **The self-regulation** approach to industry has not delivered the required results in some areas as evidenced by continuing mishaps and incidents. Critics say self-regulation needs to be more prescriptive, especially in **WHS** matters.
- **Chemicals of security concerns** to the horticultural industry include many pesticides. Effective and efficient control of these products should minimise impact on legitimate users (CRC CARE & DPI Vic. 2007).
- **Pesticide registration** could require the toxicity of a pesticide to biocontrol agents for each cropping system to be on the label or on readily available online databases. Some lists are currently available online.

Compliance No excuses!

There are excellent websites for registered uses, permits, etc

Contractors or growers who misuse agvet chemicals and do not follow label instructions face prosecution and incur significant fines. The **Land and Environmental Court**, in NSW imposed fines and costs approaching \$600,000 against the Warringal Golf Club after finding it negligent for its role in a pesticide spill at its wash bay which led to **a major ecological disaster in the Manly Lagoon in 2001**. This incident was a message for the need for adherence to regulations for storage areas and other environmental improvements across the industry. Wash bays are where pollution of surface water is likely to occur unless appropriate systems are in place (Muir 2011a, Muir 2011b).

Conflict resolution

Conflict resolution procedures can go on forever. There is a need for more effective communication and legislation over the human health aspects of using agvet chemicals on neighboring properties.

Access to effective chemicals

Minor crops include most fruit, vegetables and nuts, all of which depend on pesticides to maintain quality and productivity. The Australian market is considered too small for some products.

Access to effective chemicals in Australia is through a tiered national system of:

- Registered uses
- Permit usage
- Allowable variations of approved uses

Access problems include:

- **Shortages**, eg grape growers facing a horror season for fungal diseases such as downy mildew in wet and humid spring weather may be further exacerbated by shortages of appropriate fungicides. Shortage of bait during recent mouse plagues forced **APVMA** to approve bait preparation by growers.
- **Time and costs of registration**, eg some biopesticides.
- **The withdrawal from the market** of an increasing number of pesticides.
- **Resistance to some chemicals** means that alternative management is needed.
- **The number of registered pesticides**, particularly for “minor crops” is decreasing.

<p>National Toxics Network (NTN) The 4 Pillars Policy Precautionary approach Right to know No data, no market Substitution principle</p> <p>A national scheme for assessment, registration and control of use of agricultural and veterinary chemicals (March 2011). A discussion paper. www.ntn.org.au NTN</p>	<p>The NTN has proposed that the National assessment and registration scheme for agvet chemicals should be based on the 4-pillars policy to help ensure that responsibility for pesticide information and safety sits on top of the supply chain; stakeholders are able to access information on pesticide products including so called inert ingredients; the most problematic pesticides are removed from circulation and the market is stimulated to provide low risk products.</p> <ol style="list-style-type: none"> 1. The precautionary approach states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking an action. 2. The right to know which ensures that information about chemicals in circulation is available in a convenient form to all relevant stakeholders, eg effect on human health, environmental properties, potential use, protective measures and relevant regulation. Pollutant releases and transfers should be freely available. 3. The principle no data, no market requires manufacturers or importers of potentially toxic chemical substances to ensure that all necessary information on the product is available. 4. The substitution principle which requires that a less hazardous alternative be used in the place of a hazardous substances when this does not entail unreasonable cost or inconvenience. This is encouraged in Europe and elsewhere; in some areas it is required by law. Support research into lower risk products chemicals and formulations and encourage the development of improved storage, handling and disposal technologies.
<p>Right to know</p> <p>Manufacturers, growers, spray operators and the public have a right to information</p>	<p>APVMA is responsible for the assessment, registration and regulation of agvet products up to and at the point of retail sale (page 259).</p> <ul style="list-style-type: none"> • Increase leadership on emerging issues, eg new technologies such as nanotechnology. • The need for more frequent and faster reviews of existing registered chemical products has frequently been made (see also page 264). Cost may prevent this happening. • Notification regulations. Public authorities and other organizations like local councils and government agencies are required to notify the community when they use, or allow the use of, pesticides in public places. The Pesticide Use Notification Plan sets out how, when and where it will notify the general public of any recent or intended pesticide applications to prescribed public places under its control. Notification regulations in NSW are working well but the agricultural sector has successfully argued for self-regulation; little notification seems to occur in the agricultural sector.
<p>Harmonization</p> <p>Control of use</p> <p>Assessment and approval processes</p> <p>Changes take so long to implement</p> <p>Move from purely economic to predominantly social regulation</p>	<p>The control of use regulations have varied from State to State and Territory to Territory with obvious disadvantages.</p> <ul style="list-style-type: none"> • APVMA is working with other Commonwealth Departments and State / Territory jurisdictions to harmonize control of use regulations throughout Australia and support further development of compliance programs regarding storage, handling and application to minimize potential risks. • APVMA supports international harmonization of assessment and approval processes between Australia, NZ and other nations via the development and implementation of internationally accepted scientific and quality assurance principles and practices in the assessment of product safety and performance. <ul style="list-style-type: none"> • Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH) is the European Community Regulation on chemicals and their safe use (EC 1907/2006). REACH will be phased in over 11 years and regulation: <ul style="list-style-type: none"> • Aims to improve the protection of human health and the environment • Places greater responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. • Requires manufacturers and importers to gather information on the properties of their chemical substances. • Calls for progressive substitution of the most dangerous chemicals when suitable alternatives have been identified. • Regulation in the USA, the European Union and Brazil (Pelaez et al 2013). <ul style="list-style-type: none"> • The USA shifted regulatory powers from the US Department of Agriculture to the Environmental Protection Agency in the early 1970s. • The EU in 2011 shifted in risk-assessment criteria and corporate financial liability to reveal a prevalence of concerns involving social-environmental regulation. • Brazil's new regulatory model in 1990s adopted a troika of decision-making ministries with the prevalence of economic over social-environmental interests.
<p>Sustainable use of pesticides UK Plant Protection Products (Sustainable Use) Regulations 2012.</p>	<p>The Directive includes a number of provisions aimed at achieving the sustainable use of pesticides by reducing risks and impacts on human health and the environment, eg</p> <ul style="list-style-type: none"> • The establishment of National Action Plans (page 314) • Compulsory testing of application equipment. • Provision of training for the certification of operators, advisors and distributors. • A ban (subject to limited exceptions) on aerial spraying. • Provisions to protect water, public spaces and conservation areas. • The minimisation of risks from handling, storage and disposal. • The promotion of low input regimes, eg Integrated Pest Management (IPM)). • Progress is to be measured through the use of 'risk indicators'.

Community health and safety

Often the toxicity of pesticides is poorly understood.

<p>Perceptions</p> <p>Pesticides include BIOLOGICAL CHEMICAL PRODUCTS</p>	<p><u>The public perceives that residues of all synthetic chemical pesticides</u> create food safety problems and that chemicals are inherently deleterious to the environment. Memories of pesticide disasters are still fresh in peoples' minds, eg DDT. The pesticide industry has moved on but there are still new challenges, including:</p> <ul style="list-style-type: none"> • The perception of pesticide residues in food and the environment remains in spite of major changes in pesticide use in the food production and processing industries and the government-mandated reductions of pesticide use. • In Australia, total diet studies indicate very low levels of pesticides in food. • The Australian Centre for Agricultural Health and Safety (ACAHS) at the University of Sydney reassures farmers there are no known carcinogens in pesticides sold in Australia, but these chemicals are nonetheless poisonous and misuse causing direct contact can cause injury and illness. They are poisonous but a stringent registration process in Australia confirms they are safe when users follow the manufacturer's instructions.
<p>Continued research needed</p>	<p><u>Identify and minimize risks, monitor, assess and act on outcomes.</u> Investigate adverse health incidents and support the development of information on:</p> <ul style="list-style-type: none"> • Hazard identification (human toxicology). • Exposure (dietary / residues, occupational, bystander, community). • Human health effects, odors, etc. • Long term cumulative effects of pesticides which are much discussed by the public.
<p>Reducing exposure is the most effective approach</p>	<p><u>Areas of pesticide toxicology and policy of key international concern</u> include:</p> <ul style="list-style-type: none"> • <u>Foetal and early childhood exposure.</u> Children are particularly vulnerable to pesticide exposures that occur during pregnancy (Watts 2013). The Ontario College of Family Physicians (OCFP) recommends the public reduce exposure to pesticides wherever possible, increased vigilance is needed to minimize the exposure of pregnant women, children, and adults from all potential sources of pesticides, including dietary, indoor and outdoor air, water and farm exposures. • <u>The current regulatory process assesses the risk of a single pesticide.</u> However, other considerations must be included (Mnif et al 2011): <ul style="list-style-type: none"> • The presence of pesticide by-products and • The reality of exposure to mixtures of pesticides and exposure to ongoing low doses of mixtures of pesticides. • <u>Endocrine disruptors</u> are chemicals that at certain doses can interfere with the hormone system in mammals. Currently no country has an adequate regulatory process for assessing the effects of endocrine disrupting pesticides. <ul style="list-style-type: none"> • Any system in the body controlled by hormones can be derailed by hormone disruptors. Many pesticides that are endocrine disruptors are widely used for agricultural, municipal, and home and medical purposes worldwide (Mnif et al 2011). • Endocrine disruptors can have permanent and irreversible effects on early life stages, the effects continuing long after the exposure to the endocrine disrupting chemical has ceased (OCFP 2012). • <u>Widespread adoption of pest management techniques.</u> <ul style="list-style-type: none"> • Precautionary principles. • Substitution.
<p>Need to protect other staff, visitors</p>	<p><u>Spray operators have a duty of care not only to themselves</u> but also to their employer, other staff and the community. Spray operators wearing PPE should not allow unprotected family members, other staff or visitors to assist.</p>
<p>Inert ingredients should be listed</p>	<p><u>Inert ingredients are added to pesticide formulations</u> for many reasons, eg helping the product stick to the surface of leaves and soil, spread over surfaces, or dissolve in water.</p> <ul style="list-style-type: none"> • They can be more toxic than the active constituent to humans, nontarget plants, animals and microorganisms, eg inert ingredients such as surfactants increase aquatic toxicity. • Generally there is no requirement to identify the inert ingredients on pesticide labels or publically available registration information as pesticide manufacturers claim the identity of 'inerts' as confidential business information.
<p>Many groups raise concerns</p>	<ul style="list-style-type: none"> • The National Toxics Network (NTN) is a community based network giving voice to community and environmental groups across Australia, NZ and the South Pacific (page 298). • A European Food Safety Authority evaluation states that glufosinate poses a high risk to mammals. • World Health Organization (WHO) estimates that the number of people who are poisoned by pesticides at 3-25 million per year. At least 40,000 people are killed accidentally by pesticides; numbers of unreported cases is much higher. • Glyphosate European Food Safety Authority. A group of scientists have raised concerns about glyphosate use. Industry comments that glyphosate binds tightly to most types of soil, is not harmful and does not harm the crops and research shows that it is safe for humans and the environment.

Work health and safety (WHS)

Protecting the health and safety of operators is a must

BMP manuals

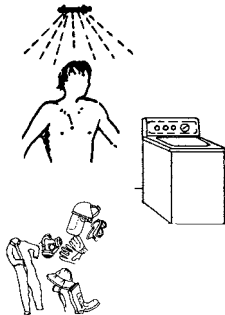
BMP practice didn't stop the cotton industry problem with endosulfan. It was label changes that forced the industry to use the chemical in a less damaging way.

Information is available but is it used?

Best Practice manuals for pesticide application are available for most industries, eg fruit, vegetables, production nurseries, cotton, agricultural crops. Others are also available on Commonwealth, State / Territory and local government websites. Codes of practice for farm chemical spray application are also available, eg

- **Best Practice Manual** for Pesticide Application in the Nursery Industry.
- **A Guide to using Ag chemicals** in Vic-Ground-based Spray application.
- **SpraySense** the safe and effective use of farm chemicals.
- **Best Practice Application Procedures**. Spraywise Decisions® provides industry best practice for all aspects of spray application. www.spraywisedecisions.com.au
- **Environmental Best Practice Guidelines for Chemical Management** (Dairycatch).
- **Chemical Management Systems (CMSs)** emphasize compliance and best practice, setting the standards for the turf industry (E-par).
- **The Advisory Standard** for the Storage and use of Chemicals in Rural Workplaces.
- **ChemSmart** dealing with modular and compliant chemicals storage facilities, WashSmart, WaterSmart and Training.

Achieving compliance



Re-entry period

**KEEP OUT
PESTICIDES APPLIED**

Compliance in the recommended use of personal protective equipment (PPE) can be difficult. It can be uncomfortable, hot, wrong size, has to be cleaned, etc. Disposable PPE can alleviate some problems.

- **Follow label directions, Safety Data Sheets (SDS) and in-house safety procedures.**
- **The importance of PPE is said to be overkill** but feedback from rural doctors confirms its importance in preventing injury and illness. Each spray operator should have their own PPE. Commercial labels contain directions regarding safety equipment appropriate to the method of application and the status of the product. Otherwise check the SDS and the manufacturer (Thomas 2002). Seek advice if still unsure.
- **Respirators** are often little understood by operators. It is one thing to select and purchase PPE but for optimum user safety and peace of mind, it must be **properly selected, stored, maintained, worn, and cartridges replaced** when recommended (Thomas 2002). Disposable respirators have made life easier for operators. Tractor cabins can ease the discomfort of spraying while providing a safe environment for the operator to sit in, if an air filtration system that provides a continuous supply of clean fresh air, free of pesticide is fitted. Always check expiry dates for filters.
- **Drift reduction technologies**, nozzles and equipment should be more widely used to minimize operator exposure and reduce risks of off-target drift.
- **Closed mixing and transfer systems**, to transfer chemical from a container to a spray tank to minimize operator exposure and possible environmental contamination should also be more widely used.
- **Growers who have poor English language skills or have English as a second language** may lack the language skills to use agvet chemicals safely and correctly (see pages 312, 443).
- **Report** any adverse experience to **APVMA** to provide feedback about pesticide quality and performance. Free call 1800 700 583.
- **Record** accidents and **incidents**. This can avoid a future accident.
- There are many private consultants and companies who are willing to give advice often without charge, eg **3M** for respiratory protection.

Health monitoring

Be particularly careful with S7 pesticides. If in doubt, seek professional advice

Many people incorrectly think that PPE is overkill

The routes of chemical exposure are **dermal** (through the skin), **inhalation** (breathing) and **optical** (eye). A person's reaction to exposure can vary depending on their particular sensitivity to different chemicals. **Ingestion** of some pesticides can also be fatal - all products should be stored out of reach of children.

- **Keep records** of health monitoring.
- **Absorption of chemicals through skin** is the most likely cause of pesticide poisoning.
- **The risk is greatest** when mixing chemical concentrates or when applying fine mist sprays without wearing adequate protective clothing. The rate of absorption is increased during hot weather or heavy work when the pores of the skin are open.
- **This risk increases with the length of time of exposure**. Different parts of the body absorb pesticides at varying rates. Those areas where we perspire most, namely the forehead, scalp and groin absorb pesticides faster.
- **Currently low level exposure receives less attention** than does acute poisoning; additionally the few screening tests for low level occupational exposure are of doubtful sensitivity.
 - **A pilot study of safe-handling practices** among a group of workers with occupational exposure to organophosphate-based pesticides in the Riverina area, Australia, indicated that **no farmer in the test group had abided by recommended safety procedures** (McKenzie et al 2004). It is obvious that safe handling practices need to be reevaluated in order to increase compliance or a different pesticide selected.
 - **Follow your workplace Standard Operating Procedures (SOPs)**, eg have you had a general health check, what other health monitoring is available to you?

Quality assurance (QA) and trade, records

Mandatory record keeping is the basis of Quality Assurance and meeting trade requirements.

Record keeping is improving



How long do you need to keep records?

Mandatory record keeping of pesticide spraying activities is now required across Australia and a spray application sheet should form a part of an overall risk management program to demonstrate pesticide spraying is being well managed and controlled. The failure to maintain pesticide application records can result in significant fines for both the individual and the business.

- **Records** provide an accurate idea and recording of overall pesticide use in the community. From an ecological and a community health point of view this is an extremely important goal. Train all staff to fill in records.
- **Trade and market access** may require:
 - Records of **MRLs** in produce. Overseas countries may have **lower or zero MRLs**.
 - Phytosanitary certificates.
 - Vendor declarations, Quality Assurance (**QA**).
 - Organic standards.
 - Records used to ensure that any chemical used is acceptable to trading partners and is supported by scientific data.
 - Pesticide records can be used as a defense against a complaint.
- **In-farm and other programs** provide a detailed and reconcilable record of uses with purchases, etc so that:
 - Check that the storage manifest is always up to date.
 - Allow quick and easy checking of resistance buildup.
 - Herbicide tracking and lateral mobility are of particular concern to certain industries, eg the golf course industry.
 - Allows you to keep the records for the required length of time. Check requirements.

Requirements range from 2, 3 and 5 Years

- Records are used to check safety equipment required for use of pesticides, resistance rotation, and monitoring post-application efficacy.
- Accurate records of pesticide applications are necessary to ensure beneficials are not killed in **IPM** programs.
- **Records must be accessible**, online or paper.
- **Each industry has its own diary** designed to provide it with the means to comply with various legal requirements and making the records easy to access and use.
- **Assist with planning, training.**
 - Spraywise Decisions®. www.spraywisedecisions.com.au
 - Spraywise® Broadacre Application Spray Log books have been specifically designed to meet applicator's needs.
 - Date trained.
- **Work Health and Safety.**
 - Records of **"incidents"** are grossly under recorded which is unfortunate because they are an important part of reviewing current practices. **Standard Operating Procedures (SOPs)** can be improved and practiced (page 302).
 - Records of **"accidents"** are usually recorded adequately because of necessity!

Online record keeping

Records completed while on the job

The time required to complete application records on paper is frustrating and is probably the main reason for lack of consistent and robust pesticide application record keeping.

- **A well-executed and useful iPhone app** is a necessary part of a risk management strategy, providing the opportunity to load the details of individual applicators and which has "memory" for your most commonly used products and settings (reducing onerous and repetitive data entry).
- **MoDOT Protect Environment (Missouri)** is an online herbicide tracking application responsible for 32,000 miles of roadside each year, maintaining the proper vegetation so motorists' views are not hindered. Obviously saving time and money.

Inadequate QA, auditing

QA systems have similar steps eg **Plan-Do Check-Improve**. Lack of compliance includes:

- Not keeping **adequate** records.
- Not having a required **3rd party audit** of the records.

Risk assessment and management

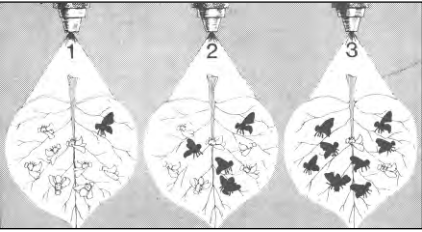

**Risk is “the effect of uncertainty on objectives” (AS/NZS/ISO 31000:2009).
The challenge today is the way the risk is calculated.**

Everything today is about risk! As in other leading agricultural economies and international regulatory agencies, Australia has progressively moved to science and risk-based assessment, planning and action, particularly in guiding biosecurity policy. The challenge today is for **growers** to adopt risk assessment and management strategies. There is a need to better explain the **process of risk management** and the **criteria against which the risk is evaluated**, however complicated. Methods of managing risks are well documented for most industries, eg pesticides, biosecurity. See also page 425.

The standard	<p>Risk management—Principles and guidelines. AS/NZS ISO 31000:2009, in addition to describing the process for managing risk, describes the framework in which it is developed and principles for managing risk. It provides guidance on good management practice.</p> <p style="text-align: center;">AS/NZS ISO 31000:2009 is not a certification standard.</p>
AUSTRALIAN STANDARDS	
Risk assessment	<p>Risk assessment plans are best done in a considered way, rather than the moment before chemical application jobs. Advances in personal protective equipment (PPE) means that protection does not have to come at the expense of comfort. Considerations include:</p> <ul style="list-style-type: none"> • Where is the crop, eg on the ground or on benches? • Which part of the operator’s body is most likely to contact the chemical? • What sort of equipment is being used? • What sort of droplet size does it produce and how likely is spray to drift? • Is the chemical being applied outside or in an enclosed area? • Has a concentrate to be diluted? • Weather conditions.
Risk management	<p>A risk is the likelihood of the hazard resulting in injury or diseases together with the likely seriousness of the injury or disease.</p> <ul style="list-style-type: none"> • The level of risk for a particular situation is measured by the combination of the toxicity of the chemical and the hazards associated with its use. • The risk is minimal if the label instructions are followed as directed. • Failure to do this can result in an accident leading to poisonings or environmental contamination. <p>A risk management approach is applied to the use of agvet chemicals, to reduce the risks associated with handling and applying agvet chemicals to people living in the environs of application, to handlers of produce and to consumers.</p> <ul style="list-style-type: none"> • Identify the hazards of a chemical. • Assess the risks. • Manage the risks, minimize the risks to health, the environment and trade. • Monitor, assess and act on outcomes while maximizing the level of plant production. <p>The OECD Pesticide Assessment and Testing project works to harmonize the methods used by OECD countries to evaluate pesticide risks to health and the environment.</p> <ul style="list-style-type: none"> • This includes developing test guidelines for the tests used to fulfill the pesticide registration data requirements and harmonizing exposure, hazard and risk assessment methods.
<div style="border: 1px solid black; padding: 2px; margin-bottom: 5px;">Seek professional advice on risk assessment in the use of chemicals</div> <div style="margin-top: 20px;">Risk ID Risk assessment Risk management Risk communication</div>	
<div style="border: 1px solid black; padding: 2px;">Risk Compendium</div>	
Environmental risk management Standard Operating Procedures (SOPs)	<p>There is a risk associated with every pesticide operation that chemicals may be transported off-site to contaminate waterways and or ground water. Environmental risk management is a process that involves making a distinction between acceptable risk and unacceptable risk (Muir 2007).</p> <ol style="list-style-type: none"> 1. Risk management is the responsibility of the employer even when a producer employs a specialist contractor, the producer remains responsible for any impact the chemical he uses has on his neighbors or on the environment. 2. Assess your risks and vulnerabilities. 3. Create prevention, contingency and response plans and choose options that reduce your risk and protect you key business assets: <ul style="list-style-type: none"> • Assess the potential impact on you organization. Consider the likelihood of a spill and the potential cost of remediation and possible prosecution. • Plan to prevent or mitigate significant issues. Some steps are obvious; does your storage area and mixing area comply with legislation? Ensure mixing is carried out in a contained area with sufficient bunding, etc. Train all staff and have Standard Operating Procedure (SOPs) for spill management. Have a spill kit. • Determine how to spread you risk, eg buy a spill kit, purchase a shut-off hose fitting and conduct a chemical filling demonstrate and regularly monitor staff operations during filling? • Have SOP’s for pesticide applications, eg for spray drift management, etc.

Pesticide resistance

Strategies should be in place before resistance becomes a problem.

<p>Pesticide resistance is increasing</p>	<p>Chemical resistance is the inherited ability of an organism, eg disease organism, insect, mite, weed, etc) to survive doses of fungicide, insecticide, herbicide) that would normally control it. Pesticide resistance is an increasing threat.</p> <ul style="list-style-type: none"> • Growers should not expect new pesticides will be released regularly to overcome this issue. Fortunately control by some of the more recent pesticides including IPM compatible insecticides registered for use on some crops have remained effective with minimal evidence of resistance developing (Rainbow 2010). • Examples of resistance in herbicides, insecticides and fungicides are on page 427.
<p>Why does resistance develop? Pesticide resistance is not new</p>	<p>Any pest population has the potential to contain a number of individuals (insects, weeds, fungal spores) that are able to survive an application of a particular pesticide.</p> <ul style="list-style-type: none"> • If no resistance management strategy is in place, repeated use of a chemical or other chemicals with a similar mode of action, removes the susceptible pests whilst the naturally resistant pests survive and multiply, producing a resistant population. • The more frequent the application of a single mode of action pesticide the greater the potential for resistant individuals to dominate the population. <i>Helicoverpa armigera</i> is resistant to several groups of insecticides; grey mold (<i>Botrytis cinerea</i>) has developed resistance to a number of fungicide mode of action groups. <p>Selection of resistant pests.</p> <ol style="list-style-type: none"> 1. Crop almost free of target moths (black). 2. Target pests seem to be more abundant - spray seems to have lost some of its effect even when the spray is used at the recommended rate. 3. Almost all of the target pests survive treatment - there is a resistance problem. Photo©Shanahan, G. J. and Hughes, P. B. 1981. <i>Looking at Insecticide Resistance</i>. Seed and Nursery Trader. Mar. 
<p>Detect and minimize resistance Croplife Australia</p>  <p>Manufacturers have a role in addressing the way pesticides are developed and registered.</p> <p>IPM essential</p> <p>Research mechanisms of resistance with a view to improving the monitoring and management of resistance (Rainbow 2010).</p>	<p>Resistance Management Strategies (RMSs) have the goal of delaying rather than preventing resistance and they must be a broad-based multi-tactic endeavor.</p> <ul style="list-style-type: none"> • CropLife Australia is the peak industry organization representing the agricultural chemical and biotechnology sector (GM crops) in Australia. RMSs have been developed for the application of pesticides in those crops where resistance by a particular pest is already known or a considered risk. This indicates how to rotate agvet chemicals through product groups. www.croplifeaustralia.org.au/ • Their RMSs are based on a mode of action group classification system of pesticides, eg all the herbicides in one group control weeds by similar means. • The mode of action group code and resistance warnings is printed on commercial pesticide labels and are approved by the APVMA. This allows users to choose pesticides with different modes of action. • These RMSs are a guide only, they do not replace product labels or APVMA permits which must be followed for specific use instructions and application rates. Check with the APVMA product database (PUBCRIS) for contemporary information on products and active constituents. APVMA online services portal http://portal.apvma.gov.au • By alternating chemical applications between products from different groups or with different modes of action, the potential for resistance development is minimized. • Agvet chemical rotation reduces selective pressure on an insect or mite population and avoids exposing several generations of pest populations to the same mode of activity. • Programs of alternative management strategies are employed to minimise development of resistance, whilst contributing towards the quality of the environment (see below). • Follow IPM strategies. <ul style="list-style-type: none"> • Chemical rotation, eg preventative and eradicant fungicides. Follow RMSs on labels, eg rotate products or use tank mixes. • Good records help growers identify problems and develop long term resistance strategies. • Limit the total number of applications of insecticides from any one mode of action group and alternate insecticides from different mode of action groups. • Growers should reduce the risk by rotating insecticide groups and only applying insecticides after correctly identifying and monitoring pest species. • Follow resistance warning on the label. Never cut recommended rates. • Use preventative methods, eg cultural, sanitation, biocontrol, resistant varieties, biosecurity, disease-tested seed and physical methods where possible. • Other strategies include: <ul style="list-style-type: none"> • Reducing pesticide use is an effective resistance management strategy. • Controlling weed and native hosts which carryover resistant aphids within and around crops can reduce the size of spring populations of aphids. • A regional rather than a crop-based approach is more efficient for pests and diseases that have a broad host range, eg diamondback moth, <i>Helicoverpa</i> and tobacco streak virus which infect a wide range of crops. Good pesticide management across all crop types is required to minimize potential of resistance developing.

Pesticide selection

Need to be trained beyond AQF Level 3	<p>Higher training is needed for those who are required to select pesticides for application, advisors, consultants and trainers.</p> <ul style="list-style-type: none"> • Training needs to be at the higher levels of AQF 4 or AQF 5 or specialized units dealing with the selection of pesticides. Knowledge of how pesticides work and understand their relevance in integrated pest management programs is required.
Selection criteria for registered pesticides	<p>Commonly, several pesticides may be registered for use for particular crop for a particular pest in a particular region or situation. Select a registered pesticide / permit, then consider:</p> <ul style="list-style-type: none"> • Policy of the industry etc. • Identity of the problem. Do you need it verified? • Cost, effectiveness. Check directions for use to ensure it is registered for use on your crop, your pest and suitable for use in your situation. • Safety: <ul style="list-style-type: none"> • The product - check the signal heading on the label and the Safety Data Sheet. • Select an appropriate product that is: <ul style="list-style-type: none"> • Least toxic and so minimize risks to health, the environment and trade. • Least persistent, this applies not only to the crop sprayed but also to any adjacent areas if drift is likely. • Target specific that does not harm natural enemies and other insects are ideal, broad spectrum chemicals can be responsible for resurgences of established pests and upsurges of previously unknown or unimportant pests. Pest flare-ups may occur quickly. • Not volatile (produce vapors) and so less likely to drift. • Unlikely to leach. • Some formulations may be more toxic than others to natural enemies, eg granulated formulations and seed dressings, where appropriate, are less harmful than most other formulations. Wettable powders are safer than emulsifiable concentrates. • Some wetting agents can turn non-toxic products into contact killers. • Chemicals have been rated for their environmental impact, eg water solubility, persistence and potential impact on non-target organisms, eg bees, birds and fish. Public Release Summaries produced by the APVMA for new chemicals to be registered in Australia, include such information. • Pesticide Impact Rating Index (PIRI) is a free risk-based assessment software package developed by CSIRO Land and Water that provides the relative risk of a pesticide moving off-site, polluting waterways and being toxic to organisms, to assist planning and decision-making associated with pesticide operations. www.clw.csiro.au. Other rating systems also group horticultural chemicals into levels that indicate a degree of environmental harm. • Suitability for use in an Integrated Pest Management program. • Check that you can implement everything on the label and in the SDS, eg <ul style="list-style-type: none"> • Personal protective equipment (PPE). • Health surveillance if required. • Emergency planning and response, deal with spills. • Transport and storage. • Bunding of measuring and mixing areas and storage tanks to prevent surface water contamination and pesticide washings entering storm water drains. • Application equipment, eg drift reduction technologies. • Withholding periods. • Resistance management strategies. • Application, eg weather, buffer zones spraying trees overhanging streams and dams. • Environmental protection, eg effect on bees, etc. • Post-application procedures. • Disposal and cleanup requirement. • All chemicals can vary in toxicity depending on concentration, type of application, etc. Insecticides are generally more toxic than herbicides or fungicides.
Out with the Old, in with the New! Generations of pesticides	<p>3rd generation products are less toxic and less persistent and are replacing some older 1st and 2nd generation chemical products (pages 432-440).</p> <ul style="list-style-type: none"> • 1st Generation. Organochlorines (OCs), organophosphates (OPs) and carbamates with long residual activity. Natural enemies are very susceptible to accumulations of persistent insecticides which drift into their habitats. • 2nd Generation. New synthetic chemical pesticides, eg Confidor® (imidacloprid). • 3rd Generation. Reduced risk biological chemical products, eg biopesticides, biorationals, semiochemicals, soft pesticides, etc have minimal effect on beneficials and are an important part of any IPM system, eg <i>Bacillus thuringiensis</i> (Dipel®). <ul style="list-style-type: none"> • Soaps and oils are contact killers of beneficials but relatively safe if used as spot sprays. • More producers are beginning to use non-chemical controls to they can compete on the organic food market and also delay resistance development. • Low hazard biological chemical products often only provide the required control when disease and pest pressure is low.
Identify the hazards. Assess the risk to: The operator Natural enemies The crop The environment	
Assess risk Manage the risk Audit management Reassess risk	
Right to know Precautionary No data, no market Substitution principle	
Minimize use of the more hazardous products	

Why pesticide “fail” - Errors cost \$\$\$

Over-reliance on pesticides; not used within an Integrated Pest Management (IPM) program.

Why fungicides “fail”?

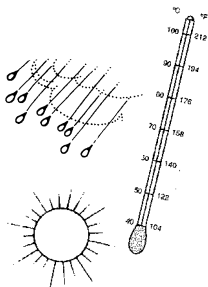


Misdiagnosis – it can be remarkably difficult to diagnose diseases from symptoms alone, especially for root diseases. The presence of more than one pathogen is quite common which may mean the application of an ineffective product.

- The more established the disease the harder it is to control.
- Fungi cannot really be eradicated unless the subject of an eradication campaign.
- Routine scouting to pinpoint disease outbreaks is also critical.
- Selecting the wrong fungicide, wrong rates, and wrong water volume.
- **Improper timing of application**
- Poor coverage.
- Incorrect nozzles.
- Workshops help growers apply fungicides properly in some crops, eg grain crops.
- Not using fungicides in an **Integrated Disease Management program**.

Why herbicides “fail”

Right crop?
Right pest?
Right pesticide?
Right rate?
Right place?
Right time?



1. **Poor weed identification**, lack of knowledge of weed biology, susceptible growth stages.
2. Improper herbicide selection.
3. Incorrect calibration, rate too low; a rate too high kills the top but not the roots.
4. Improper application, skipped areas.
5. **Improper timing of application** Pre-emergent herbicides are applied before weeds emerge. With post-emergents, **young actively growing annual weeds** are more easily controlled than older, well established plants. For perennial weeds the aim is to kill the plant’s underground parts. Systemic foliar herbicides need to move from the foliage to the roots. Many deciduous woody vines and rhizomatous perennials are controlled by late summer, autumn or early winter applications, spring applications only burn the tops.
6. Temperature is too hot or too cold.
7. Water is critical for herbicide performance– too much, too little, too soon or too late.
 - Irrigation and rainfall affect both pre and post-emergents.
 - Some pre-emergent herbicides need rainfall or irrigation for incorporation into the soil but too much causes them to decompose too rapidly. Too little rain and the herbicide stays on the surface and volatilizes, degraded by sunlight and is ineffective. Prolonged drought can result in hot dry soils that promote volatilization.
 - Drought reduces weed growth and consequently reduces post-emergence herbicide performance of many broadleaf and grass products, soil-applied and foliage-applied.
 - Rain following application may result in the herbicide being washed off treated target.
8. Drift, failure to deliver the herbicide to the target.
9. Droplet size too large.
10. Herbicide resistance (this must be confirmed).
11. Incorrect herbicide incorporation.

Why insecticides “fail”

Choose wisely.
Water wisely.
Manage wisely.
Most insecticides work well as long as they are used appropriately.

Did the material really fail? If the insect population was not monitored before the application was made, there is no way of knowing how many insects were present before the application; it will be very difficult to know whether this application “failed.”

- **Have you chosen an appropriate insecticide?** **PUBCRIS** will tell you which insecticides are registered for use on the pest in your crop and usually **what stage of the pest** it is effective against. <http://portal.apvma.gov.au>
- **Have you timed your application well?** Most insects have a few developmental stages, eg eggs and pupae, which few, if any, chemicals will affect. Use **ovicide** rates for pesticides only where crops are monitored regularly for eggs and larva and where eggs are targeted.
- **Small larval stages often are quite susceptible to chemicals.** Ideally, an insecticide application should be made when most of the pest insects are in small, sensitive stages, eg spray eggs and small caterpillars (up to 5 mm long) particularly of corn earworm.
- Some insects are nocturnal, so late afternoon or evening applications are more effective.
- No chemical will eliminate every insect - so be reasonable with your expectations.
- Insect vectors of persistently transmitted viruses that require long feeding times can be management effectively with insecticides. However spread of non-persistent transmitted viruses that requires short feeding times of only few seconds, may actually be increased.

Table 23. General reasons why pesticides do not work as well as expected.

<ul style="list-style-type: none"> • Product too old, inactivated, caked or separated into layers. • Not reading the label and/or following label directions • Alkaline water (high water pH), hydrolysis and herbicide degradation. Many chemicals applied as spray are most effective when mixed with slightly acidic water. • Chemical and / or physical incompatibility. • Some situations will require special treatment, eg insecticide may need to be watered into turf soon after application. This helps to move the material off the surface and into the soil. • Lead time to acquire the appropriate products to meet potential demand, permits may also be required. 	<ul style="list-style-type: none"> • Timing is everything, eg scales. Predicting exactly when a susceptible stage or threshold is to be reached can be tricky, activity can be stalled by cold weather. Use predictive services if available. • Unsuitable equipment. Not matching technology with the job to be done, eg nozzle type, etc. . • Ignoring possibility of pesticide resistance. • Using the wrong pesticide. • Spray an unproven chemical or tank mix. Always test spray on small groups when dealing with new chemicals, new tank mixes. • Heavy dust on foliage.
--	---

Phasing out pesticides, restricting use

The public is concerned about operator safety and pesticide drift in heavily populated areas, close to susceptible crops and environmental areas. In Germany pesticides are not available for use by home gardeners.

When a pesticide is withdrawn there is a need to find alternative products or new control methods. As new knowledge and techniques become available it is easier to test and measure residues, toxicity to humans and other environmental effects. This inevitably means that the more toxic pesticides will be **restricted** (labels changed) or **deregistered**. However, it should not be assumed that replacements will be developed; there are costs in developing new pesticides which cannot be recovered on some crops.

<p>International conventions</p>	<p><u>Delegates of top international conventions set a collaborative regulation agenda:</u></p> <ul style="list-style-type: none"> • The Stockholm Convention on Persistent Organic Pollutants (POPs) currently regulates 22 toxic substances – 15 of which are pesticides – that are persistent, travel long distances, bioaccumulate in organisms, and are toxic. • The Rotterdam Convention regulates information about the export / import of 43 hazardous chemicals listed in the Convention's Annex III. • The Basel Convention regulates the export / import of hazardous waste and waste containing hazardous chemicals. • Further details on page 265.
<p>More hazardous insecticides Withdrawal from market</p>	<p><u>Companies aim to withdraw all WHO Class 1 pesticides by the end of 2012.</u> These include WHO Class 1a (extremely hazardous) and 1b (highly hazardous) including thiocarb, fenamiphos, aldicarb and ethoprophos and are replacing and withdrawing older chemistry products from the market, with products with enhanced biological efficiency.</p> <ul style="list-style-type: none"> • There is a National awareness program targeting appropriate use of phosphine, etc.
<p>Fumigants Cancelled registration</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Research efforts associated with phase-out of methyl bromide have generated new knowledge about the biology, ecology and management of soil-borne diseases suggesting that more attention should be directed towards crop and soil health.</p> </div>	<p><u>Replacements are needed for the following:</u></p> <ul style="list-style-type: none"> • Methyl bromide (MB). The search for alternative fumigants has been ongoing since the 1992 Montreal Protocol classified methyl bromide as a Class 1 controlled substance and destined it for phase out. Soil disinfestation with MB to control soil diseases is no longer accepted for sustainable farming as it is a major ozone depletory and has been banned for use under the Montreal Protocol (UNEP 2006). <ul style="list-style-type: none"> • In the vegetable sector various researchers have been examining alternatives to MB (Colla et al 2012). The search for effective, economically and environmentally sound methods for soil and substrate disinfestation remains a continuous and challenging task for growers. New diseases and the re-emergence of old ones on several crops are difficult to control by other means. • Proposed fumigants as alternatives for pre-plant soil fumigation in tomato production also have hazards. (Sande et al 2011). Ethanedinitrile (EDN), CSIRO and BOC Gases have signed an agreement to deliver and commercialize EDN to the international market as a new environmentally safe fumigant for treating soil, insect pests, weeds and diseases. • Phosphine because of toxicity and development of resistance. Nitrogen gas could replace phosphine in some situations for use on-farm and by bulk handlers and exporters.
<p>Herbicides Cancelled registration</p>	<p><u>The Australian Pesticides and Veterinary Medicines Authority (APVMA)</u> has cancelled 11 selected High Volatile Ester (HVE) products, retailed as ester 800, and two active constituent approvals, product registrations and associated label approvals, as part of APVMA's ongoing review of 2,4-dichlorophenoxyacetic acid (2,4-D) on the basis of unacceptable environmental risks (spray drift). These products are used in broadacre agriculture and sugarcane. No horticultural uses are currently listed.</p>
<p>Insecticides Restricting use www.apvma.gov.au</p>	<p><u>The APVMA has suspended the use of the pesticide dimethoate on a number of food crops,</u> following the risk assessment which found that its use on many food crops could exceed the recommended public health standards and pose potential dietary risks (2013). The suspension periods lasts for 12 months and prohibits:</p> <ul style="list-style-type: none"> • <u>Use of dimethoate on certain horticultural food crops to control fruit fly.</u> <ul style="list-style-type: none"> • Use on all food producing plants in the home garden. • Supply / possession of dimethoate products unless they carry new instructions of use. • Neonicotinoid insecticides are suspended in France due to bee health concerns. <ul style="list-style-type: none"> • Using neonicotinoids as a seed coating is the most effective way to apply insecticide to crops and target specific (pest and virus) threats (see also pages 215, 436). • The alternative of spraying post-emergent crops with insecticide in the field is less effective, less targeted and means higher input costs for farmers. • Up to £630m could be lost from the UK economy each year if neonicotinoids insecticides are withdrawn due to bee toxicity (2013). • Creosote. Why does it take so long to restrict the use of some products when their effects have been known for decades? One can understand difficulties in removing a product from commercial use but to take so long to remove creosote from home garden use is amazing. Creosote products currently may only be used in certain commercial situations.

Spray drift remains a problem

When it comes to spraying the 2 major decisions are when to spray and when not to spray.

Spray drift is bad for humans, water, soil and air and plants. Spray equipment operators have a legal obligation to ensure that spray applications do not impact on neighboring properties and crops (pages 285, 286, 289-291).

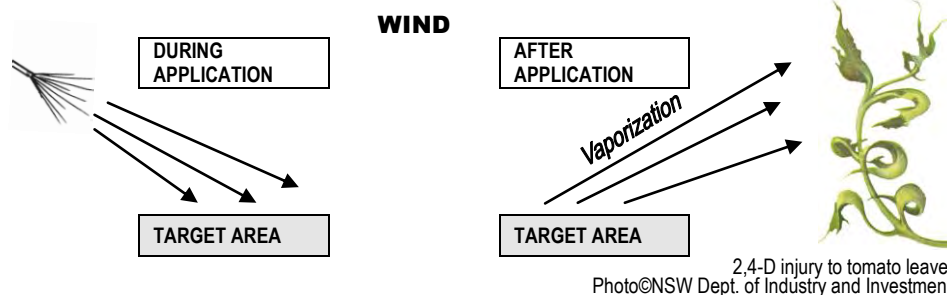
Volatile 2,4-D formulations



Hormone herbicide injury to grapevine. Photo© Canberra Institute of Technology.

Beware of volatile phenoxy herbicides, eg 2,4-D, MCPA, near susceptible crops, eg vines, cotton, roses, nurseries, home gardens, seedling lucerne, lupins, safflower, vegetables (beans, cabbage, cauliflower, cucurbits, radish, tomatoes) (Gainer 2000). Leaf twisting off-target damage is very obvious. Generally a uniform pattern of injury occurs over many broadleaved species over a relatively large area.

- An **estimated 10% of the national cotton crop was damaged** as a direct consequence of phenoxy herbicide drift with an estimated loss of \$8.9 million (2010). Phenoxy herbicides from the 2,4-D range of herbicides can drift up to 10km.
 - The APVMA has withdrawn certain highly volatile formulations of 2,4-D.
 - The Australian cotton industry has a website to help farmers identify nearby cotton fields that could be damaged by drift from 2,4-D herbicides www.cottonmap.com.au



Other herbicides

Spray drift can also be a problem during aerial spraying of herbicides to control woody and other weeds in forests close to residential areas and waterways.

Recompense for damage

In areas where several crops are grown or where organic practices have been adopted, conflicts may arise due to the use of pesticides. Policy makers need to re-evaluate the current situation and allow aggrieved parties to have a chance of recovering damages.

Drift reduction technologies (DRTs)

There are regulations which restrict the use of hormone herbicides.

There is also a 'duty of care' for landholders and spray contractors not to cause off-target spray damage.

Operators need to balance spray effectiveness in controlling the target pests with environmental protection. Only spray if recommended conditions prevail.

- **No single nozzle or application volume** will do all jobs optimally but in general, results have shown that **low drift nozzles**, particularly **air-induced nozzles** are able to reduce drift by 75% or more while maintaining good performance over a range of conditions.
- **Growers will be able to operate** under a number of improved regulatory frameworks and use the significant environmental benefits of modern **DRTs** such as air induction spray nozzles. **No-spray buffer zones** could be reduced if drift reduction systems are used. Check regulations and labels.
- **Spray domes** enable operators to spray even on windy days.
- **Seek advice regarding drift retardants** to achieve the correct droplet spectrum, because there is no consistent data supporting the efficacy of these (MacGregor 2010).
- **AgDRIFT model** includes:

Low-drift nozzles,	Adjuvants	Dose reductions
Shrouds & shields for boom sprayers	Reduced boom height	Meteorological conditions
Windbreaks	Tunnel or band sprayers	Operational adjustments

Buffer zones, no-spray zones, Pesticide-free places, pesticide-reduced places

In parts of the USA the application of pesticide on school grounds has been banned to protect the health of young children. Weeds News 20/2/2012. Plans to overturn it.

There are many areas where the application of pesticides is restricted, eg

- **Buffer zones** of various widths are mandatory for waterways, residential areas and certain crops. Pesticide applications must be applied according label instructions.
 - The imposition of no-spray buffer zones and other spray drift mitigation measures are based on 2 models for predicting exposure in pesticide applications. AgDRIFT® (ground applications) for and AgDISP® (aerial applications) (Leonard 2011).
- **Pesticide-free places or Pesticide-reduced places**. The local Hazardous Waste Management Program in the King County in the USA has launched an interactive online map detailing outdoor recreation areas which are marked either "pesticide-free place" or "pesticide-reduced place" (Weed News 8/3/2012), ie

"Children's play areas and lawns are pesticide-free. In outlying areas of the site flower beds, fence lines, natural areas and playing fields, grounds managers use their own IPM policy to determine pest control needs and minimize use of pesticides".

Training Risk management and spray drift

A National Working Party on Pesticide Application (NWPPA) has been established to provide **realistic and practical risk management**, eg

- Seek and facilitate investment from stakeholders and affected parties in a national coordinated program that supports the use of **practical DOWNWIND barriers**.
- Training and workshops help to significantly **reduce** the incidence and risk of spray drift damage to a range of crops **without compromising spraying efficacy**. www.ispray.com.au/

Residues, pesticides in food and the environment

One of the public's main concerns is pesticides in food

Residues



Residue in agriculture and horticulture is a term used to describe the chemical or its breakdown products that remain in or on a product, eg fruit, vegetables, soil, etc.

- Pesticides can leave residues in or on produce and in the environment.
- Some pesticides have undue persistence and persist in the environment, constituting a threat to the health and survival of people, animals, plants and the ecosystem.
- Residues are a threat for export markets. Procedures must ensure that any chemical used is acceptable to trading partners, supported by scientific data and the required **MRLs** met.

Pesticides in food

Remember,
all food in
Australia is good
(Rick Roush)

The international and Australian Standard for residues is the **Maximum Residue Limit (MRL)** and is the highest concentration of a residue of a particular chemical that is **legally permitted or accepted in a food or animal feed** (page 429).

- **The Withholding Period (WHP)** is the period that must elapse between the last application of a chemical and harvesting of plants, grazing, cutting for stock feed or consumption by humans and animals postharvest, eg **WHPs** must be observed for late-arriving locusts.
- **Research and records of application must demonstrate** that the **MRL** will not be exceeded when the appropriate **WHP** is observed (page 430).
- **Testing is carried out by various bodies**, eg national basket surveys are used to check on chemical residues in fruit and vegetables, advertising must not be misleading. Local growers can send their produce direct to local markets without any testing (page 429).

Residues in the environment, Persistence

Identify and minimize risks, monitor, assess and act on outcomes



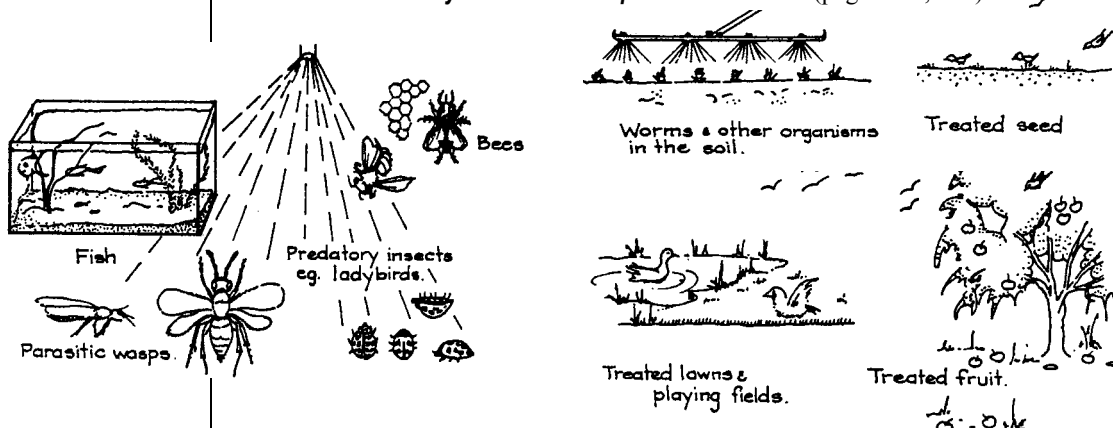
An increasing problem is ground and surface water quality

Residues in water, air, soil, plants and plant products have been well documented.

- **Horticulture Environmental Audits** include disposing of chemicals, soil degradation and contamination, irrigation scheduling, managing farm vegetation, using buffer zones, dust management, pest monitoring and chemical / non-chemical weed control options.
- **Fungicide residues.** Fungicide use is increasing in horticulture production systems and contamination of adjacent waterways has occurred but has received relatively little attention compared with insecticides and herbicides. Experts say that there is inadequate environmental monitoring and information on the chemicals' safety (Israel 2013).

Environmental contamination can occur when pesticides are used incorrectly, eg

- **Contaminated food for humans, feed and pasture for stock.**
- **Contaminated water,** resulting in fish kills. Aerial herbicide applications, spills from storage, mixing and measuring areas and using them beside swimming pools and rivers. There are regulations for herbicides being applied near waterways.
- **Contaminated soil.** Herbicide residues affecting crop performance may be the result of herbicides applied less than 1-2 seasons ago.
- **Reduced crop pollination** is suspected to be due to bee deaths.
- **Killed natural enemies of plant pests,** causing upsurges of established or previously unimportant pests.
- **Commercial compost** can be contaminated with a wide array of herbicides, heavy metals and other chemicals as well as bacterial pathogens, prescription drugs and sewage sediments and sludge unless preventative steps are taken (Kohlhaase 2010).
- **Lack of compliance with label instructions.**
- **Refer to the Safety Data Sheet for specific information** (pages 295, 296).




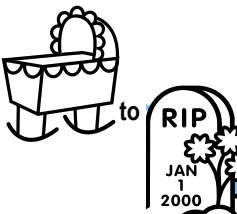


Traceability

Traceability must be able to be demonstrated. Documentation of product back to the individual grower and through to an individual field, orchard or glasshouse.

- Record of all pesticides and fertilizers applied to the crop.
- Copies of pesticide residue testing on the product undertaken by the grower, in that season.
- Pesticide store records for that grower, in that season.
- Copies of seed / root stock purchase to show traceability to the source.
- Copy of current Quality Assurance audits.

Moving, tracking	Moving and tracking of herbicides , eg the herbicide Tribute (formsulfuron) on certain turfgrasses. Treated areas must be dry to avoid natural movement of the product or tracking by equipment or foot traffic when used according to labels directions .
Phytotoxicity	<p>Crop injury results from spray drift, non-uniform application, inappropriate chemical or rate, inadequate mixing, application in enclosed areas.</p> <ul style="list-style-type: none"> • Injury to trees by herbicides such as 2,4-D, Banvel and triazine compounds is common and arborists need to be able to distinguish them from non-herbicide damage. • Liquid formulations may have various solvents which may damage plants. Wettable powders cause less plant damage. Poor application. • Pesticides damage is more frequent in ornamental crops than in other horticultural situations because of the relatively large number of species and cultivars grown; the lack of knowledge about the sensitivity of each of the crops and the lower level of pest and disease damage that can be tolerated. • Herbicide residues may be found in cattle feed and materials used for mulching.

Industry Waste Reduction Scheme (IWRS)


<p>Agsafe A subsidiary of CropLife Australia</p>   <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-top: 10px;"> <p>Growers need to improve this 50% collection rate</p> </div>	<p>The chemical industry is developing its own schemes to deal with chemical containers and to ensure that the industry focuses on waste minimization.</p> <ul style="list-style-type: none"> • Agsafe and its members are committed to a full 'lifecycle' approach to crop protection products. Members adopt and promote ethical and responsible practices from discovery and development of a crop protection or biotechnology product, through to its use and final disposal (see also page 310). CropLife Australia oversees the Industry Waste Reduction Scheme. • It supports research into the use of refillable, reusable, recyclable or degradable containers with the aim of minimizing the generation of waste chemicals and need to dispose of chemical containers. • Agsafe runs the recycling programs, drumMUSTER and ChemClear® along with training and accreditation programs for the agvet chemical supply chain (page 281). <ul style="list-style-type: none"> • drumMUSTER has collected more than 23 million empty and cleaned containers (drums) which represents more than 27,000 tonnes of waste avoiding landfill and being recycled into new and useful things again, like plastic cable covers, wheelie bins and pipes. <ul style="list-style-type: none"> • The numbers reflect the on-going success of the program. However, to date only about 50% of drums have been collected and obviously the aim is to improve this (Landline drumMUSTER 23/9/2012). www.drummuster.com.au • drumMUSTER works in partnership with local government depots or local waste transfer stations. There are over 750 collection sites around Australia. <div style="text-align: center; margin: 10px 0;">   </div> <ul style="list-style-type: none"> • ChemClear® is an industry stewardship program that has been helping users in Australia appropriately dispose of their unwanted or out-of-date agvet chemicals. Nationally the program has collected in excess of 397 tonnes since it commenced service in 2003. www.chemclear.com.au 1800 008 182 • ChemCollect was a nationally coordinated scheme for the collection and safe disposal of unwanted and deregistered agvet chemicals from farms during the period 1999 to December 2002, eg persistent organochlorine pesticides (OCPs). Final Report of the National ChemCollect Program A publication of the Environment Protection and Heritage Council April 2004. www.ephc.gov.au
--	---

Minimizing use of (hazardous) pesticides

Use strategies to reduce dependence on pesticides	<p><u>This has been driven by the desire to manage pesticide use to:-</u></p> <ul style="list-style-type: none"> • Minimise the impact of pesticide resistance developing. • Satisfy the consumer's desire for minimum residue food. • Reduce environmental impacts. • Limit possible restrictions in trade (domestic and export).
Registration APVMA	<p><u>Registration protocols continue to improve.</u></p> <ul style="list-style-type: none"> • Changing the way pesticides are registered. • Chemical reviews are now routine, removing some from the market. • Pesticides registered are increasingly less toxic.
Life cycle stewardship (LCS) manufacturers, growers	<p><u>In the US the Life Cycle Stewardship (LCS) concept hinges on a full life-cycle assessment of inputs, outputs and impacts, moving beyond recycling as the sole means for reducing the use of resources. LCS focuses instead on product design and use, with the objective of reducing throughput, eg</u></p> <ul style="list-style-type: none"> • <i>If end-users have incentives to reduce the amount they purchase</i>, only buying enough for 1-2 seasons, if pricing of smaller packages is cost effective, if return policies are attractive, if advertising encourages this behavior, and so forth. • <i>If end-users purchase only the quantity of pesticide they need</i>, less unused product remains and the potential for improper storage and unintended exposure is reduced. • <i>New formulations</i> are making active constituents more effective (page 437).
Growers commit to reducing pesticide use	<p><u>The majority of citrus and cotton growers</u> are committed to reducing the use of insecticides, improving farm profits, conserving beneficial insects and using pesticides more selectively and to using plant monitoring to improve pest management decisions.</p> <ul style="list-style-type: none"> • <i>Cotton growers have reduced the amount of insecticide applied</i> in 2002 to conventional cotton fields by 65% compared with the late 1900s; the amount of insecticide applied to <i>GM cotton (Bt cotton)</i> fields was 80% less. • <i>AUSVIT</i> for the wine industry also has programs to reduce pesticide use.
Area-wide management	<p><u>Grower involvement in large-scale area-wide pest management</u> of key pests can provide more effective pest control, eg corn earworm (<i>Helicoverpa</i> spp.), fruit fly.</p>
Can training reduce pesticide use?	<p><u>Training provides one part of the system required</u> to improve and minimize pesticide use.</p> <ul style="list-style-type: none"> • <i>Training however must be appropriate and relevant.</i> • <i>Growers must learn</i> the properties of the pesticides they use and how they work. • <i>Follow Best Management Practice (BMP)</i> of pesticides. However, <i>BMP</i> practice didn't stop the cotton industry's problem with endosulfan. It was label changes that forced the industry to use the chemical in a less damaging way. • <i>However, BMP</i> must reduce the risks associated with handling and applying agvet chemicals and when used with <i>Integrated Pest Management (IPM)</i> strategies, reduced pesticide dependency.
IPM, BMP, GM crops, trade, organic standards	<p><u>There is increasing social, economic and ecological pressure to reduce pesticide use</u> and to increase development and adoption of <i>IPM</i> strategies.</p> <ul style="list-style-type: none"> • <i>Many growers already use IPM</i> strategies to varying extents. Growers can start with a low level of <i>IPM</i> and progress to higher levels (page 334) • <i>IPM strategies</i> can include Best Management Practice (<i>BMP</i>), organic standards and other management systems. • <i>GM crops</i> play a part in <i>IPM</i> and <i>BMP</i> programs for cotton. • <i>Organic standards</i> limit pesticide use. • <i>Trade.</i> Biosecurity regulations for export produce may also limit pesticide use. • The <i>National Action Plan (NAP) IPM 2012</i> EU directive for sustainable use of pesticides recommends using preventative, non-chemical methods and only using sustainable pesticide applications after monitoring and as a last resort.
Protocols	<p>Have protocols for <i>school grounds, pre-schools, and pesticide-free places.</i> Encourage home gardeners to minimize pesticide use by using non-chemical methods.</p>
Precautionary principle	<p>Adhering to the <i>precautionary and substitution principles is a good start</i> (page 298).</p>
Avoid errors	<p>Avoid errors in rates, calculations, area sprayed – avoid accidents and spills – avoid pesticides which are persistent, volatile (produce vapors), highly toxic, broad spectrum) – seek advice if in doubt.</p>

Still incidents and mishaps

There are still on-farm chemical incidents and accidents that occur across the country each year including small children imbibing chemical that isn't stored correctly, chemical spills ending up in waterways, soils becoming toxic due to chemical spills, the list goes on and on.

<p>Why do they still occur?</p>	<p>Does training improve the safe and effective use of agvet chemicals? Surely the basis for training in any industry, especially one that utilises dangerous substances, is already established. However, the training must be appropriate and relevant and is only one part of the system required to improve the safe use of pesticides.</p> <ul style="list-style-type: none"> • Relying on training alone can lead to a false sense of complacency and a belief that one will be able to apply the correct practice.
<p>Carelessness</p>  <p>Right crop? Right pest? Right pesticide? Right rate? Right calculations? Right area sprayed? Right time?</p> <p>Recent incident Testing by the EPA of samples from dead birds in the Dubbo area indicates fenthion, a pesticide commonly used to kill insects, spiders and birds such as starlings, was the most likely cause of the deaths (SMH 11/3/2014)</p>	<p>How widespread are the following practices?</p> <ul style="list-style-type: none"> • Not reading the label before each use (pesticides are constantly reviewed, labels are regularly updated, pesticides are only registered for a limited time). • Unapproved off-label use may damage the crop, reduce yield, and pose a health and environmental hazard and loss of markets if residues are over legal limits. • Putting herbicide in an inappropriately unlabeled container still occurs. • Over-application and overuse of pesticides, even low toxicity pesticides have restrictions on their use. • Incorrect pesticide, calibration, rate, and / or time of application, area sprayed, drift. • The construction of a wash bay, the purchase of spray equipment, etc will not remove all environmental risk. Staff need to know how to operate the wash bay safely. • Some pesticides are readily absorbed through the skin and / or by inhalation. Measures taken to prevent absorption by operators may not be properly carried out. • Personal protective equipment (PPE) not worn properly, eg incorrect or no filters in a respirator for glasshouse spraying. In one study, it was found that not one of the farmers tested abided by all recommend safety procedures despite the fact that 84% of them had attended a chemical safety course in the previous three years (McKenzie et al 2004). • Applicators are too tired, too hot when discomfort can lead to heat exhaustion and poor application, possible plant injury, etc. • Re-entry intervals for crops, greenhouses not properly observed. • Urban expansion can lead to issues such as spray drift, chemical disposal and other issues causing antagonism. • Spraying an unproven chemical or tank mix. • Not avoiding accidents and spills, drift, leaching in soils, pesticide washings from equipment entering storm water drains. • Environmental hazard and loss of markets if residues are over legal limits. • Rates lower than those recommended on the label which encourages resistance. • See also pages 27 (people) and 273-282, 312, 441 (training).
<p>Formal training</p> <p>Quality assurance</p>	<p>Effective training in correct pesticide use should aim to improve practice and reduce pesticide use. This is important for worker health and safety, environmental health and reducing pesticide residues in food. Training should lead to practical on the ground improvements.</p> <ul style="list-style-type: none"> • How do you measure the effectiveness of training? • Has the training been audited to ensure that appropriate standards are maintained? • Can you train people in techniques so incidents and mishaps are minimized?, eg <ul style="list-style-type: none"> • Improve skills of registered training providers. • Improve practical training of operators and update regularly. • More frequent use of skills learnt, eg fire alarm practice in schools, etc. • Improve work experience with experienced trained operators. • Improve literacy and language skills.
<p>In-house training Standard Operating Procedures (SOPs)</p>	<p>There is a risk associated with every pesticide operation that there may be an incident or mishap, eg chemicals may be transported off-site, contaminate waterways (Muir 2007).</p> <p>Have standard operating procedures (SOPs) in the workplace and provide training on a regular basis in the workplace (Muir 2006). Safe handling practices may need to be re-evaluated in order to increase compliance. SOPs need to be practiced regularly for:</p> <ul style="list-style-type: none"> • Emergency response. • Storage areas, compliance with legislation, signage. • Storage manifests. • Chemical measuring and mixing procedures. Conduct a chemical filling demonstration for staff and regularly monitor staff operations during filling. • Application. • Disposal of chemicals. • Record keeping.
<p>Management responsibilities</p>	<p>Management must ensure that SOPs are carried out. It is not enough just to train users – manager and supervisors must also be appropriately trained to ensure that every user of agvet chemicals has the correct storage facility, signage and the correct skills to use and apply pesticides safely and effectively.</p>

User training

Just because you are trained does not mean you are good at it! It is appropriate to address future training needs, but the following detail describes the current position. Also adequate training doesn't just apply to the operator but also to the supervisor, and senior management. This includes considerable understanding of the impact of the chemicals they use on others and the environment.

<p>Plenty criticism</p>	<p>Private Registered Training Organizations (RTOs) and a multitude of State / Territory government departments provide their own accreditation schemes in competition with the industry scheme. This has resulted in quite a variation in the Farm Chemical Users Courses, some of which has attracted criticism.</p>
<p>Trained operators</p>	<p>Trained operators a key to spray efficiency (Gordon and Bettes 2011).</p> <ul style="list-style-type: none"> • State / Territory governments regulate control of use, including basic training requirements for users and licensing of commercial operators. • Training is mandatory in some states and should be mandatory in all. • Reaccreditation is required. Use-by-dates vary from 3-5 years depending on the course. Re-accreditation should certainly not be longer than 5 years. • The value of in-house training and work experience is often overlooked.
<p>All users of agvet chemicals must be accredited</p> <p>Businesses should ensure that at least 2 staff members are adequately trained in the safe handling, application and storage of farm chemicals (Thomas 2002)</p>	<p>All commercials users of agvet chemicals must have an accredited level of training. This training should be determined by the person's role within the business rather than the one training level for all, eg AQF 3 for those who apply without supervision (page 275).</p> <ul style="list-style-type: none"> • Quality Assurance. Grain farmers in the near future will need to have a quality assurance program in place and be able to demonstrate that they have produced grain which is of high quality and in a way that safeguards the environment. That may mean they'll need to have a recognized qualification like Auschem to be able to sign off on a QA program. • Higher levels of training is required, eg AQF 4 or AQF 5 or specialized units dealing with certain pesticides, eg <ul style="list-style-type: none"> • People who are selecting chemicals for use should have a higher level of training. • Access to high risk pesticides, eg 1080. • Advisors, consultants, trainers.
<p>Language, maths often lacking</p> <p>Don't assume that because you are Australian born, that you have good, reading and math skills</p>	<p>The need for good language, maths and IT skills is outlined on page 443.</p> <ul style="list-style-type: none"> • Growers who have poor English language skills or have English as a second language may lack the language skills to use farm chemicals safely and correctly. • It is essential that applicators are able to read and understand the label attached to the product container or have it read to them. This applies to safety Data Sheets (SDSs) as well. There is material available to help course presenters support people with language, literacy and numeracy skills, eg appropriate product labels and Safety Data Sheets (SDSs) must be available. • It can be a problem to get anyone to read a label, particularly when one is handed a liter of glyphosate in a bottle labeled "Glyphosate"! • Growers from Culturally and Linguistically Diverse backgrounds (CLDB) form an integral component of the Australian horticultural industry. There is a wide diversity of language groups. Although information is available in some languages there is no doubt a need to extend the range.
<p>Re-accreditation Keeping up-to- date</p>	<p>APVMA legislation hopefully will require re-accreditation every 5 years. Relying on a once only training course alone can lead to a false sense of complacency and a belief that if they have been trained they will know to apply the correct practices. There must be follow up and provision of accessible information on an ongoing basis to keep abreast of the latest techniques and developments.</p>
<p>Practical component often missing</p>	<p>The coroner recommended that the Australian Construction and Training Services consider conducting random audits to assess whether training is being delivered appropriately, that training has a practical component and has a topic devoted to specific problems, eg heat stroke and dehydration. There was too much focus on getting everyone 'trained'.</p>
<p>In-house training and work experience should complement formal training See also previous page</p>	<p>Work experience under a trained experienced operator is much underrated.</p> <ul style="list-style-type: none"> • Internal training in the individual business is required, as well as the formal ticket. • Standard Operating Procedures (SOPs). • Targeted courses address specific needs of growers in terms of crops grown and production systems, etc. • The value of work experience is often overlooked.

Assessment is a difficult topic	<p>From the number of recorded mishaps by trained operators (and many go unrecorded) there is a need to carefully examine training topics and assessment.</p> <ul style="list-style-type: none"> • Some courses have a pre-course assignment relating to their workplace. • What does an operator need to know and be able to do? <ul style="list-style-type: none"> • Read and interpret a label. • Use a computer to access information. • Transport and store pesticides. • Do a storage manifest, spray records / diaries, etc. • Awareness of the long term and chronic effects of pesticides. • Understand personal protective equipment and how to use it. • Calibrate equipment, measure, mix and apply pesticides. • Cleanup, disposal, post entry post application. • Worksite visit. • Assessments are print-based and require written answers. The national procedure has not been adopted by all States. The ChemCert course is based on the competency standards in the agricultural and horticultural training packages. • Draft assessor guides by the Rural training Council of Australia suggest the following 4 types of evidence be gathered to demonstrate competence in use of farm chemicals, eg <ul style="list-style-type: none"> • Document a storage manifest. • Record an application, eg fill in a spray diary, record incidents and accidents. • Calibration assessment. • Label reading assignment. • AND preferably a work site visit (to check compliance - the author's comment).
Quality assurance (QA)	<p>Grain farmers will eventually need to have a QA program in place and be able to demonstrate that they have produced grain for export which is of high quality and in a way that safeguards the environment. That may mean that they'll need to have a recognized qualification like Auschem to be able to sign off on a QA program.</p>
Self-regulation more prescriptive	<p>Industry self-regulation initiatives centre on codes of practice, complaints schemes run by APVMA and prosecution by the appropriate agencies. Many consider that Codes of Practice and Standards should be to be more prescriptive.</p>
Trainers, advisors consultants, etc	<p>From the number of recorded mishaps by trained operators (and many go unrecorded) there is a need to carefully examine training methods, topics and assessment.</p> <ul style="list-style-type: none"> • The training of advisors, consultants, extension officers, researchers and agronomists also needs to come under scrutiny.
Training topics	<p>Targeted courses which address specific needs of grower groups in terms of crops grown and production systems.</p> <ul style="list-style-type: none"> • Emphasis in training has been on the application process with insufficient attention paid to other aspects of exposure such as subsequent dermal exposure through sprayed foliage. • The inclusion of specific and health information. Users need to know what the harmful effects are; they are often unaware of the long term and chronic effects. • The inclusion of specific environmental information for the pesticides being used by the operators, eg fenthion is very toxic to birds, which herbicides are likely to leach, which herbicides are likely to drift, how to use Drift Reduction Technologies (DRTs). • Criteria for selecting pesticides. Operators who select the pesticides they use need to have extra training in this area. • Training of women. In greenhouses situations, men spraying may use PPE but women often follow behind maneuvering hose lines through the foliage with no protection. On market gardens children and pregnant women who are often given no warning about the importance of avoiding pesticide exposure during pregnancy. <ul style="list-style-type: none"> • In market gardens women do most of the weeding and picking but re-entry times are rarely emphasized. Need for specific courses to address these and other pesticide issues in protected cropping. • How to keep up to date with new and relevant topics, eg changes in Work Health and Safety legislation, new pesticides on the market, how to use new equipment etc. • Target problem areas which have surfaced in recent times, eg a recent spill.
Training manuals	<p>Training manuals are getting so big and complex it can be difficult to find your way around some of them, some have no page numbers, or index, print may be faint and hard to read. Remember, much information is well presented and updated regularly on the relevant websites. You can go on their mailing lists. Training material and extension publications should address current knowledge gaps.</p>
Limitations of a 1-2-day course	<p>It can raise awareness, particularly if embedded in an approach which emphasizes the importance of personal chemical safety and reasons for this, rather than taking an excessive legislative driven approach. Many courses are held indoors and cannot do enough practical work in 8 hours.</p>

MANAGING PESTICIDES

There is increasing social, economic and ecological pressure to reduce pesticide use and to increase the use of non-chemical methods. Chemical pesticides are one only tool among many others.

<p>IPM essential Is there an IPM program for your crop? If so access Guidelines.</p>	<p>IPM involves a more targeted, scientific approach to chemical pesticides, ensuring they are used judiciously in the most effective way along with non-chemical control methods and should be more widely adopted (page 333).</p> <ul style="list-style-type: none"> • Non-chemical methods include cultural, sanitation, biological control, resistant varieties, biosecurity, disease-tested planting material and physical methods (page 15). • Need to enhance the knowledge of compatibility of pesticides with biological control agents and other non-chemical methods. • Encourage use of effective low hazard products. • Access IPM strategies for various crops already in use in Australia. • Assess the actual and potential costs and benefits of IPM. IPM has to be profitable. • Know how to develop IPM programs, access guidelines. • The secret of IPM is to identify the pests and predators, know their life cycle, monitor them and ensure that appropriate pesticides are only applied when needed. • National Action Plan (NAP) IPM for the sustainable use of pesticides which advocates: <ul style="list-style-type: none"> • Prevention (rotation, sanitation, host resistance, healthy seed, landscaping). BIOLOGICAL > PHYSICAL > NON-CHEMICAL > CHEMICAL. • Monitoring pathogens. • Limit chance resistance / virulence development. • No side-effects. • Sustainable pesticide application. • Appropriate, science-based measures.
<p>Other management systems</p>	<p>Check what other management systems are available for your crop, eg</p> <ul style="list-style-type: none"> • Best Management Practice in pesticide application. • Best Practice Manual for Pesticide Application in the Nursery and Garden Industry. • Organic Standards. • Environmental management, eg Ecohort, Ausveg. • Farm chemical management. • Biosecurity.
<p>Role of pesticides</p>	<p>Integration of pesticides with the action of natural enemies or biological control agents is an important technique of IPM and the other systems above. Possible ways of selecting or applying chemicals so that they are least harmful to natural enemies include:</p> <ul style="list-style-type: none"> • Only applying pesticides when needed, eg after systematic monitoring of pests and their natural enemies. • Pesticides must play a supportive rather than disruptive role. • Pesticides should supplement sound horticultural practice, not replace them. • Only compatible chemicals must be used with natural enemies. Spray guides for beneficials are available (page 349). • Pesticide applications can be timed to optimize effect on pests but minimize effects on natural enemies, eg apply oil prays in winter on deciduous trees to control scales.
<p>Nematicides and vine crops <i>Biocontrol</i> Resistant rootstock Pesticides</p>	<p>Limited nematicides are registered for use, so:</p> <ul style="list-style-type: none"> • A wide range of fungi, bacteria and invertebrates parasitize or prey on nematodes. Healthy soils, rich in organic matter allows for some natural nematode suppression. Incorporating organic matter in the soil in the inter-row area, such as slashing a seasonal crop cover, may have no impact on nematode populations under vine rows. • Use resistant rootstocks, if practical (see also page 167). • Apply nematicides only after: <ul style="list-style-type: none"> • Monitoring indicates that infestation levels are high enough to justify treatment. • Then only apply to areas in the vineyards where nematode populations are highest, usually along the vine rows rather than the inter-row strip.
<p>Soil fungicides Know how your pesticide works</p>	<p>The impact of fungicides on soil microbial communities in turfgrass has been examined:</p> <ul style="list-style-type: none"> • Repeated applications of fungicides do not appear to have major impacts on soil microbial communities of golf courses in the USA despite their high use (Harman et al 2007). • Non-target effects of fungicides in turfgrass management systems include selection of fungicide-resistant biotypes of pathogens, promotion of non-target diseases, etc. High levels of applications of frequently applied tested fungicide did not alter or perturb soil and foliar microbial communities. This may be because: <ul style="list-style-type: none"> • Fungicides are mostly water soluble and so do not penetrate deeply into soil or • The soil microbial community is highly competitive and able to rebound very quickly after fungicide applications. • Trichoderma spp. are prevalent in the fungal community; many members of this genus are highly resistant to a variety of fungicides and their populations could be selected over the years since a green has been established. • However, while total numbers of fungi on leaf blades do not change, the application of fungicide, changes the composition, in favor of yeasts. This effect may be transitory, or longer lasting. The fungal community on leaf blades appears highly dynamic and changing in response to fungicide applications.

Twospotted mite

Twospotted mite (*Tetranychus urticae*) once detected, can be difficult to control. This pest has developed resistance to more than 70 different pesticide compounds in the Southern US (2004). The problem is exacerbated for several reasons, including:

- Miticides**
 - **Some miticides are toxic to the predators.** Mite populations resurge following applications that inadvertently kill their resident natural enemies.
 - Some miticides are only effective **against the eggs or the adult mites.**
 - Some chemicals have been shown to actually **stimulate egg production** in mites.
- Biocontrol**
 - **Biocontrol offers advantages but convincing growers can be difficult** - need to be able to identify pest and beneficial mites, monitoring takes too long, it is too expensive compared to conventional pesticides, etc.
 - **Identifying the optimal time to introduce the biocontrol agents** during a cropping cycle.
 - **Research indicates the ability of predatory mites to control mites is affected by crop age** – results supported the recommendation for early initiation of predator mite releases within a crop production cycle if the biocontrol program is to be effective.
 - **One of the real benefits is that staff prefer biocontrol products** to chemical pesticides.
 - **New predators are continually being sought.** The potential of *Feltiella acarisuga* is being investigated by researchers in Denmark and the UK as a control for two spotted mite (red spider mite). The results are promising and show this predator is **better able to withstand low humidities** than *Phytoseiulus persimilis*.
- Cultural**
- Sanitation**
 - **Sanitation.** Remove weed plants which host twospotted mites.



Left: Chilean predator mite (*Phytoseiulus persimilis*).
Right / Top: Twospotted mite (*Tetranychus urticae*)
Photo©Canberra Institute of Technology.

REVIEW QUESTIONS AND ACTIVITIES

Legislation

- Name commonwealth legislation responsible for **registering** pesticides in Australia.
 - Name the legislation which controls the **use** of pesticides in your State/Territory.
 - Explain '**Duty of Care**'.
2. **Select a registered pesticide.**
- Describe at least 3 ways of finding out which pesticide is currently registered for a particular pest on a specific crop.
 - Select **1 registered pesticide** to control at least 4 diseases, pests or weeds in a **commercial** crop of your choice, eg
 - Fruit fly Grass weeds
 - Twospotted mite Crown gall (peach)
 - Snails Powdery mildew
3. **Licensing and training**
- Name courses available for **training pesticide operators** in horticulture, turf, farming or other relevant industry in your State / Territory.
 - Describe the **licensing requirements** for pest control operators in your State / Territory.
 - List at least **5 records** which must be **legally** kept for pest control operations.
4. **Read all of the label and any attached leaflets.**
- Describe the **legislation** that requires you to read all of the pesticide label and its attached leaflets.
 - **Locate the following information** on at least two commercial labels:
 - A. Warnings and product description
 - B. Directions for use
 - C. General instructions
 - D. Precautions
 - E. First Aid, storage and disposal

5. Safety data sheets (SDS).

- **Locate information** on a pesticide label requiring you to obtain an **SDS**.
- Where can you **obtain** an **MSDS** from?
- Determine the following from an **SDS** for a product used in your workplace:
 - How hazardous is the product?
 - **PPE** to be worn, health effects, **FIRST AID**.
 - Safety information for storage, transport, spills, disposal and fire.
 - Persistence in soil or water.

6. Challenges. What do you think about the following as they relate to pesticides?

- Policy and regulation.
- Community health and safety.
- Work, health and safety.
- Quality assurance and trade.
- Risk management and assessment.
- Pesticide resistance.
- Pesticide selection.
- Reasons why pesticides fail.
- Phasing out pesticides, restricting use.
- Spray drift remains a problem.
- Residues, pesticides in food and the environment.
- Industry waste reduction scheme.
- Minimizing use of (hazardous) pesticide.
- Still incidents and mishaps.
- User training.
- Using pesticides within management systems.

SELECT RESOURCES

- Agriculture Resource Management Council of Australia and New Zealand (1998). *Management of Agricultural & Veterinary Chemicals: A National Strategy*. Ground Cover. Jan 2011.
- Australian Centre for Agricultural Health and Safety (ACAHS).
- APVMA. 2013. *Overview Report: Neonicotinoids and the Health of Honey Bees in Australia*. online
- Branach-McConachy, M. 2011. *Pesticide Use Checklist*. Ground Cover. Jul-Aug 2011.
- Center, T. C. 2012. *Securing Recompense under Nuisance Law for Crop Damages from Pesticide Applications*. Science of the Total Environment, Vol.432, 15 August:78–84.
- Cloyd, R. A. 2004. *Allelochemicals – Natural Instincts*. American Nurseryman. July 15.
- COAG. 2012. *A National Scheme for Assessment, Registration and Control of Use of Agricultural and Veterinary Chemicals*. Product Safety and Integrity Committee (PSIC). Also a Discussion Paper with a similar title by National Toxics Network (NTN). 2011. www.ntn.org.au/
- Colla, P., Gilardi, G. and Gullino, M. L. 2012. *A Review and Critical Analysis of the European Situation of Soilborne Disease Management in the Vegetable Sector*. *Phytoparasitica* 40:515–523.
- Com. of Australia. 2002. *Primary Industries Standing Committee Spray Drift Management Principles, Strategies and Supporting Information (PISC SCARM)*. Report B2. CSIRO Pub.
- CRC for Contamination Assessment and Remediation of the Environment (CRC CARE) and DPI, Vic. 2010. *Fungicides*. Intech, Dec. 2010. (copper).
- CropLife Australia www.croplifeaustralia.org.au/
- CropLife International 2004. *Guide for Industry on the Implementation of the FAO Code of Conduct on the Distribution and Use of Pesticides* (revised version).
- Davidson, J. 2011. *Novel Fungicides on Trial*. Ground Cover. Jul-Aug 2011.
- Gainer, B. L. 2000. *Applicator Beware*. American Nurseryman. Jan 15.
- Gordon, B and Bettes, G. 2011. *Trained Operators a Key to Spray Efficiency*. Ground Cover. Nov-Dec.
- Gordon, B. 2011. *Guidelines for Fungicide spraying*. Ground Cover. Sep-Oct (top 10 tips).
- GRDC. 2010. *A Strategic Approach to Storage*. Grain Storage Supplement. Nov-Dec 2010 (Fumigation).
- GRDC. 2013. *Herbicide Resistance*. GRDC Supplement. May-June.
- Growcom. 2007. *Response to Council of Australian Government (COAG) Review of Hazardous Materials: A Discussion Paper on the Control of Chemicals of Security Concern*. Growcom.
- Harman, G. E., Nelson, E. B. and Ondik, L. L. 2006. *Fungicide Applications Effects on Non-target Microbial Populations of Putting Greens*. Aust. Turfgrass Management. pp.42-45.
- HortStats (Horticulture Statistics). <http://hortstats.horticulture.com.au>
- Israel, B. 2013. *Fungicide Use Surging, Largely Unnoticed*. Environmental Health News. 22 Feb. Uni. of Kentucky.
- Kohlhaase, B. 2012. *Herbicides Pollute Commercial Compost*. The Weed's News Digest 20/3/2013 (Planet Natural 07 Dec 2012).
- Lake, J. 2000. *Spray Diaries Simplifies Record Keeping*. Aust. Hort. Jan.
- Leeson, G. (ed). 2009. *Organic Crop Protectants*. Synergy Newsletter Summer.
- Leonard, E. 2011. *Rules Change but Responsibilities the Same*. Ground Cover. July-Aug.
- MacGregor, A. 2010. *Spray Application*. Fact Sheet. Sept 2010. GWRDC.
- McConachy, M. 2011. *Pesticide Safety Starts with the Label*. Ground Cover. Jul-Aug.
- McKenzie, G; Haworth, E; Webster, L; Moriarty, H. and Kent, J. 2004. *Organophosphate-based Pesticides and Bladder Cancer* [online]. Australasian Epidemiologist, Vol. 11, No. 2, 2004 Jun: 7-12.
- Mnif, W. E., Hassine, A. I. H., Bouaziz, A., Bartegi, A., Thomas, O. and Roig, B. 2011. *Effect of Endocrine Disruptor Pesticides: a Review*. Int. J Environ Res Public Health. 2011 June 8(6): 2265–2303.
- Muir, T. 2006. *Getting the Mix Right: Washdown Bays and Chemical Mixing Areas*. Aust. Turfgrass Management. April-May.
- Muir, T. 2007. *Turfgrass Environmental Risk Management and the Concept of “De-risking”*. Australian Turfgrass Management. Dec.
- Muir, T. 2011. *Wash Bays Environmental Responsibility*. Keeping it Green. Dec. 2011.
- Muir, T. 2011a. *Warringah 10 years on: What haven't we Learned?* Aust. Turfgrass Man. 13.2. Mar-April.
- Muir, T. 2012. *Harnessing the Personal Mobile Computing Power at your Golf Course to Simplify Pesticide Application Record Keeping*. Keeping it Green 10/5/2012.
- Nichols, D. 2006. *The Best Practice Manual for Pesticide Application in the Nursery and Garden Industry*. NGIA.
- OCFP (Ontario College of Family Physicians). 2012. *Systematic Review of Pesticide Health Effects*.
- Parker, F. 2002. *The Future of Farm Chemical Management for Farm, Food and Fibre Safety: Managing the Risk while Maintaining the Farm*. Training Needs workshop 17th & 18th Sept Canberra.
- Pelaez, V., Rodrigues da Silva, L. and Araújo, E. B. 2013. *Regulation of Pesticides: A Comparative Analysis*. Science & Public Policy. Online 04 April.
- Penfold, K. 2011. *Growers Face New Weeds Learning Curve*. Ground Cover. May-June.
- Penfold, K. 2011. *The Link between Resistant Ryegrass and Food Demand*. GRDC. May-June.
- Penfold, K and Cussons, D. 2011. *Grower says Spray Drift a Best-Practice Challenge*. Ground Cover. July-Aug.
- Petroski, R. J., Teliez, M. R. and Beble, R. 2005. *Semiochemicals in Pest and Weed Control*. American Chemical Society.
- Pollock, D. W., Kookana, R. S. and Correll, R. L. 2005. *Integration of the Pesticide Impact Rating Index with a Geographic Information System for the Assessment of Pesticide Impact on Water Quality*. Water, Air & Soil Pollution: Focus 5.
- Quarkes, W. 2000. *Anti-transpirants as least Toxic Fungicides*. IPM Practitioner Vol XX11, 1. Jan.
- Rainbow, R. 2010. *Unified Attack on Pests and Diseases*. Ground Cover. 86. Collaborative Supp.
- Sande, D., Mullen, J., Wetzstein, M and Houston, J. 2011. *Environmental Impacts from Pesticide Use: A Case Study of Soil Fumigation in Florida Tomato Production*. Int. J. Environ. Res. Public Health. 8:4649-4661.
- Smith, J. 2008. *Fungicides Revisited: A Critical Look at Copper and Sulphur-based Fungicides in Organic Agriculture*. FARMSTART.
- Thomas, S. 2002. *Personal Protection: Matching the Clothes to the Job*. Aust. Hort. Dec.
- Thomas, S. 2002. *Look After the Equipment that Looks After You*. Aust. Hort. Dec.
- Thomson, S. P., Heinz, K. and Krauter, P. C. 2004. *Timing is Everything*. Ornamental Outlook. Sept.
- Ware, G. W. and Whitacre, D. M. 2004. *The Pesticide Book*, 6th ed. MeisterPro Information Resources.
- Watts, M. 2012. *Human Health Impacts of Exposure to Pesticides*. WWF Australia. Contract ref: 011005.
- Wightwick, A., Walters, R., Allinson, G., Reichman, S. and Menzies, N. 2010. *Environmental Risks of Fungicides Used in Horticultural Production Systems*. Chap 14. *Fungicides*. Intech 2010. CRC CARE and Vic DPI. www.crccare.com
- Infopest News from Growcom State / Territory websites
The Weed's News (Join the Weed's Network) <http://weedsnetwork.com/>

MANAGEMENT & QUALITY ASSURANCE (QA)

Managing a Crop

Integrated Pest Management **IPM**



Environmental Management

Organic Standards

Holistic Management

MANAGEMENT SYSTEMS	318
Steps in Management Systems	319
QUALITY ASSURANCE (QA)	320
Audits, some QA standards	322
SOME MANAGEMENT / QA PROGRAMS	324
Piggybacking QA programs,	325
CHALLENGES	326
SELECTED RESOURCES	326

MANAGEMENT SYSTEMS

Definition	<p>A management system is a documented framework of processes and procedures to ensure that an organization can fulfill all tasks to achieve its policies and objectives, eg</p> <ul style="list-style-type: none"> • Satisfy the customer's quality requirements. • Comply with regulations. • Meet policy objectives, eg environmental objectives.
Legislation, standards  AUSTRALIAN STANDARDS	<p>Legislation, regulations, codes of practice, etc must be adhered to. ISO standards requirements give guidance on good management practice. Many, although not all, are modeled on the management system structure of ISO 9001 and ISO 14001 which can be used for certification. Others are not certifiable requirements standards, but provide guidance only:</p> <ul style="list-style-type: none"> • ISO 14001:2004 – Environmental management which gives the requirements for environmental management systems, confirms its global relevance for organizations wishing to operate in an environmentally sustainable manner. May be used for certification. • ISO 9001:2008 – Quality Assurance management which gives the requirements for quality management systems, is the global standard for providing assurance about the ability to satisfy quality requirements and to enhance customer satisfaction in supplier-customer relationships. May be used for certification. • ISO 31000:2009 – Risk management provides guidance but is not certifiable.
Three essential properties	<p>Scientific management systems generally consist of:</p> <ul style="list-style-type: none"> • Knowledge of the various elements needed to implement a strategy, eg growing the crop, irrigation, soil tests, pests, diseases and weeds and their control, diagnostics. • Organization of this knowledge, eg the legislation planning, documentation, auditing. It must be accessible to others. • Interactive relationship between the various elements. In large management systems the knowledge base required is large and their organization complex. Most importantly, they emphasize the interactive relationship between the various elements and that these interactions are not static but dynamic processes. The many circular interlocking, sometimes time-delayed relationships between the elements, are often just as important, if not more so, than the individual elements themselves. Improvements in one area can adversely affect another area of the system.
Increasing size, flexibility and complexity It is the <u>meeting</u> of computing, networking, environmental, sociological and information technologies	<p>Information Technology has made it possible to integrate many considerations when deciding how to control a particular pest. In the past, pest control tended to be studied and implemented in isolation, eg what pesticide or biocontrol agent to use for a particular pest? Today it has evolved into being part of various management systems, eg</p> <ul style="list-style-type: none"> • Those that promote more effective, environmentally sound methods of horticulture and agriculture and pest control, eg Integrated Pest Management (IPM), Best Management Practice (BMP), Organic certification. • Some management systems are large and complex, so it is important to ensure that a group of people working within the management system has training in pest, diseases and weeds. • A management system is not an alternative to having knowledge and experience of growing the crop, pests, diseases and weeds! • Are they becoming too complex?
Appropriate management options 	<p>Decision-making is based on the information available from monitoring, previous experience, knowledge of the area, estimate of crop volume, market value and the current season. Control options include an understanding that:</p> <ul style="list-style-type: none"> • Legislation must be complied with. • Responses must be cost-effective. • Control measures are more likely to succeed where a range of different control methods is employed and reliance is not placed solely on pesticides. • Non-chemical methods can readily be used in most management systems. • When control is necessary, choices should be made which do not damage beneficials and the surrounding environment. • Control methods which encourage bio-diversity should be used where possible. • Some nurseries use biocontrol methods. Although expensive, this can be offset by lower chemical and labor costs and a more sustainable and healthy environment for workers and neighbors. • When monitoring indicates that no action is required, none should be taken. • Decision-support computer systems which model the relationship between stages of development of pest insects and their surrounding temperatures have been developed for specific crops and conditions.

Steps in management systems

Environmental Management Systems

An example

ISO 14001:2004
ENVIRONMENTAL
MANAGEMENT

When the common feature of all management systems are examined and compared it will be found that the similarities are extensive (Fig 27). Although they might have a diverse range of strategies, most management systems have similar management processes, and it is therefore possible to have a generic standard.

- **Generic** means that the same standard **can be applied to any organization**, large or small, whatever its product or service, in any sector of activity, and whether it is a business enterprise, a public administration or a government department.
- **Management system standards** provide a **model to follow** in setting up and operating a management system. This model incorporates the features on which experts in the field have reached a consensus as being the international state of the art.
- **Common steps** include:
 1. **PLAN**
 2. **DO** (implementation)
 3. **CHECK** (measurement and evaluation)
 4. **IMPROVE** (review & improvement)

This cycle is repeated over and over again leading to constant improvement

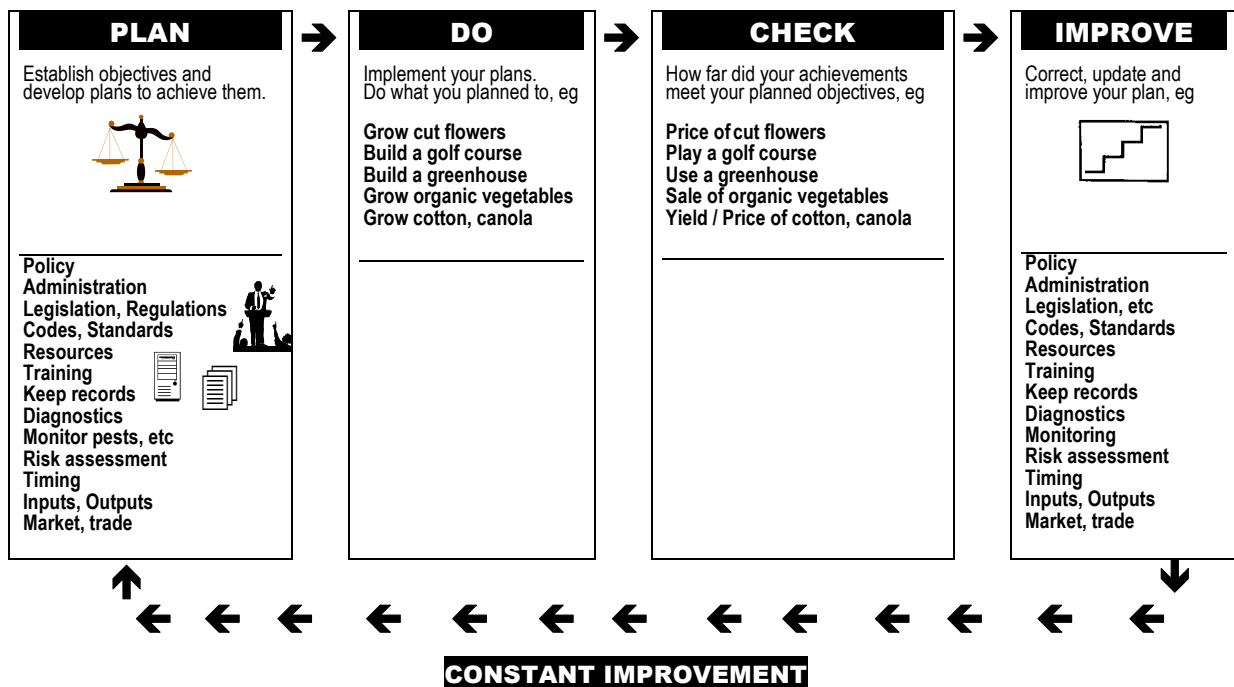
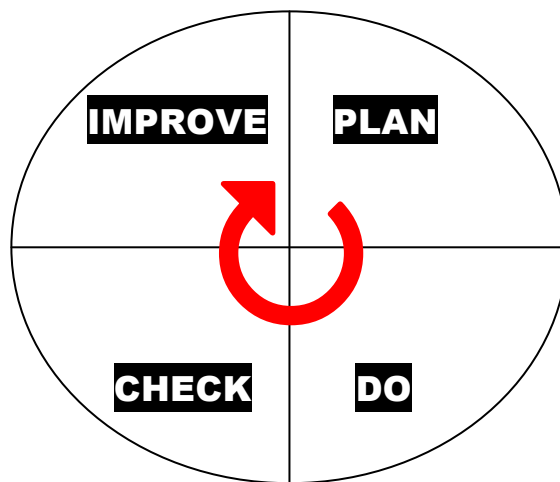


Fig. 27. Steps for compliance with AS/NZS ISO 14001:2004 Environmental Management Systems.

QUALITY ASSURANCE (QA)

QA should be a big part of agriculture and horticulture

What is quality assurance?



Quality assurance (QA) is the systematic measurement, comparison with a standard, monitoring of processes and an **associated feedback loop** that confers error prevention. It is a set of activities intended to establish confidence that quality requirements will be met. Suitable Quality is **determined by product users, clients or customers**, not by society in general.

- **Two principles included in QA are:**
 - **"Fit for purpose"**, the product should be suitable for the intended purpose, ensuring that a product meets the consumers' expectations.
 - **"Right first time"**, mistakes should be eliminated. A company can be sure that they are bringing the best product they can to the market.
- **Guidelines are available for many QA programs.** Some are voluntary but to achieve quality assurance they must be **completed, audited and reviewed**.
- **Many industries have QA or Quality Management programs.** Knowing where to get started with monitoring and documentation often presents a problem but there is a range of programs already in place at different levels of sophistication for growers across most commodity sectors to get involved with.
- **Ongoing training and continuous improvement.** A business or organization requires effective leadership and commitment at senior levels, together with full involvement of each staff member, to reach and maintain being a quality provider.

Legislation, standards, protocols and guidelines

AS/NZS ISO STANDARD

ISO 9001:2008 QUALITY ASSURANCE MANAGEMENT. To assist in the assessment of quality management systems for compliance with **ISO 9001:2008**, a checklist has been developed which can be used as a tool for implementing the quality management system and for self-assessment of the system.

AS/NZS ISO 9001:2008. SELF ASSESSMENT CHECKLIST

Remember to achieve quality assurance they must be **completed, audited and reviewed**

Accreditation, certification



Accreditation is certification of competence in a specified subject or areas of **expertise**, by a **recognized accrediting organization**.

- **Organizations that certify third parties** against official standards are themselves formally accredited by accreditation bodies; sometimes known as **"accredited certification bodies"**.
 - The accreditation process ensures that their certification practices are acceptable, typically meaning that they are **competent to test and certify third parties**, behave ethically and employ suitable quality assurance.
- **Examples of QA schemes** include:
 - Nursery Industry Accreditation Scheme Australia (**NIASA**).
 - Australian Certified Organic.
 - Phytosanitary certificates for Biosecurity.

Trade, vendor declarations

Remember all food in Australia is good (Rick Roush)

QA is about assessing performance against known industry best practices and regulatory requirements so that a company can assure their customers and regulators that they manage environmental issues to an acceptable standard.

- **Customer / vendor declarations** are commonly requested for both domestic and international markets. The customer usually specifies what they want to purchase.
- **Consider different ways of assessing and managing risk** that will protect existing markets into the future.
 - In the past focus has always been on **agronomic factors**, eg varieties, seeding dates, row spacing, crop protection and nutrition.
 - Nowadays growers see **profitability, better targeted inputs** and **management of risk** as major drivers.

Who can develop QA programs?

Documenting and charting procedures and practices is a complicated and time-consuming process often skipped by companies, even though they may practice the proper processes consistently. **Businesses can develop QA programs either by:**

- **Companies who do this professionally.** They will clarify policy; write all the procedures, train staff, produce the manual, through to the final audit.
- **Another way is to do the work yourself 'in house'.** Engage someone to guide the business step-by-step through the process. The business itself can then write the procedure manual. **The manual must be audited against the particular standard.**
- Guidelines and training courses are available.

Quality Assurance (QA) (QA)

This is the standard you use to assess your ability to meet customer and applicable regulatory requirements.

- **Certain third party companies** are authorized to assess you to this standard (audit) and provide you with the **certification**.
- **Common steps include:**
 1. **PLAN** (policy and guidelines).
 2. **DO** (implementation).
 3. **AUDIT / CHECK** (measurement and evaluation).
 4. **IMPROVE** (review & improvement - did actions taken resolve the problems or does more need to be done?).

This cycle is repeated over and over again leading to constant improvement

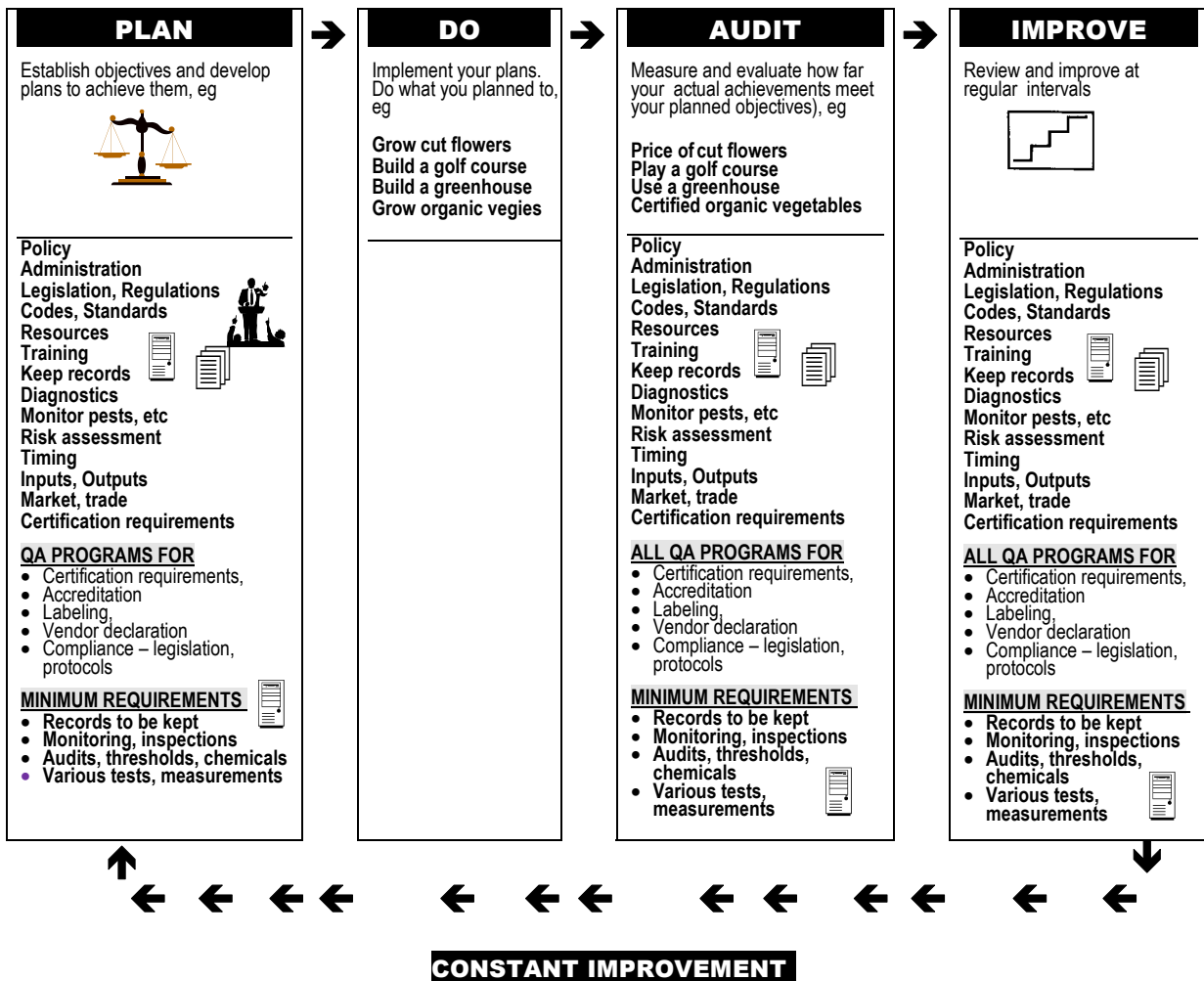
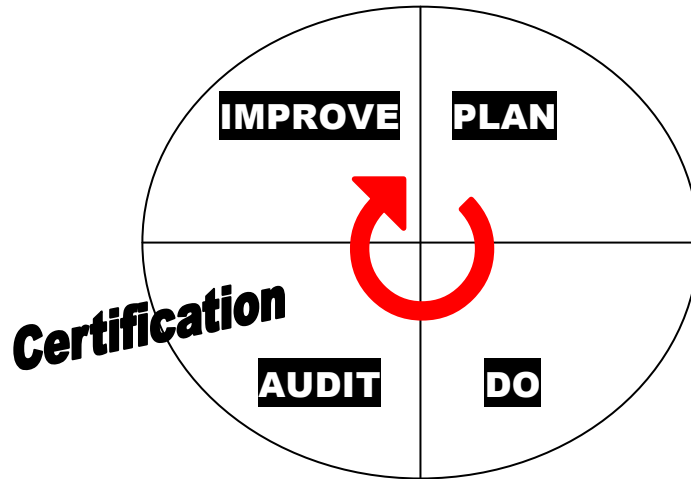


Fig. 28. Steps for compliance with ISO 9001:2008 Quality Assurance Management (QAM).

Audits, some QA standards

Minimum requirements

All have roughly the same steps

TYPES OF AUDITS

Check that what you want to audit is auditable

All QA programs as a minimum will require:

- **Records to be kept.** A **record is a document** which provides evidence that activities have been performed or results achieved. Records can show the following:
 - **That traceability requirements for the produce** are being met.
 - **Appropriate tests and records** kept for compliance with organic produce, phytosanitary certificates. Customer Vendor Declarations provide records of all crop treatments, eg fertilizers, chemicals, etc, applied on the grower's property within a certain distance of the crop, list of properties within a certain distance tested for chemical residues. It enables the recording of when, where and what is sprayed, as well as chemical batch numbers, prevailing temperatures and wind direction.
 - **Verification is being performed** and that preventative and corrective actions are being carried out, eg no genetically modified (GM) contamination (Organic standard).
- **Monitoring,** tests etc. Have the required tests been carried out? What are the results?
- **Auditing.** An audit is an evidence gathering process. **Audit evidence** is used to evaluate how well **audit criteria** are being met. Audits must be objective, impartial and independent and the **audit process must be both systematic and documented.** Check that what you want to audit is auditable, eg risk assessment is not auditable.
 - **There are several different types of audits;** check which one you need.
 - **Desk audits** review of written procedures manual and any outstanding matters.
 - **Site audit.** Once the desk audit is cleared, a site audit is carried out to assess the entire system to ensure that the **EMS** system is in place.
 - **Compliance audit** ensures that procedures are being followed.
 - **Who carries out the audit?**
 - **Self-audit,** eg Nursery Environment Self-audit (**NESA**).
 - **Third party external audits** which may cost money, but is necessary for trade.
 - **Timing of audits**
 - Number of times that audits are required for vendor declarations, eg every 1-3 years.

GlobalGap

(formerly EuroGap)

The **GlobalGap Program** sets standards for the certification for **Good Agricultural Practices (GAP.s)** of agricultural products around the globe. The **GlobalGap standard** assures consumers that food is produced with minimal environmental impacts with a responsible approach to worker health / safety as well as animal welfare.

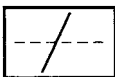
- **Training courses provide** an understanding of the **requirements for GlobalGap** implementation as well as options for registration.

HACCP

Preventing hazards

The seven HACCP principles are included in the International Standard ISO 22000 FSMS 2005.

1	2	3	4
5	6	7	8



Hazard analysis and critical control points (HACCP) is a systematic preventive approach to **food safety and allergenic, chemical, and biological hazards** in the production processes that can cause the finished product to be unsafe. It designs measurements to reduce these risks to a safe level. In this manner, **HACCP** is referred as the **prevention of hazards** rather than finished product inspection.

THE HACCP SEVEN PRINCIPLES

- Principle 1: Conduct a hazard analysis.** Determine the safety hazards and identify the preventive measures the plan can apply to control these hazards.
- Principle 2: Identify critical control points.** A critical control point (CCP) is a point, step, or procedure in a food manufacturing process at which control can be applied and, as a result, a safety hazard can be prevented, eliminated, or reduced to an acceptable level.
- Principle 3: Establish critical limits for each critical control point.** A critical limit is the maximum or minimum value to which a physical, biological, or chemical hazard must be controlled at a critical control point to prevent, eliminate, or reduce it to an acceptable level.
- Principle 4: Establish critical control point monitoring requirements.** Monitoring activities are necessary to ensure that the process is under control at each critical control point.
- Principle 5: Establish corrective actions.** These are actions to be taken when monitoring indicates a deviation from an established critical limit. The plant's **HACCP** plan identifies the corrective actions to be taken if a critical limit is not met.
- Principle 6: Establish procedures for ensuring the HACCP system is working as intended.** Verification ensures the **HACCP** plan is working as intended.
- Principle 7: Establish record keeping procedures.** The **HACCP** regulation requires that all plans maintain certain documents, including its hazard analysis and written **HACCP** plan, and records documenting the monitoring of critical control points, critical limits, verification activities, and the handling of processing deviations.

JAS-ANZ	<p>JAS-ANZ is the <u>government-appointed accreditation body</u> for Australia and NZ responsible for providing accreditation of Conformity Assessment Bodies (CABs) in the fields of certification and inspection.</p> <p>Accreditation by JAS-ANZ demonstrates the competence and independence of CABs.</p> <div> <pre> graph TD A[JAS-ANZ] -- accredits --> B[Conformity Assessment Bodies (CABs)] B -- "who certify or inspect" --> C[Organizations for programs such as ISO 9000 and ISO 1400] </pre> </div>
AUS-QUAL	<p>AUS-QUAL is a <u>certification body accredited by JAS-ANZ</u>, providing conformity assessment services for quality management and food safety (HACCP) management systems, as well as Product Certification Systems for the wider Australian and NZ agricultural, horticultural and secondary processing sectors.</p> <ul style="list-style-type: none"> • AUS-QUAL offers auditing services for Freshcare Food Safety and Quality Certification, Freshcare Environmental Certification, Freshcare Environmental - Viticulture Certification; and Freshcare Environmental - Winery Certification, etc.
Safe Quality Food (SQF)	<p>The SQF Program is a <u>food safety and quality certification program and management system</u>, designed to meet the needs of buyers and suppliers worldwide.</p> <ul style="list-style-type: none"> • It is the only “farm-to-fork” certification program endorsed by the Global Food Safety Initiative (GFSI) for primary production as well as for manufacturing, distribution and agents / brokers. • Training is available and includes guidance documents and third party assessment to verify producers are adhering to the rigorous requirements of the SQF 2000 Code. • Certification provides verifiable assurance that your products have been produced in accordance with all SQF Code, following the HACCP method and local requirements. • Updated editions of the SQF Code are released from time to time.
Good Manufacturing Practice (GMP) GMP certification	<p>GMP is a <u>sanitary and processing requirement</u> applicable to all food processing establishments. Many food industry companies have implemented the GMP certification scheme for food processing as the foundation upon which they have developed and implemented other food quality assurance systems and food safety management systems, such as HACCP, SQF 2000, ISO 9001 and ISO 22000. Certifying your food management system against the GMP standard will bring the following benefits:</p> <ul style="list-style-type: none"> • Enhancement of your food safety management system; • Demonstration of your commitment to producing and trading safe food; • Prepare you for HACCP certification; • Increase in consumer confidence in your products; and • Prepare you for inspection by regulatory authorities and other stakeholders.
Total quality management (TQM)	<p>TQM is a <u>management system for continuously improving the quality</u> of products and processes. TQM requires the involvement of management, workforce, suppliers, and customers, in order to meet or exceed customer expectations, ie customer satisfaction. Nine common TQM practices have been identified as:</p> <ol style="list-style-type: none"> 1. Cross-functional product design 2. Process management 3. Supplier quality management 4. Customer involvement 5. Information and feedback 6. Committed leadership 7. Strategic planning 8. Cross-functional training 9. Employee involvement <p>Traceability and Quality Management systems are relatively new to agriculture and horticulture. As food safety becomes a more important issue and consumers want a closer connection with the production of their food, the need for quality management systems will expand.</p>
BRC Global Standards	<p>The British Retail Consortium (BRC) Global Standards are a leading global product safety and quality certification program used by certificated suppliers in over 100 countries. The Standards have gained usage world-wide. Training packages are available.</p>

SOME MANAGEMENT / QA PROGRAMS

Everything about crops today is about **Management**. Programs with many different names are in place with different levels of sophistication for growers, but remember, they are only Quality Assured (QA) if they have been **audited by an independent third party** and **no one system fits all situations!**

Similar aims	<p><u>Although there are many types of management / QA systems</u>, most have similar aims, eg</p> <ul style="list-style-type: none"> • Satisfying the consumer's desire for minimum residue food. • Minimising the impact of pesticide resistance developing. • Reducing environmental impacts. • Limiting possible restrictions in trade (domestic and export).
Types of management systems	<p><u>The way the crop is grown</u>, eg</p> <ul style="list-style-type: none"> • Best Management Practices (BMP) for the environment, fertilizer management, water management, irrigation management, soil management. • Biological farming. • Organic Standards for Agriculture and Horticulture. • Sustainability – A Golf Course Architect's View. • Area-wide Management Systems, eg locusts, fruit fly, rust diseases of wheat. • Holistic Management, eg Biosecurity.
Pest, disease and weeds	<p><u>Pests</u></p> <ul style="list-style-type: none"> • Insect management, eg <i>Helicoverpa</i>, fruit flies, locusts. • Vertebrate pests, eg rabbit and fox management, feral pigs, dogs and cats. <p><u>Diseases</u></p> <ul style="list-style-type: none"> • <i>Phytophthora</i> root rots. • Irish blight of potato (<i>Phytophthora infestans</i>). • <i>Rhizoctonia</i> diseases in cereals. • Wheat rusts. <p><u>Weeds</u></p> <ul style="list-style-type: none"> • Individual Weeds of National Importance (WONS), eg St John's wort, prickly acacia, Chilean needlegrass. • Individual Noxious weeds in individual States / Territories, eg skeleton weed, thorn apples, broomrape.
Industry / crops Management systems are being improved all the time as there is more emphasis proper management	<p><u>For a particular crop different management systems</u> can be integrated into a single program, eg</p> <ul style="list-style-type: none"> • Cotton BMP. • Apple and pear fruit IPM. • Tree Management. • Turf management, golf course management. • Potato management. • Production nursery management. • Plant Health Australia, Biosecurity. • Integrated Crop management (ICM) for vegetable production to control pests and diseases. ICM includes the principles of IPM including the use of beneficial organisms for the control of various diseases, insect pests and weeds.
Brand names	<p><u>In Australia QA programs for growers have proliferated in recent years</u>. Contact your industry association for information. Producers in the horticultural industries have many options for QA, eg</p> <ul style="list-style-type: none"> • Nursery Industry Accreditation Scheme, Australia (NIASA). • Ecohort. • Enviroveg. • Freshcare. • Oil Mallee Cropping Code of Practice (WA). • Australian Certified Organic. • Leucaena Code of Practice. • Environmental Assurance in Australian Horticulture. • Biosecurity HACCP. • Nursery Farm Management system (FMS). An information kit is available which contains information on NIASA, EcoHort and BioSecure HACCP. • Growcom Farm Management systems.

Expert systems

Are expert systems available for your crop?

Ex

Expert Systems are computer programs that try to equal or do better and surpass the logic and ability of the expert professional in solving problems, the solution of which require experience, knowledge, judgment and complex interactions (page 347).

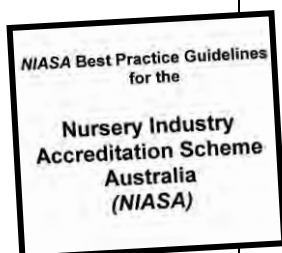
- **The dependability of an expert system** is proportional to the knowledge of the experts who produced it.
- **Frequently used for diagnostic purposes**, ie identifying the cause of a disease by symptoms, related observations and DNA testing.
- **Some incorporate the decision-making process** of the expert and advise growers in making disease management decisions.
- **Expert systems are used primarily**, but not exclusively, with high value horticultural crops that require frequent application of pesticides as part of their disease and pest management.
- **In Australia**, disease forecasting models such as TOMCAST may be useful to time and reduce fungicide applications for celery late blight based on the disease predictive model TOMCAST (Minchinton et al 2005). **Predictive weather systems** are discussed on pages 39, 347, 407.
- **In the USA**, they have been developed for **diagnosis or management of diseases of some crops**, eg **tomato** (TOM), **grape** (GrapES), **wheat** (CONSELLOR), **peach and nectarine** (CALEX), **apple** (POME). The Penn State Apple Orchard Consultant (PSAOC), **wheat** (MoreCrop) and Managerial Options for Reasonable Economical Control of Rusts and Other Pathogens in different geographic regions in the USA.

Piggybacking QA programs

It can be easier sometimes and more useful to keep each **Management systems / QA** system separate. Expertise is often limited to one area only. However, all systems may be addressed concurrently and revisited at any time. The nursery industry is used as an example, but it equally applies to other industries.

Nursery & Garden Industry accreditations schemes

www.ngia.com.au/



The nursery and garden industry has several accreditation schemes which, while aiming to reach benchmark standards, help to improve business and to become recognized providers of a standardized level of quality. Businesses and business practices are independently assessed to ensure they meet the standards. Accreditation provides consumers and the industry with assurance that the business they are dealing with is committed to the highest quality business practices, consistency and reliability in delivering service, professional standards and dedication to continuous improvement.

- **Nursery Production Farm Management System (FMS)** enables you to critically evaluate each component of your production nursery identifying areas of concern and manage the identified risks. It includes 3 key programs:
 - **The Nursery Industry Accreditation Scheme Australia (NIASA) Guidelines** detail industry **Best Management Practice (BMP)** for crop hygiene, crop management, water management and general site management. Ensures you maintain a benchmark standard and assists in continuous improvement.
 - **The FMS EcoHort Guidelines** detail the nursery industry's National Environmental Management System for production nurseries, growing media manufacturers and Greenlife markets. Demonstrates that you have sound environmental stewardship and natural resource management.
 - **BioSecure HACCP Guidelines** detail the industry specific on-farm biosecurity program designed to assist production nurseries, growing media manufacturers and Greenlife markets in assessing their current and future pest, disease and weed risks and guide businesses in the implementation of management strategies at critical control points. Manages your biosecurity risks for both imported and exported material.
- **Other accreditation schemes accessed by the nursery industry:**
 - **The Australian Garden Centre Accreditation Scheme (AGCAS)** is a national accreditation scheme that encourages business improvement and acknowledges excellence in garden retailing. The program has an emphasis on the sale and promotion of plants and gardens.
 - **Certified Nursery Professional (CNP)** program is the industry's professional recognition scheme for individuals. **CNP** members are acknowledged for their skill and expertise within the nursery and garden industry.
 - **Nursery ChemCert accreditation** specialist module at several levels, eg supervisory and management roles.
 - **Organic certification**. Some nurseries, etc may seek organic certification (page 381).
 - **Australian Citrus Nursery Certification Scheme (ACNCS)**.

CHALLENGES

- **Being clear about planning and policy objectives.**
- **Being clear about the type of audit** and its requirements for your market.
- **Quality assurance** will become an essential and larger part of agriculture and horticulture in the next few years as software enables to record, when, where and what we spray, as well as chemical batch numbers, prevailing temperatures and wind direction.
- **Retailers** need to see your records before they purchase in bulk for their consumers.
- **Consumers** will soon request more information on how the product was grown and harvested before they buy.
- **New management systems** will be required for programs that are not currently effective. There is a need to stem the rising tide of the nation's escalating weed and feral animal crisis. The invasive Species Council has called a national task force - www.invasives.org.au David Low / WeedsNews 3477 / June 28, 2012 Keeping Nature Safe 2012.
- **All growers need to keep up to dates** with the rising number of apps and other software. Software has reduced the time taken to plan inputs and retrieve key information re planting dates, etc.
- **Horticulture Australia (HAL)** moving from the current model of Peak Industry Body membership to a **grower-owned** Research Development Corporation (RDC).

SELECTED RESOURCES

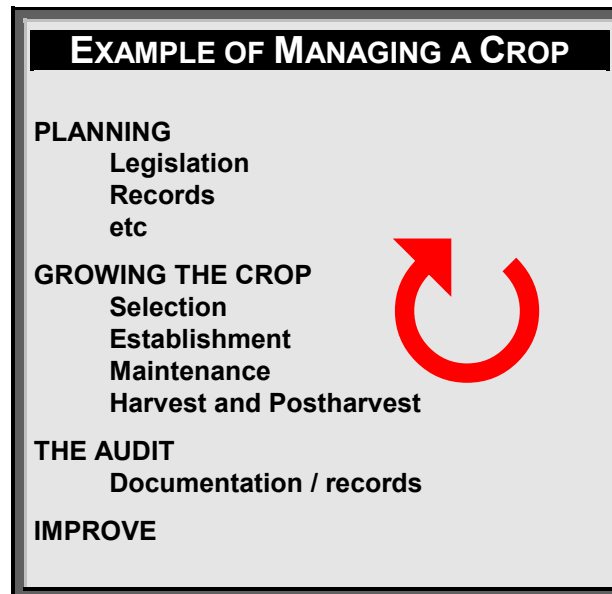
- Baxter, N. 2009. *More Farm Planning Encouraged*. Ground Cover. Nov-Dec.
- Cooke, T., Persley, D. and House, S. 2009. *Diseases of Fruit Crops in Australia*. CSIRO Pub.
- Doevendans, H. 2010. *Total Quality Management in the New Zealand Pipfruit Industry: An Exploratory Study*. Massey University, NZ.
- Francis, P. 2006. *Outstanding Horticulture EMS Package for Horticulture*. Australian Landcare. Oct.
- Hetherington, S. (ed.). 2009. *Integrated Pest management for Australian Apples & Pears*. NSW Industry & Investment.
- Horticulture for Tomorrow: Environmental Assurance for Growers and Industry
www.horticulturefortomorrow.com.au
- NGIA. 2010. Nursery Industry Accreditation Scheme Australia (NIASA) *Best Management Practice Guidelines*. 4th ed. NGIA.
- Persley, D., Cook, T. and House, S. 2010. *Diseases of Vegetable Crops in Australia*. CSIRO Pub.
- Minchinton, E. J., Galea, V. J., Thomson, F., Trapnell, L. and Nadesan, S. (2005). *Evaluation of the Disease Predictive Model TomCast for Timing Fungicide Sprays for Late Blight Control in Celery*. In Innovations for Sustainable Plant Health. *15th Biennial Australasian Plant Pathology Society Conference*, Deakin University Waterfront Campus, Geelong, Australia, 26-29 September 2005
- Prince, R. 2012. *Nursery Production Farm Management System (NPFMS)*. HAL (Horticulture Australia Ltd).
www.ngia.com.au/

Standards

- ISO 14001:2004 – Environmental management.
- ISO 9001:2008 – Quality Assurance management
- ISO 31000:2009 – Risk management
- ISO 22000 FSMS 2005
- AS/NZS ISO 9001:2008. Self-assessment checklist
- AS/NZS ISO 9002 – Quality Assurance Standards

“Improvement Programs” are many, eg
Improving the Productivity and Profitability of the
Apple and Pear Industry

MANAGING THE CROP





PLANNING	328
Legislation	
Records	328
The crop	328
Aim	328
Resources	328
Pests, diseases and weeds, Fact Sheets	329
Timing of activities	329
More planning needed	328
GROWING THE CROP	330
Selection	330
Horticultural requirements	330
Disease, pest and weed control	330
Establishment	331
Propagation	331
Disease, pest and weed control	331
Maintenance	331
Culture	331
Disease, pest and weed control	331
Harvest and postharvest	332
When and how to harvest	332
Grading, packaging	332
Quality control	332
Disease, pest and weed control	332
THE AUDIT	332
Evaluation, certification	332
IMPROVE	332

PLANNING

This section briefly outlines considerations when planning the management of an individual crop. Crop management is a systematic, comprehensive, step-by-step process for managing all aspects of growing the crop from establishment through to postharvest including:

Plant / variety identification	Soil management	Landscaping	Policies
Propagation, culture	Water management	Computer programs	Quality assurance
Fertility management	Irrigation	Pest management	Vendor declarations
Environment, sustainability	Machinery, equipment	Disease management	
Biodiversity	Contractors	Weed management	

Legislation	<p>All legislation must be complied with.</p> 
Records Quality Assurance	<p>Keep a record of all the steps in the crop management program that you intend to implement. This is necessary for the audit, vendor declarations, etc.</p> 
The crop	<p>Crop management programs vary considerably depending on the type of activity, eg</p> <ul style="list-style-type: none"> • An orchard, eg apple, stone fruit. • Production nursery. • Hydroponic system, lettuce. • Cut flowers, eg roses. • Vegetables, eg potatoes. • Field crops, eg wheat, canola, soybean. • Processing Cider Australia Fruit Juice.
Aim	<p>What are you hoping to achieve?</p> <ul style="list-style-type: none"> • Improved or maintaining product quality to maintain and improve your market? • Increase yield and profit? Save time and money, reduce costs? • Quality Assurance, Certification. • Comply with environmental standards, Best Management Practice? • Use Integrated Pest Management tactics to control pests, diseases and weeds? • Organic Standards? • Minimize pesticide use, reduce calendar-based spraying? • Increased use of biocontrol agents and other non-chemical methods? • Reduced risk of pest outbreaks? • Identify key pests problems and consider the impact of their control on other species? • Manage the crop via computer models, eg weather warning systems, keeping records of inputs and outputs, improved testing, monitoring and auditing? • Undertake some training, eg learn to identify pests, carrying out a risk assessment? • Better timing of activities, eg soil, water and disease tests, monitoring mites, fungal spore counts, weather warning services?
Resources Much information is available free online	<p>Commercial growers, eg</p> <ul style="list-style-type: none"> • Industry associations. • Specialist growers. • Wholesale nurseries and retail outlets. • Nurserymen's Associations. • Australian Flower Growers' Council. • Lobby groups. • APAL (Apple & Pear Australia Ltd.) is the peak industry body representing commercial apple and pear growers in Australia. • Farms IPM Future Orchards Crop Protection Quality Certification. <p>Sources of information include:</p> <ul style="list-style-type: none"> • Best management practice (BMP) and integrated pests management (IPM) guidelines which have been prepared for your crop, some of these are available online. • Commonwealth / State / Territory Departments of Agriculture/Primary Industry, eg Fact Sheets, Farmnotes, etc are available online. • Biosecurity Manuals for specific crops in specific areas and available free online. • Company catalogues and technical bulletins. • The pesticide label attached to the container, Safety Data Sheets (SDSs). • Field days, workshops are an excellent way of meeting people and keeping up-to-date with new developments. • Diagnostic facilities. • The internet usually provides much information on a particular crop. If overseas information is accessed, apply it to Australian conditions with care.

**Pests, diseases and weeds
Fact Sheets**



Symptoms of rose mosaic

As an example, prepare a:

- **List** of diseases, pests and weeds that affect your crop(s), eg rose.
- **Fact Sheet** for each one, eg Rose Mosaic.



LIST OF DISEASES, PESTS AND WEEDS

FACT SHEET

ROSES	ROSE MOSAIC
<p>PARASITIC PROBLEMS VIRUS AND VIRUS-LIKE DISEASES Rose mosaic (several viruses)</p> <p>BACTERIAL DISEASES Crown gall (<i>Agrobacterium</i> sp.)</p> <p>FUNGAL DISEASES, eg Black spot (<i>Marssonina rosae</i>) Blossom blight (<i>Botrytis cinerea</i>) Downy mildew (<i>Peronospora sparsa</i>) Powdery mildew (<i>Sphaerotheca pannosa</i>) Rust (<i>Phragmidium mucronatum</i>)</p> <p>PARASITIC FLOWERING PLANTS Not applicable</p> <p>NEMATODE DISEASES, eg Root knot (<i>Meloidogyne</i> spp.)</p> <p>INSECTS & ALLIED PESTS, eg Aphids include: Green peach aphid (<i>Myzus persicae</i>) Rose aphid (<i>Macrosiphum rosae</i>) Plague thrips (<i>Thrips imarginis</i>) Rose scale (<i>Aulacaspis rosae</i>) Twospotted mite (<i>Tetranychus urticae</i>)</p> <p>SNAILS AND SLUGS None listed</p> <p>VERTEBRATE PESTS, eg Birds</p> <p>NON-PARASITIC PROBLEMS Deficiencies Drought Frost Herbicide injury Leafcutting bees (<i>Megachile</i> spp.)</p> <p>WEEDS</p>	<p>CAUSE/SCIENTIFIC NAME: Several viruses have been associated with this disease.</p> <p>HOST RANGE/PLANT AFFECTED: Each virus has its own host range.</p> <p>SYMPTOMS/DESCRIPTION AND DAMAGE: Leaves: Symptoms only on the leaves and include: Veinbanding: A narrow band of yellow along the entire veinal network of the leaflet, an isolated area of the leaflet or only around the margins. Chlorotic mottling: A yellow mottle involving the minor veins of the leaflet which may gradually spread to a general chlorosis. Line patterns: Many lines or broad bands of pale green or creamy-white tissue. General effects: Reduced vigor and flowering.</p> <p>DISEASE CYCLE: See spread.</p> <p>OVERSEASONING: In the canes, buds and roots of infected rose plants.</p> <p>SPREAD: Commonly by propagation, eg budding / grafting from infected plants or by the use of infected root stocks. Some viruses also by pollen and other means.</p> <p>CONDITIONS FAVOURING:</p> <p>CONTROL: IPM including: Cultural methods: Plant virus-tested / healthy plants some distance away from older infected bushes to reduce likelihood of virus infection via pollen. Sanitation: Because rose mosaic is mainly spread by propagation there is no need to remove infected plants from home gardens. However, commercial rose propagators, growers and nurseries should remove infected rose bushes. Cutting off infected branches will not 'cure' rose mosaic. Biological control: Not applicable (na). Resistant varieties: na. Biosecurity: na. Disease-tested planting material: Make sure that mosaic-infected plants are never used as a source of budwood or rootstock. Virus-tested rose plants are available for some varieties. Physical methods: na. Pesticides: na.</p>

Timing of activities



The calendar may be organized on a daily, weekly, fortnightly or monthly basis, whichever is most appropriate.

- It may be necessary to prepare several systems, eg glasshouse, field crops.
- The chart should include information about when to propagate, plant out, prune, irrigate and fertilize, also the gathering of flowers and harvesting of fruit.
- All control methods to be used must be included. Recommended pesticides should be detailed. When and how pesticides must be applied is as important as is the time and method of release of predatory mites.
- Harvesting and marketing.



More planning needed

Baxter, N. 2009. *More Farm Planning Encouraged*. Ground Cover. Nov-Dec.

A report by Australian Bureau of Agricultural and Resource Economics (ABARE) says plans are a key tool in managing a business, yet only 19% of grain farms had one:

<p>Farm with plan 19%</p> <p>Who prepared the plan?</p> <ul style="list-style-type: none"> • External assistance 76% • Self 37% 	<p>Components included in farm plans</p> <ul style="list-style-type: none"> • Pest and disease management 81% • Marketing 66% • Risk management 51% • Environmental management 47% • People management or succession 46% • Regional natural resource priorities 30% • Training and professional development 27%
---	---

GROWING THE CROP

Selection

Choose the right crop for the market, the site and the season, cost it!

Horticultural requirements



Emphasizes the importance of selecting suitable plants for specific sites.

Select varieties with consideration for the following where applicable:

- **Plant functions**, eg
 - Food production, eg agriculture, permaculture.
 - Flower production, eg cut flowers, display.
 - Engineering uses, eg erosion control, directing traffic / circulation, screening glare.
 - Environmental uses, eg habitat creation, species conservation, pollution control.
 - Climate control, eg provide shade, windbreak.
 - Architectural use, eg create / define spaces, screens, direct views. Generally the more uses a plant has, the greater its importance in design.
 - Aesthetic uses, eg provide accents, complement / contrast architecture, to set the mood.
- **Plant attributes**, eg
 - Seed and parent plants must be genetically robust and genetically true-to-form.
 - Flowering or maturity date, flower color, fruit flavor, time of ripening.
 - Yield and quality, need for pollination.
 - Final size, growth rate, longevity, appearance during year, overall form and texture.
 - Apply attributes to groups of plants as well.
- **Economic and environmental considerations**, eg
 - The market, client needs, attitudes and prejudices.
 - Season, irrigation, drainage, waterways, overhead wires, easements.
 - Immediate and future costs, eg low or high maintenance.
 - Need for special equipment.
 - Whether work is done by employees or by contractors.

Disease, pest and weed control


Choosing rootstock & propagation material

Legislation must be complied with.


- **Cultural requirements**, eg choose varieties or species to suit the physical and other attributes of the site, eg
 - **Climate**. Avoid planting frost-sensitive perennials in frost-prone areas, drought-sensitive species in unirrigated nature strips and sunloving species in shady areas.
 - **Soil characteristics**. Avoid planting azaleas in alkaline soil. Nutrient, soil and water analyses may be required.
 - **Physical and social nature** of the surrounding environment, eg waterways.
 - **Adequate nutrients for parent stock plants** ensure maximum strike rate of cuttings.
- **Biological control**, eg assess whether natural controls operate or whether there is a need for biological control agents.
- **Resistant varieties**, eg choose species or varieties which have some resistance to any local key problems or are generally problem-free, especially for:
 - **Very large trees**, specimen trees, hedges, ground cover and edible crops.
 - **Plantings adjacent to swimming pools, barbecue areas** where pesticides are undesirable, along neighbouring fence lines and public areas where pesticide use is limited due to the inability to restrict public access.
 - **Sites** subject to particular environmental conditions, eg frost, drought, sun, shallow soil, wind, water logging/poor drainage and shade.
 - **For some diseases** such as rusts and powdery mildews (of hedge plants), **soil fungal diseases**, eg *Phytophthora* root rot and **pests**, eg borers in trees, resistant varieties may offer the only practical solution.
- **Biosecurity**, eg for large plantings check if plants, apparently problem-free locally, are subject to serious problems overseas, eg Dutch elm disease (*Ceratocystis ulmi*).
- **Disease-tested or virus-tested planting material** is available for many plants, eg carnation, strawberries and potato. Material may be certified as free from specified diseases or pests and of a specified variety.
 - The **Australian Pome Fruit Improvement Program® (APFIP)** has developed Australia's elite high-health-status certification scheme for pome fruit trees. It also supplies a large proportion of the virus-tested rootstocks for Australian orchards.
 - **Purchase planting material from reliable suppliers** and inspect closely for symptoms of diseases and pests and varietal correctness.
 - **If virus-tested planting material is not being used**, collect cuttings and seed from plants which are **visually free** from diseases and pests.
- **Recognise that there may be a need for pesticides**, eg effective control may be impossible without the use of pesticides in some circumstances.
 - **If the use of pesticides is undesirable**, eg beside swimming pools, check that the plants you wish to grow are unlikely to require spraying.
 - **Monitor the problem** so that pesticides are only applied when needed.
 - **Assess the economic cost** of not using pesticides.
 - **Some people do not wish to use pesticides**, eg organic growers.
- **Check** whether **IPM, BMP or organic standards** are available for your crop.

Establishment


Plant in the right place at the right time

Propagation 	<u>Be familiar with all the possible methods of propagation and culture</u> , cost and any other requirements. This is essential for work being put to tender.
Disease, pests and weed control	<ul style="list-style-type: none"> • Cultural methods, eg <ul style="list-style-type: none"> • Plant only during the recommended season. • Practice crop rotation where practical, for vegetables, annual and herbaceous flower crops. • Avoid exposing roots of bare-rooted nursery stock to air or sun unnecessarily prior to planting. • Check whether roots of potted plants should be unballled prior to planting. • Consider the type of soil and fertilizer required, fertilizer depth and method of planting, drainage requirements, need for sun, and protection from sun, wind and frost. • Space requirements can be important, including the position of drains, distance from dwellings, power lines and easements. • Method of culture may be a soilless mixture or a hydroponic system. • Soil and water analysis will probably be required. • Sanitation, eg <ul style="list-style-type: none"> • Remove all old crop debris. • Keep benches and containers clean, hygiene treatments may be necessary. • Biological control, eg <ul style="list-style-type: none"> • Check to see if beneficial insects are present in the crop or any biological treatments are available. • Physical methods, eg <ul style="list-style-type: none"> • Small volumes of soil in seed and cutting beds may need to be pasteurised. • Hot water treatments for bulbs, seed and other material may be recommended. • Pesticides, eg before planting check whether: <ul style="list-style-type: none"> • Soil needs to be treated with a fungicidal drench or another product. • Seeds, cuttings, bulbs or other plant material need to be treated with a fungicide. • Tools, benches and containers need to be disinfected. • Integrated pest management (IPM), Best Management Practice (BMP) and organic standards may be available for your crop.


Maintenance

Culture 	<u>Costs and contracts</u> , eg <ul style="list-style-type: none"> • Costs associated with maintenance should be calculated.
Disease, pest and weed control	<ul style="list-style-type: none"> • Cultural methods, eg <ul style="list-style-type: none"> • Maintain correct irrigation, humidity, light, temperature and fertilizer regimes. • Soil, water and tissue analyses may need to be carried out. • Plants in small containers can easily be moved outside during summer. • Sanitation, eg <ul style="list-style-type: none"> • Diseased plants should be removed as soon as practical to prevent spread of diseases to neighbouring plants. • Biological control agents can be introduced if available, eg <ul style="list-style-type: none"> • Predatory mites to control twospotted mite (<i>Tetranychus urticae</i>). • Biosecurity, eg <ul style="list-style-type: none"> • Avoid the introduction of diseased or infested plants or soil. • Have an area set aside where new acquisitions can be located until their freedom from diseases and pests can be assessed. • Isolate susceptible species for special treatments. • Physical methods, eg <ul style="list-style-type: none"> • Netting may be necessary to prevent bird damage. • Traps are used for monitoring pests and controlling mice and rats. • Pesticides, eg <ul style="list-style-type: none"> • Know which pesticides are registered for use and when to use them. • Follow regimes which prevent the development of resistance. • For some crops, early warning systems are available. • Monitor diseases and pests in greenhouses so that spot treatments can be carried out to prevent widespread damage. • Integrated pest management (IPM), Best Management Practice (BMP) or organic standards may be available for your crop.

Harvest and postharvest

<p>When and how to harvest</p> 	<p>Time and method of harvest and marketing is paramount in the production of all quality produce and best prices, whether it is a food crop or cut flowers.</p> <ul style="list-style-type: none"> • Control flowering and fruit ripening. • Flower buds picked too early may not open. • Harvesting and handling techniques that minimize injury to the commodity. Damaged fruit is susceptible to postharvest infections. • Picking and placing flowers stems directly into water. • Store in conditions that are optimum for maintaining host resistance, will also aid in suppressing disease development as a viable alternative to fungicides.
<p>Grading, packaging, labeling, marketing</p>	<ul style="list-style-type: none"> • Grading, eg <ul style="list-style-type: none"> • Size and colour of flowers and fruit. • Length of flower stem. • Packaging, eg <ul style="list-style-type: none"> • Individual packaging and wrapping. • Size of total package to avoid bruising. • Inclusion of small packets of items to increase the vase life of flowers. • Maintaining appropriate temperatures to prevent deterioration. • Labeling, eg <ul style="list-style-type: none"> • Information leaflets on care may accompany some products. • Products must be correctly labelled. • Marketing, eg <ul style="list-style-type: none"> • National basket surveys are used to check on chemical residues in fruit and vegetables. • Advertising must not be misleading. • Costs, zero food miles.
<p>Quality control</p>	<p>Various quality control systems, include:</p> <ul style="list-style-type: none"> • Quarantine regulations and various standards (within Australia and for export). • Commodity requirements. • Wholesale operations, retail displays. • Grade and quality standards. • Rapid handling.
<p>Disease and pest control</p>	<ul style="list-style-type: none"> • Sanitation, eg <ul style="list-style-type: none"> • Remove debris from packing sheds, storage areas. • Biosecurity, eg <ul style="list-style-type: none"> • Need for phytosanitary treatments required prior to dispatching the product. • Biosecurity restrictions. • Physical methods, eg <ul style="list-style-type: none"> • Cooling treatments, eg refrigerated storage and transport units, forced-air cooling, cold water, ice, room cooling, shade, vacuum cooling, hydro-cooling, cool rooms, refrigerated transport units. • Heat treatments, eg curing sweet potatoes to control <i>Rhizopus</i> and soft rot bacteria. • Lowering humidity to prevent development of grey mould (<i>Botrytis cinerea</i>) and other postharvest diseases. • Controlled atmospheres, eg reducing oxygen levels and increasing the carbon dioxide level reduces apple ripening. • Pesticide and other chemical treatments, eg <ul style="list-style-type: none"> • Fungicide and insecticide dips, waxes. • Integrated pest management (IPM), Best Management Practice (BMP) or organic standards may be available for your crop.

THE AUDIT

<p>Evaluation, certification</p> 	<p>Evaluation of the crop management program is essential.</p> <ul style="list-style-type: none"> • There may be certification requirements, eg environmental or organic standards. • Records and each step of the crop management program must be checked. • If everything is satisfactory then no action is required. • If some items are unsatisfactory, then action is required.
---	---

IMPROVE

Make recommendations for improvement in certain areas of managing the crop

IPM

INTEGRATED PEST MANAGEMENT

EXAMPLE OF IPM

STEP 1. FORWARD PLANNING

Policy, legislation, standards
Record keeping
etc

STEP 2. CROP, FARM, ORCHARD, NURSERY REGION**STEP 3. IDENTIFICATION**

Identify key pests and beneficials
Fact sheets

STEP 4. PREVENTATIVE MEASURES

Cultural methods
Sanitation
Biological control
Resistant varieties
Biosecurity
Disease-tests
Physical methods
Pesticides

STEP 5. MONITORING**STEP 6. THRESHHOLDS****STEP 7. CURATIVE MEASURES**

Cultural methods
Sanitation
Biological control
Biosecurity
Physical methods
Pesticides

STEP 8. EVALUATION

WHAT IS IPM? 334

Why IPM? 334

STEPS IN SUCCESSFUL IPM 336

Step 1. Forward planning 336

Step 2. Crop, farm, orchard, nursery, area 338

Step 3. Identify key pests and beneficials 339

Hosts, pests, diseases, weeds, beneficials and relationships 340
Fact sheets 341

Step 4. Preventative measures 342

Step 5. Monitoring pests and beneficials 343

Get advice 344

Monitoring 345

Step 6. Thresholds 346

Step 7. Curative measures 347

Curative options 348

Step 8. Evaluation (3rd party audit) 350

EXAMPLES OF INTEGRATED MANAGEMENT 351

Crops and situations 351

Integrated Pest Management (IPM) 352

Integrated Disease Management (IDM) 353

Integrated Weed Management (IWM) 355

PROS AND CHALLENGES 357**REVIEW QUESTIONS AND ACTIVITIES 357****SELECTED RESOURCES 358**

WHAT IS IPM?

There are many definitions of *IPM*. A common definition of *IPM* is “a decision-making process using multiple pest management tactics to prevent economically damaging outbreaks while reducing risks to human health and the environment” (Rutherford and Conlong 2010). **The crop is managed as a whole** and the management of the diseases, pests and weeds is part of the more complex system of producing the crop.

Features of IPM



An IPM strategy will be individual, practical, economically sound and flexible because it will need to be adapted from year to year and farm to farm, from region to region and seasonal conditions; new management techniques will become available and the value of produce and costs change.

- ***IPM is knowledge-based*** and requires skilled growers, employees, pest scouts advisers, trainers. No one size fits all.
- ***IPM is based on sound knowledge*** of the target pests and their natural enemies, monitoring, economic thresholds and different control strategies.
 - *IPM* tactics encourage the build-up of populations of beneficial species and also incorporates economic thresholds, includes using resistant cultivars, various cultural techniques and other non-chemical methods.
 - *IPM* aims not to eradicate the pest, but to maintain its population below that which causes economic and / or aesthetic damage, while achieving maximum yield and quality with minimum risk to human health and the environment.
 - *IPM* should look at all pests in the crop simultaneously. There is little point controlling one pest while allowing other pests to develop inadvertently.
- ***Maximizes the use of non-chemical methods of control*** and optimizes / minimizes the use of chemical methods which should play a supportive rather than disruptive role.
- ***IPM is an essential part*** of Best Management Practice (*BMP*) and can be piggybacked with organic standards, environmental systems, biosecurity, quality assurance, etc.

Levels of IPM



Integration with
Biological control
Environmental
Management
Organic standards

IPM programs are increasingly sophisticated. Different levels of *IPM* include:

- ***Low-level IPM*** is the most often employed form, consisting of the most basic of *IPM* practices – scouting and insecticide applications according to economic thresholds (Rutherford and Conlong 2010).
- ***Some growers have progressed to medium-level IPM***, the adoption of a few preventative measures, eg cultural controls, plant resistance, coupled with efforts to reduce broad spectrum pesticide use in order to protect beneficial organisms. These *IPM* strategies are mainly targets towards single pest species and do not consider all the pests in a specific growing system.
- ***IPM Accreditation*** (see also page 337).
 - ***Quality assurance.*** Encourages certification of integrated farm management systems and practices that incorporate and validate best-practice use of chemicals.
 - ***Advanced accreditation scheme and logo.*** Australasian Biological Control (*ABC*) implements an Advanced *IPM* accreditation scheme. www.goodbugs.org.au/
- ***High-level or Bio-intensive IPM*** is where multiple interventions are integrated in a bio-intensive approach targeting multiple pests. Bio-intensive *IPM* is based on holistic agro-ecosystem interactions, in which knowledge about insects, their symbionts, pathogens, natural enemies, plants, endophytes and interactions between all of these are combined to develop *IPM* in an area-wide, environmentally friendly manner (Dufour 2001). Other terms include ***Biointegrated PM, Biorational IPM, Organic IPM.***

Why IPM?

Minimize residues in food and the environment
Satisfy regulatory and consumer demands





There is pressure from consumers to minimize chemical use and increase use of non-chemical methods to ***minimise residues in food and the environment.***

- ***A significant proportion of growers*** have a seasonal goal of reducing the number of sprays and the number of broad spectrum insecticides used. These changes indicate that there is an increasing likelihood that *IPM* can and will work.
- ***Legislation*** has been designed to reduce pesticide usage, restrict or prevent the discharging of water from agricultural properties and nurseries to prevent pesticides (and fertilisers) accumulating in run off causing environmental contamination.
- *IPM* should increase efficiency, productivity, crop management and help meet a growing regulatory and consumer demand for efficient, effective alternatives to pesticides for pest management. SemiosBIO is a research company dedicated to developing safe and environmentally-friendly pest management solutions.

Worker safety

Concerns about worker safety, eg



- *IPM* reduces risks associated with handling and applying agvet chemicals as pesticides are ***only applied once a threshold is reached.***

Pesticide selection, trade	<p><u>Appropriate chemical selection assists effective assessment and approval processes</u>, eg</p> <ul style="list-style-type: none"> • Pesticides are only applied according to need, after monitoring indicates a predetermined threshold has been reached. • Making available products that have minimal risks to health and the environment. • Facilitate market access for Australian primary produce and limit possible restrictions.
Used at all stages crop management	<p><u>IPM uses a range of different control methods</u> to minimize the damage caused by pests to:</p> <ul style="list-style-type: none"> • Prevent the pest building up to damaging levels. • Manage the pest once it has reached a realistic economic threshold.
More effective long term control	<p><u>Pests and diseases are reduced long term due to:</u></p> <ul style="list-style-type: none"> • Maintenance of a better balance between the pests and their natural enemies. <ul style="list-style-type: none"> • Minimizing the resurgence of established diseases and pests due to the destruction of their natural enemies after spraying. • Minimizing upsurges of previously unimportant and / or unknown diseases and pests (secondary pests) due to pesticide use and other control practices. • More efficient and effective long term pest management. Crops are managed in a way to benefit the production system and disadvantages pests. • Rarely will a single control method provide good long term control. The more diverse ways the pest triangle is attacked the more effective is pest control efforts. • IPM encompasses the development of economic thresholds to guide pest management decisions, so pesticides are not applied until a threshold has been reached.
Pesticide resistance management 	<p><u>Minimises the impact of pesticide resistance developing</u>. Resistance of pests, diseases and weeds to pesticides is increasing.</p> <ul style="list-style-type: none"> • There is difficulty in developing new, effective chemicals. • IPM prolongs effectiveness of existing chemicals by delaying development of resistance caused by overuse. Because chemicals are used less frequently, pests, diseases and weeds take longer to develop resistance. • IPM promotes preventing pest, disease and weed problems, monitoring and only treating pests, diseases and weeds if they have reached an economic threshold. • CropLife Australia promotes the responsible use of a range of pest management methods to ensure sustainable agricultural outcomes. <ul style="list-style-type: none"> • Resistance management is a vital aspect of maintaining the crop protection option for integrated crop management (see pages 303, 427). • A program of alternative management strategies is employed to minimise the development of resistance, whilst contributing towards the quality of the environment. • CropLife Australia's Resistance Management Strategies provide a guide for crop protection by product rotation through product groups. www.croplifeaustralia.org.au/
Cost 	<p><u>Increased costs of pesticides and labor result from:</u></p> <ul style="list-style-type: none"> • Registration requirements becoming more stringent, fewer chemicals are being registered and becoming available. • There are also increasing restrictions on their use. • Pesticides consume energy during their manufacture and application. This together with other factors makes pesticides increasingly expensive to develop and use.
International pressures National Action Plan (NAP)	<p><u>Systemwide Program on Integrated Pest Management (SPIPM)</u> is a global group of scientists and institutions that addresses food scarcity, increased pest pressure, declining soil health, and targets:</p> <ul style="list-style-type: none"> • Adapting IPM to climate variability and change. • Improving agro-ecosystem resilience. • Managing contaminants in food, feed and the environment. • The better understanding of the biotic and abiotic interrelationships between the different components of agricultural biodiversity (see also page 378). <p><u>NAP Best Practice: Sustainable use of pesticides: Implementing NAP</u> (Directive 2009/128/EC of 21 October 2009) is a guide to assist and support EU member states in producing their NAPs as required under the Sustainable Use Directive:</p> <ul style="list-style-type: none"> • Prevention (rotation, sanitation, host resistance, healthy seed, landscaping). • Monitoring pathogens. • Choose... BIOLOGICAL > PHYSICAL > NON-CHEMICAL > CHEMICAL • Limit chance resistance / virulence development. • No side-effects, eg try to anticipate unforeseen developments. <ul style="list-style-type: none"> • Do not damage beneficials and the surrounding environment. • Do a risk assessment on each control option as to their effect on neighbouring people and beneficial and non-target plants, insects and animals. • Sustainable pesticide application should not have a broad impact on the environment. • Appropriate, science-based measures.

STEPS IN SUCCESSFUL IPM

Step 1. Forward planning

“Fail to Plan or else Plan to Fail” (Neylan 2010).

Policy, legislation, standards	<p>Nominate the policy, legislation, standards, etc that you wish to comply with.</p> <ul style="list-style-type: none"> Regulators must make sure regulations are carried out. Contracted out work can be difficult to enforce. Audit for quality assurance. 	
Record keeping, documentation Essential for QA and Trade	<p>Data recording and reporting are essential for QA, certification and trade. Records should be held as long as possible to assist with continuing improvement in IPM techniques and to reflect on the effect of crop rotations, seasonal conditions on IPM programs. IPM helps sort out the interactions between root disease, crop types, seasonal conditions, soil nutrients, host weeds spectrums and tillage systems. Trends over years can be easily seen if graphed. Records of each step of the IPM program must be kept and include:</p> <ol style="list-style-type: none"> Planning is critical to the success of IPM. How was the planning process arrived at? This may include a risk assessment of the IPM program, eg what chance does it have of achieving its aims? It may involve training, learning how to gather information, monitoring, how to keep accurate records and implementing an IPM strategy for their business, using outside consultants if needed. Crop, farm, orchard, nursery or region to which the IPM program applies. Identification of the pests, diseases or weed, their natural enemies and environmental parameters. Preventative measures, what methods did you use? Crop rotation? Monitoring of diseases, pests, weeds, natural enemies and other beneficials, growing conditions, and environment, soil, pH, soluble salts. Monitoring is a key activity to ensure successful IPM in the long term. Information collected is used for decision-making about control actions. Thresholds for each disease, pest or weed and / or beneficials. Curative measures, eg crop treatments including cultural methods, release of biological control agents, pesticide applications. Evaluation (auditing) of the treatment and the whole program, and responses to treatments. 	<ul style="list-style-type: none"> Keep records Monitor Audit (test)
 <p>Because of IT, on the go record keeping is getting easier all the time</p>		
Aims, planning and preparation Proper Planning Prevents Poor Performance	<p>What are you hoping to achieve with your IPM program?</p> <ul style="list-style-type: none"> Save time and money, reduced costs. Improving or maintaining produce quality and market. Complying with environmental legislation, codes of practice, BMP? Minimize pesticide use, reduce calendar-based spraying? Quality Assurance, certification? Increased use of biocontrol agents and other non-chemical methods. Reduced risk of pest outbreaks. Explore preventative management options to prevent pest outbreaks. Identify key pests problems and consider the impact of their control on other species. Manage the crop via computer models, eg weather warning systems, keeping records of inputs and outputs, improved testing, monitoring and auditing. Concurrently undertake some training, eg learn to identify pests and beneficials, carry out a risk assessment. Better timing of activities, eg tests, egg laying development of locusts, fungal spore counts, weather warning services. 	
Risk analysis	<p>Risk analysis and management.</p> <ul style="list-style-type: none"> How serious is the threat? The first step in designing your control strategy is an evaluation of the seriousness of the threat. www.rirdc.gov.au There is a need to manage risk better in our farming systems (see also pages 302, 425). We have moved from: <ul style="list-style-type: none"> Having a target of maximum productivity to one of setting up the crop or pasture for no more than the potential the season provides – be that good or poor. Farmers are looking to identify appropriate profitability indicators early in their planning cycle then establish trigger points to guide flexible decision making. Growers’ ability to adapt to climate change is considered to be strongly linked to their capacity to cope with change, their social connectedness and how they use information, eg cash available, comfortable non-adaptors, etc. 	

Flexible decision-making
Crops and Inputs

Growing crops is flexible and responsive. It is necessary to have the contingency plans to act on as soon as needed. While crop choice is a primary management tool, on a short time scale it is **inputs** that must be managed carefully.

- **Temper fertilizer inputs** and expectation of yields according to seasonal conditions. Tests must be carried out test to determine how much fertilizer is required.
- **Nitrogen application** is the most important factor for yield. Finishing rain determines yield but be cautious with how much and when nitrogen is applied. If it is too wet there is the risk of denitrification and run-off.

Effectiveness of control methods

The more diverse ways you attack the pest triangle the more effective will be your pest control efforts be (page18). Rarely will a single control method (including pesticides) provide good long term control. Measures are more likely to succeed where **many different control methods** are employed and reliance is not placed solely on one. Non-chemical methods, eg sanitation, biosecurity, can be readily be used in **IPM** systems.

- **Choose effective, less risky controls** first, including highly targeted methods such as pheromones to disrupt pest mating, or physical controls such as trapping or weeding. If on further monitoring, thresholds indicate that these are not working, then additional pest control methods would be employed, such as targeted spraying of insecticides.

Training



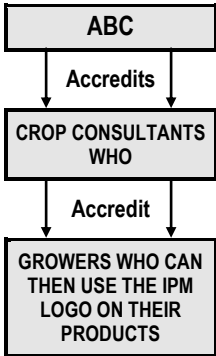
See pages 274, 441.

Accredited pesticide training usually includes some introductory IPM information but it is usually scanty

General prior knowledge of growing the crop is required.




- **Training is best on-site by trained individuals,** by student scouts working alongside a trained pest scout or entomologist with knowledge of **IPM** techniques.
- **Building up to a high level IPM** program is a gradual process. After training it takes several months of monitoring to sample confidently and accurately.
- **Providers** include:
 - TAFE network and other government funded institutes, universities.
 - Private providers, eg Beneficial Bugs, Biological Services, Bugs for Bugs, IPM Technologies, Organic Crop Protectants.
 - Some industry associations have produced their own training material.
 - Some manufacturers also produce training material, eg Bayer Cropscience, Syngenta Training Farmscape.
- **Formats** include:
 - Online, workshops, webinars, etc (page 441).
 - Scenario based learning, eg CBIT Lucid identification tools.
- **Updates and refresher courses** are available.
- **IPM accreditation details** include:
 - **Quality Assurance (QA)** encourages certification of integrated farm management systems and practices that incorporate and validate best-practice use of chemicals.
 - **Advanced accreditation scheme and logo.** **Australasian Biological Control (ABC)** is currently implementing an Advanced **IPM** accreditation scheme.
 - Crop consultants gaining accreditation are assessed by a panel of experienced **IPM** practitioners who are members of the **ABC**.
 - An accredited consultant can then nominate growers who fit **QA** requirements.
 - Accreditation enables the grower to use the Trade Marked **IPM** logo on their products which is a measure of a high level of their commitment to **IPM** and the need to reduce chemical inputs and minimize environmental and human health impacts.
 - **Applicants must meet a set of criteria:**
 - Understand the role of beneficial organisms in the crop.
 - Use cultural controls to enhance the activity of beneficial organisms or to reduce pressure from pests.
 - Conduct routine monitoring of pests and beneficial organisms specific to the crop grown.
 - Can demonstrate a genuine reduction of standard farm practices or norms in the use of synthetic insecticides.
 - That the frequency of pesticides applied and the types of materials selected is appropriate for an **IPM** program (for the specific crop).
 - Consideration is given to biological control as a component of the overall pest management strategy.
 - Have a means of maintaining and enhancing current and advanced knowledge of **IPM** principles and practices.
- **A National Training Course in IPM** follows the Australian Horticulture Training curriculum.
 - **Nursery IPM** is aimed at **supervisory staff and production practitioners** working at Australian Qualification Framework (AQF) Level 3 and above. www.ngia.com.au
 - **Many courses on weed control (AQF 3)** include integrated weed methodology, mapping and monitoring technology, restoration ecology, plant taxonomy, latest techniques for managing infested areas.

QA



Step 2. Crop, farm, orchard, nursery, area

IPM systems vary with each crop, site, property, region

<p>Crop</p>	<p>IPM programs tend to be crop specific, developed for Australian conditions, underpinned by scientific research and development and extension services. This crop area is the place where the diseases, pests and weeds must be kept to acceptable levels, eg in a citrus orchard.</p> <ul style="list-style-type: none"> • IPM looks at each crop individually and objectively, weighing up the various possibilities and coordinating the different control methods to find the best solution for that crop. • Within each crop, changes in pests, patterns of movements of key pests, available control techniques, weather conditions, and economic circumstances all contribute to various risks and options for management. • IPM systems can be difficult for some crops, eg roses, which are susceptible to many diseases and pests. • IPM systems can be easier for other crops, eg pecans, which are susceptible to only a few diseases and pests.
<p>Farm, property, greenhouse</p>	<p>Often the best way to reduce the risk of introducing exotic and endemic plant pests, diseases and weeds, is by whole-of-farm management, eg</p> <ul style="list-style-type: none"> • Biosecurity measures include making sure seed is disease and pest free, decontaminate vehicles and equipment before entering and exiting the farm (page 200). • Often the best way to initially reduce plant pests is by whole-farm management and then area-wide management.
<p>Area-wide management (AWM)</p> <p>Fruit fly Rabbits, foxes <i>Helicoverpa</i> Cereal rusts</p>    <p>Corn earworms (<i>Helicoverpa</i> spp.) (up to 40 mm long) Agric. NSW</p>	<p>A regional rather than crop-based approach is more productive for pests and diseases that have a broad host range (Rainbow 2010).</p> <ul style="list-style-type: none"> • Area wide management (AWM) is basically IPM that operates over a broad region and attacks the pest when and where it is ecologically weakest without regard to economic thresholds (Hertel et al 2011). Good crop management across all crop types is required to minimize the potential of resistance developing. • Sharing fruit fly responsibility. Tas. 28/Oct 2011. Managing fruit fly will become a community responsibility after the suspension of the use of dimethoate on a number of food crops by the APVMA. While the decision has a significant impact on the horticultural industry, there are measures that can be taken for fruit fly management. <ul style="list-style-type: none"> • The recommended systems approach involves growers in local areas working together to adopt suppression practices. • Community education is a necessary part of the overall approach to effectively manage fruit fly. We need to make the community aware that they play a role in helping reduce pest pressure, eg simple practices such as removing abandoned fruit trees and spraying infested fruit with a commercially available products in both orchards and urban properties, can make an area-wide difference. • National Feral Animal Control Program (2006). Helps reduce the damage to agriculture caused by pest animals. It funds government, non-government and community group projects which address pest management issues of national significance and directly improves pest management at the property level. www.brs.gov.au/feral. <ul style="list-style-type: none"> • Overall populations of foxes are only reduced if carried out across regions. Otherwise the program is only offering protection to growers who are baiting. Rabbits control is in similar position. • <i>Helicoverpa armigera</i> in cotton. AWM co-ordinates farmers in implementing management strategies on their own farms to control local populations of <i>H. armigera</i> and prevent high numbers building up later in the season. <ul style="list-style-type: none"> • AWM strategies involve a detailed understanding of the biology and life cycle of the pest and how the pest moves around in a region. • Strategies can include the coordinated timing of operations like pupae busting, sowing and destroying trap crops and spraying of certain chemical types including “soft” or biological insecticides. • Resistance to a number of the older broad spectrum insecticides is widespread but IPM compatible insecticides registered for use on crops in this region have remained effective. Continued good management is required to minimize the potential of such resistance developing (Hertel et al 2011). • Cereal rusts could be much easier to control if every property grew resistant varieties.

Step 3. Identify key pests and beneficials

The secret of IPM
Identify pests and beneficials present



Successful IPM requires correct identification of the various stages of the **key pests, diseases and weeds** and **the beneficials** in your crop, knowing their life cycles and regularly monitoring.

- This provides access to information on the problem and the appropriate responses. Incorrect identification can lead to inappropriate control methods.
 - You can use illustrated guides or Lucid keys, etc to identify the pest and its various life stages.
 - You may need to send off specimens for identification to a diagnostic service for a species, strain or race identification (page 10).
- Correct identification assists growers in making informed decisions that target pest species while minimizing harm to beneficial species.
- Routinely monitor to ensure **early detection and determine the scale of the problem**, etc.



Left: Chilean predatory mite (*Phytoseiulus persimilis*) - 0.5mm long.
Right and Top: Twospotted mite (*Tetranychus urticae*) - 0.55mm long
Chilean predatory mites are slightly smaller than twospotted mites, more oval in shape and have no spots. Photo©Canberra Institute of Technology.

Environmental and other factors

Successful IPM also involves assessing the effect of environmental and other factors on **pest populations, beneficial insects** and **plant growth**, eg

- **Weather warning systems**, eg temperature and humidity helps predict an outbreak of certain insects and diseases (predictive programs).
- Irrigation management.
- Nutrients available for beneficials.
- Fertilization programs, nutrient availability and pH of the host.

Know what to expect and when to expect it

Make a list of the pests, diseases and weeds in your crop (pages 329, 341).

- Being able to identify the usual problems that affect your crop will help you recognize anything new or unusual.
- You should know biosecurity threats to your industry. These are described in Industry Biosecurity Plans and Manuals (page 186-187).
- Send suspect plants, soil and water to a professional laboratory for accurate results.
- Check out disease prediction software. Early warning services have been developed which use weather data to predict the need for control measures.
- Keep written and photographic records of unusual observations. Constant vigilance is vital for early detection of any plant pest threat.

Hosts, pests, diseases, weeds, beneficials and relationships

Exploit a weakness in the pest or disease life cycle

Understanding the life cycle of the pest or disease itself and its biocontrol agents is essential to devising management tactics that can exploit certain pest behavior or weaknesses in its life cycle.

- Their relationship with the surrounding environment must be understood. Weak links must be identified and targeted.
- You may achieve long term control by changing the environment and understanding the environmental influences on host / pest / beneficial relationships.
- Gather information about the pest, damage potential and economic threshold.
- Choose the best time to use a particular control method, eg when it can be broken by sanitation, the release of biocontrol agents or pesticide application.
- Check Fig. 29 below to refresh thoughts on pest and beneficial relationships.

Weed life cycles

Pest and disease management has always been focused on the **their life cycle**, however, the concept of grouping weed control methods according **to their main aim** emphasizes the options for weed management based on the **weed life cycle** (CRC for Australian Weed Management, Fact Sheet 2005) is comparatively recent (Tactical Groups page 355).

- Deplete the seedbank.
- Kill emerged weeds.
- Stop weeds setting seed.
- Stop weed seeds returning to the seedbank.
- Stop weed seeds from external sources entering the seedbank.

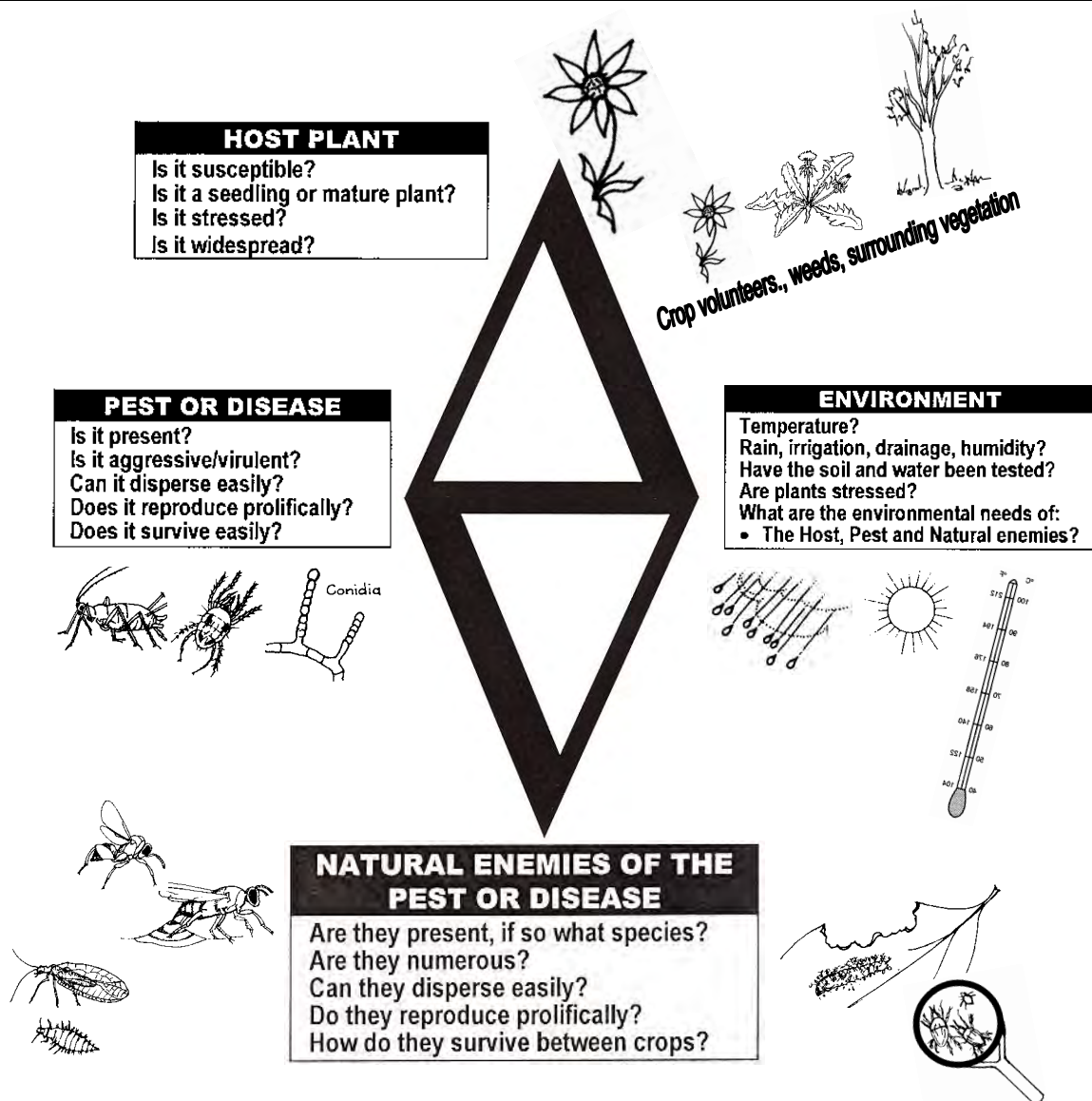


Fig. 29. Triangles – the host, pest, beneficials and the environment

Fact sheets

Fact sheets	<p>Obtain a fact sheet for each disease, pest and weed and beneficial in your crop.</p> <ul style="list-style-type: none"> • The more that is known about a pest and the factors that influence its behavior, the easier and more successful IPM becomes. • Include life cycles of the disease, pest or weed and its natural enemies and its seasonal biology (Fig. 30 below). • A Fact Sheet will: <ul style="list-style-type: none"> • Assist with identification of problems associated with the plant or situation. • Provide information on the disease, pest or weed or beneficial. • Provide information on management measures, whether the problem is under natural / biological control, the availability of resistant varieties / species and disease-tested planting material (seeds or nursery stock) for key problems, need for biosecurity measures, which pesticides to use an IPM program has been developed.
--------------------	---

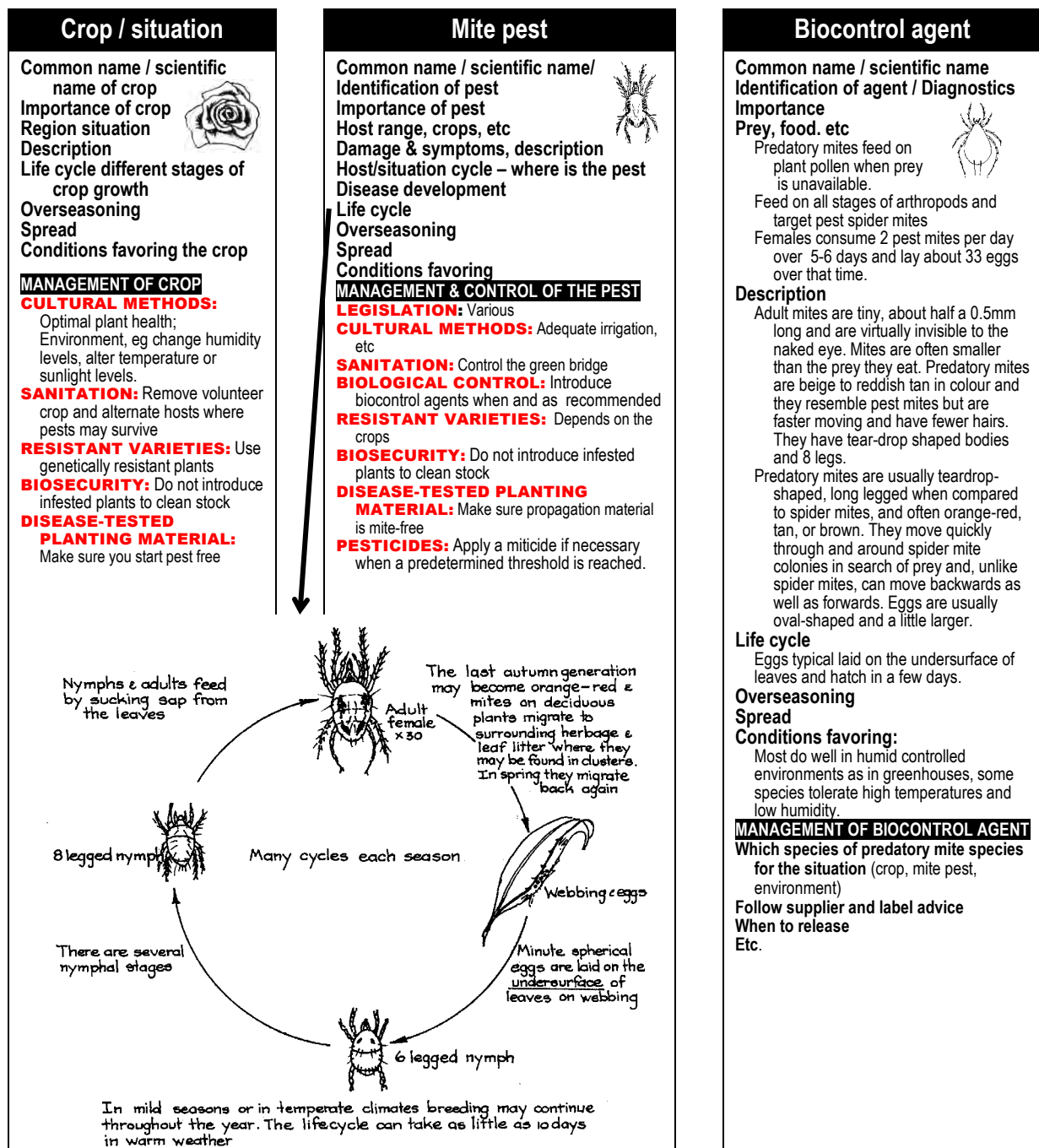






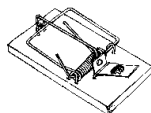



Fig. 30. Fact sheets of host, pests and biocontrol agent.

Step 4. Preventative measures

At each stage of the crop – Establishment, Maintenance, Harvest, Post harvest

<p>National Action Plan</p>	<ul style="list-style-type: none"> • Prevention (rotation, sanitation, host resistance, healthy seed, landscaping). • Monitoring pathogens. • Choose... BIOLOGICAL > PHYSICAL > NON-CHEMICAL > CHEMICAL • Limit chance resistance / virulence development. • No side-effects, eg try to anticipate unforeseen developments. <ul style="list-style-type: none"> • Do not damage beneficials and the surrounding environment. • Do a risk assessment on each control option as to their effect on neighbouring people and beneficial and non-target plants, insects and animals. • Sustainable pesticide application should not have a broad impact on the environment. • Appropriate, science-based measures.
<p>Cultural methods</p> 	<p>Many cultural practices (page 29) are useful in IPM systems, eg</p> <ul style="list-style-type: none"> • Crop rotation. • Timing of planting, sowing and harvesting to avoid peak diseases and pests. Blackspot Manager is an example of such a model already in use – growers can minimize disease risk by delaying the time of sowing field peas until after the peak spore release has occurred. • Analyses of water, soil, and plant tissue. • Irrigation scheduling and planning. • Providing optimum culture for the crop, but least favorable for the pest, eg stressed trees are very susceptible to borer infestations. • Manipulation of micro-climate conditions to make it less suitable for pests and more suitable for the beneficials, eg planting density, row spacing and row orientation.
<p>Sanitation</p> 	<p>Sanitation (page 65) is an essential part of nursery industry accreditation schemes, postharvest systems and for biosecurity.</p> <ul style="list-style-type: none"> • Unfortunately the benefits of sanitation practices are often hidden and mostly impossible to quantify in cost/benefit terms, eg clean growing facilities. • Pruning cuts and mower damage provide entry points for disease, cankers, wood rots. • Field sanitation to eliminate weed populations prevents potential migration of pests and viruses.
<p>Biological control</p> 	<p>Biological control (page 83) should be the cornerstone of IPM where possible.</p> <ul style="list-style-type: none"> • Biological control programs do not have disruptive effects on the natural enemies present in the environment and so can be integrated with partially resistant varieties. • Integration of biocontrol agents with pesticides can be difficult but can be done. • Releases of biocontrol agents must coincide with susceptible pest stages. • Suppliers of biocontrol agents (see page 125). • Know which biocontrols are present or could be introduced
<p>Resistant varieties</p> 	<p>Resistant varieties (page 137) play a vital role in IPM systems, reducing the need for pesticides, allowing biological control agents and natural enemies of diseases and pests to play a significant role in pest control.</p> <ul style="list-style-type: none"> • Select cultivars on the basis of their resistance to diseases and pests, eg in areas where phylloxera occurs growing resistant rootstock of grapes is compulsory. • Partially resistant varieties may suffer some economic loss. • Pre-emptive breeding and commercialization of resistant or tolerant varieties provide immediate protection against the arrival of exotic pests and diseases. • Rotate between different crop varieties. Select crops which inhibit weeds.
<p>Biosecurity</p> 	<p>Biosecurity (page 171) to keep pests out of crop areas can be one of the first avenues considered to reduce the need for other measures.</p> <ul style="list-style-type: none"> • Phytosanitary certification of plant material. • Inspect and quarantine incoming plants for pest and other problems. • Prevent viable weed seeds from external sources entering the target area.
<p>Disease-tested planting material</p>	<p>Select disease-tested planting material (page 205) which is certified to be free from specified diseases and pests:</p> <ul style="list-style-type: none"> • This may be the only way a problem can be controlled, eg strawberry viruses. • Crop seeds must be free from undesirable seeds and weed seeds. <div style="text-align: right;">  </div>
<p>Physical methods</p>	<p>Physical and mechanical methods (page 229) include:</p> <ul style="list-style-type: none"> • Insect-proof screens to exclude pests from greenhouses. • Sticky traps to control monitor / flying pests. • Heat treatments. 
<p>Pesticides</p> 	<p>Integration of pesticides with the action of natural enemies or biocontrol agents is an important technique of IPM systems. Pesticides must play a supportive rather than disruptive role (page 257). Use “soft” options where possible, eg seed dressings.</p>

Step 5. Monitoring pests and beneficials

Unsatisfactory IPM results can often be related to inadequate monitoring but help may be at hand!

Monitoring is an important and hard part of **IPM**. **Wireless technology** is reducing the labor and cost of monitoring while increasing efficiency of monitoring in crops and orchards both in Australia and overseas. In Canada, SemiosBIO Technology's program involves:

- **Camera-monitored trap applications to monitor insect population changes**, reducing manual monitoring costs.
- **Software for precise record keeping capabilities** that will help open new markets for Canadian crops.
- **Developing and testing a pheromone tracking system for mating disruption pest control**, so that there is more efficient use of biopesticides, such as pheromones, and traditional pesticides if necessary.

What is monitoring?

1	2	3	4
5	6	7	8

Monitoring is a program of sampling, inspecting and recording which aims to:

- **Detect, locate, identify and quantify** potential pests, diseases, weeds and their natural enemies at an early stage of infestation.
- **To be** quick, accurate, reliable, systematic, efficient and repeatable.
- **To maintain** the quality of the crop and avoiding economic losses.

Why monitor?

Routinely monitor your crop

- | |
|--|
| Why Monitor? |
| <ul style="list-style-type: none"> • Claims for area freedom • Trade • Reduce pesticide use • More effective control efforts • Biosecurity • Resistance • Changes in pest populations |



Knowing the usual appearance of your crop will help you recognize any new pest, disease or weed and ensure early detection. These will help you gain **an understanding** of the peaks in pest populations and the pest complexes that are characteristic of your crop.

Data from monitoring forms the basis for informed decision-making with regard to:

- **What pests, diseases or weeds required management?**
 - Map distribution of weeds, to determine if, when, where and why, weeds are growing or posing a problem, and prioritize for habitat change and least-toxic weed suppression.
 - Checking for the developing of resistance.
 - Biosecurity. Have new weed incursions been found and treated?
 - Claims for area-freedom. Constantly scanning crops for anything out of the ordinary. Growers and consultants together provide an extensive national passive surveillance network for exotic pests. This surveillance is part of a national biosecurity effort.
- **Prevention.** Growers should identify paddocks of higher risk of pest pressure and carefully monitor them in autumn before sowing susceptible crops. Reduce the impact on **next year's crops** by taking measures now.
- **Curative.** Allowing prompt intervention with appropriate controls before crop quality is affected, eg improved timing of the release of beneficials, using spot sprays instead of blanket sprays, improved spray timing and reduced frequency of application.
- **Record any changes in levels of pest infestation and spread.** Continuous monitoring can show regular seasonal patterns of pest occurrence.
- **Measuring effectiveness of control actions already taken.** eg
 - Use of resistant varieties, seed treatments or biocontrol agents.
 - To check that the treatment methods used are the most effective.
 - Have particular tactics like herbicides, tillage and crop rotation resulted in a decline in the seed bank over time? The **wizard model** simulates weed seeds in the soil, their germination or mortality and what happens to the plants that grow from the seeds that do germinate. How effective are the Seed Destroyers?
 - To demonstrate to the community, accountability for the use of government resources and helps in setting priorities for weed management.

Quality assurance (QA)

*Data entering
Record keeping*

GPS and apps programs allows instant recording of monitoring
--

QA

Quality Assurance requires training and checklists

- **Monitoring participants are trained** in the standardized methodology, completion and management of data sheet and species identification.
 - Clearly defined competency levels that the trainees should achieve, and are assessed on.
 - Refresher and other training sessions ensure updating in any new methodologies introduced in the project and to maintain standards and constancy between participants.
 - Site localities include directions and maps to ensure that sites are easy to locate.
 - Standardized data collection sheets are used for **recording data in the field**.
 - Easy to interpret monitoring protocols, readily accessible to monitoring participants.
 - Appropriate pilot study to identify the number of samples required has been conducted.
 - Reason and method for selecting the monitoring sites. Is it representative of the project?
- **Quality assurance protocols or guidelines.**
 - Datasheets checked by monitoring coordinator after each monitoring session is complete.
 - Field data sheets copied and stored in safe, accessible and separate storage systems with other relevant information.
 - The data base is regularly maintained. Questionable or unreliable data is clearly identified with links to a description of issues concerned and invalid data removed.
 - Comparisons are only made between data collected using consistent methodologies.
 - Seasonal and sampling differences are identified and separated from other differences when interpreting data.
 - Protocols are strictly followed (do not collected data from outside the defined area).
 - Standard equipment and standard measures are used, eg GPS generated grid.
 - **Check the following:**
 - Identity of plant specimens checked with a recognized expert or herbarium,
 - Identity of pest, disease or weed specimens checked with recognized expert.
 - Questionable or unknown species identifications verified by recognized expert.
 - Entered data is cross-checked with field data sheets after data entry.

Get Advice

Who, tools, sampling, what and where?



Plenty of areas that you can get advice about!

- **A professional pest scout or employee.**
 - **Professional monitoring services (IPM scout)** can monitor, advise on pest development, when to spray or release beneficials and their post-release progress.
 - **Choose a reliable trained employee to scout.** An inexperienced scout will take at least 35 minutes to sample a 2 hectare block; a professional scout will take 25 minutes.
 - **Plan ahead** never underestimate the time it takes to do a good job of scouting. If you don't want to do it, get a scout.
- **Basic tools** include 10x - 20x magnifying hand lens carried around the neck. Small tubes and plastic bags for specimens. Clippers, paper towels, soil probe, tally meter, sample vials with alcohol, collection bags, hand lens, pens and notebook, identification guides. Use nets, traps, etc as an aid to detection of pests.
- **Patterns of sampling.**
 - **Establish a pattern of sampling traps / indicator plants.** The type of crop affects the scouting pattern. **Sample incoming plant material.**
 - Where insects or diseases are likely to come from, eg crop edges, doorways, vents.
 - Follow a specific path through the crop, eg walk along every aisle from bench to bench in zig-zag pattern and follow grid patterns.
 - Fixed stations prevent traps from being removed. Assign a number to each trap or indicator plant site. Sometimes susceptible plants can be grouped.
 - Choose plants at random and the first diseased or pest-infested plant found on a bench becomes key plant and should be tagged with a stake.
 - Nurseries have a wide range of cultivars and monitoring should focus on those that are most susceptible to key pests and diseases.
 - Remember to sample a number of representative areas in the production area.
 - **Density and height of traps and indicator plants.**
 - How many traps?
 - Sticky traps should be positioned above plant height and adjusted to the growth of the crop. Replacement traps should be placed in the same spot and alignment.
 - Indicator plants may be placed on benches or at floor level.
- **What do you have to measure / count / trap??** A very simple **YES/NO** to record the presence or absence of a pest or disease on leaves, or the number of plants visually affected or testing positive for disease? This is usually easier than precise counts.
- **Where and what are you going to monitor?** Effective monitoring requires knowledge of when and where to look, eg **soil, leaves, fruit, buds**, etc. Ability to identify pests and predators, knowledge of their life cycles, conditions favoring pests, diseases and weeds, eg weather station and soil tests.
 - Stages of the host to be monitored.
 - Nutrient levels – soil, water tests, etc.
 - Stage of pest, disease or weed to be monitored.
 - Stage of beneficial insects, mites, pathogens, etc to be monitored.
 - Virus diseases - observing symptoms on plants.
 - Insect surveys of vectors on sticky traps.

Timing

When to monitor?

Warning services
How much rain has
fallen?

1	2	3	4
5	6	7	8



- **Early detection.**
 - **Ongoing surveillance for endemic and exotic** virus diseases in crops provides the best chance of their early detection, eradicate ion or control.
 - **Some in-field test kits** are available.
 - **Pests as well as beneficials** should be monitored to get a complete picture.
- **Weather warning services** helps predict an outbreak of diseases and pests. They can predict when damage is likely to occur, eg the need for monitoring or control. Record weather when monitoring as some pests are less active on overcast days.
- **Monitoring frequency** depends on location, level of pest activity and time of year.
 - **Regular frequent monitoring** is generally preferable to infrequent monitoring.
 - **May be weekly, monthly**, but may be more or less frequently, eg daily, to determine whether the interaction between parasite and predator is proceeding satisfactorily.
 - **Chose particular days** each week and stick to them through the growing season.
 - **Start to monitor** when pest problems in a crop are still **low in numbers** because:
 - There must be little visible damage on some crops, eg cut flowers.
 - Some pest populations may suddenly explode overnight.
 - Pests detected early can be suppressed by spot treatments.
 - Seasonal trends and conditions favoring pests may be well established.
- **Before sowing** (crops are most susceptible during emergence).
 - Soil tests may indicate significant fungal or nematode disease populations.
 - If economic damage is likely consider seed dressings or with a less susceptible crop.
- **Reduce the impact on next year's crops** by taking measures now.
 - While the practice of controlling summer weeds is primarily a means of conserving moisture and of cutting down weed numbers, it can also be **crucial in lowering damaging insect numbers**. Growers should identify paddocks at higher risk of pest pressure and carefully monitor them in the autumn prior to sowing susceptible crops.
- **At flowering.** Many environmental weeds, eg St John's wort are easier to locate when they start to flower.
- **Before harvest** and **after any treatment** to check for efficacy.

Monitoring

Weed monitoring

1 2 3 4
5 6 7 8

Even a small lapse in the continuity of this effort can cause an increase in the seedbank that has a significant effect over subsequent years



Techniques for weed monitoring are improving all the time, eg

- **Detect and monitor the distribution of existing / emerged weeds** to determine if, when, where and why weeds are growing or posing a problem and to assign priorities for habitat change and least-toxic weed suppression.
 - **A Field Manual for Surveying and Mapping Nationally Significant Weeds** (C.of.A. 2008).
 - **States / Territories have Weeds Strategies** including their impact on the economy, environment, effectiveness of weed control strategies and impacts of climate change.
 - **Mapping weed habitats in small areas** need not be a detailed or time consuming, a rough map may do. Identify weed species, know the scientific name, learn about the weed's growing conditions and method of reproduction, etc (Sharp and Gould 2009).
 - **Drones** can record weed distribution over large areas.
- **Monitoring the weed seedbank** evaluates the differences in weed control over the long term and assists in the fight against herbicide resistance. The aim is to establish and maintain a falling trend in the size of the weed seed bank. Predicting potential weed emergence is fundamental in developing **IWM** strategies.
 - **Mostly they involve taking many large core samples**, put them through various laborious treatments to obtain the weed seeds for counting. This process can be speeded up with the use of equipment which separates the coarse soil organic matter, including weed seeds from the mineral portion of the soil.
 - The **Weed Seed Wizard is a computer simulation tool** which gives growers an insight into the **hidden weed seedbank** which applies to all Australian grain growing areas.
 - Weed Seed Wizard uses paddock management information to predict weed emergence and crop losses now and in the future.
 - Helps growers understand and manage weed seedbanks on their farms.
 - Uses farm-specific management and site-specific weather.
 - Shows how weed management affects crop yield.

Insect monitoring

Pests and beneficials



1 2 3 4
5 6 7 8

Incidence of pest damage varies from year to year and locality to locality. Occasionally one or more pests may be numerous and cause serious damage.

- **All insect and mite samplings are subject to error**, reliability depending on:
 - The number of samples taken. A large number of small samples will provide a more reliable result than small number of large samples.
 - Other effects, eg response to changes in soil moisture and temperature, etc.
- **Monitoring and sampling techniques** to check pests and beneficials include:
 - Sweep nets used in pastures and in standing crops that you can easily walk through.
 - Colored sticky traps for small flying insects, eg aphids, thrips, whiteflies, fungus gnats.
 - Pitfall traps for mobile ground dwelling insects and spiders.
 - Suction samples for small mites and insects on plants and soil.
 - Pheromone delta traps attract specific pests, eg codling moth, lightbrown apple moths.
 - Light traps for nocturnal flying insects.
 - Beat sheets for standing crops hard to walk through (cotton, canola, soybeans).
 - Fruit fly traps (with different attractants).
- **Indicator plants** are plants which are susceptible to the disease or pest to be monitored. You must know which **part** of the plant to monitor. The attraction of pests to indicator plants will **not** prevent the crop from becoming infested.
 - **Twospotted mite** (*Tetranychus urticae*) do not fly, monitor by foliage inspection.
 - **Aphids** produce winged forms only when they are crowded. Inspect buds and leaf undersurfaces for aphids, older plants for nymph skins and honeydew.
 - **Pest egg monitoring** is essential for timing release of *Trichogramma* egg parasitoids.
 - **Some highly susceptible host plants** and the **pests** they attract are listed below (Goodwin and Steiner 1994). Position in strategic places in greenhouse and regularly monitor.

Whiteflies	Tomato, gerbera, fuchsia
Spider mites	Marigold, rose, parlour palm, bush beans
Aphids	Sweet pepper, fuchsia
Western flower thrips (WFT)	Gloxinia, gerbera, ivy geranium
Tomato spotted wilt virus (TSWV)	Petunia, gloxinia, fava beans

Disease monitoring

Monitoring and sampling tips - Submit anything suspicious. Check transplants when they begin to emerge, then as a rule of thumb visit field 2 times/week.

Get out early in the morning before the dew burns off when the fungus can be seen much more easily, in the heat of the day spores dry up and are not very conspicuous

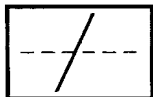
Indicator plants for visual examination and **ELISA** tests for early detection of viruses carried by **WFT** and other thrips species. Plants must be very attractive to the thrips vector, shows symptoms of infection within a few hours or days and cannot serve as a systemic host for the virus, eg some petunia cultivars Calypso.

- **Soilborne diseases and pests.**
 - **Presowing** soil tests for nematodes and Sclerotium stem rot (*Sclerotium rolfsii*) (page12).
 - **Fungal root problems**, eg each 6 weeks pick 6 randomly selected plants from approximately 200 m² of crop area; remove plant from pot to visually examine roots.
 - **Using a time series of orthophotos** (1953–2008) in combination with Landsat satellite imagery, including trend analysis, and GIS, to identify the presence of vegetation impacted by *P. cinnamomi* in WA (Wilson et al 2012).
- **Hot spots.** After a good rain, low spots, leaking irrigation systems and tractor tracks may collect water and increase humidity, so disease can gain entry to the rest of the field. Natural vegetation in field margins, house gardens and vegetation around telephone poles can host diseases and pests.
- **DNA tests kits** for virus and other diseases. **Spore assays** are used by Biosecurity.

Step 6. Thresholds

The determination of thresholds guides pest management decisions, eg when to apply an insecticide, release predators and parasites, use bio-pesticides (viruses, and fungi) and more recently, the development and testing of an area-wide management approach for the major insect pests of broad acre crops, eg *Helicoverpa armigera*.

What are thresholds?



Threshold levels are the levels at which treatment should be applied. Presence of a pest organism does not necessarily indicate a pest problem.

- The **economic threshold (ET)** is the level or density of a **pest population** where control measures need to be initiated to prevent the pest from causing **economic injury**.
 - **The ET is the pest density at which damage caused is equal to the cost of control.** Control is not warranted below the **ET**. Above the ET, the gains from controlling the pest are greater than the cost of control in most cases; all we need to do is apply enough controls to reduce the pest population to a level when it is no longer a problem. Generally, we need to manage the pests to prevent significant economic loss, not try to eradicate them.
- The **action threshold (AT)** is the point at which a decision must be made about control. When the action threshold is reached the most appropriate control strategy must be selected and implemented, eg release of parasites or use a selective pesticide. Such decisions are critical to **IPM** success. The **AT** is the most useful threshold for crop managers who have to implement control measures.
- The **aesthetic threshold** is the point at which a decision must be made about control so the appearance of produce is not affected, eg cut flowers, fruit.

Using thresholds pests and beneficials

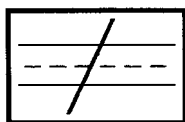
What are acceptable pest levels?

IPM involves using established thresholds and refraining from control below these thresholds. You must know the level of diseases, pests and weeds that your crops can tolerate before implementing control measures.

- **Guidelines for thresholds** are usually estimates based on research and experience.
- **Thresholds may be reviewed.** Growers often spray long before pests reach damaging levels. This is prudent practice if a grower knows from experience that 10 thrips on a sticky card will grow to 30 in a week he'll spray today. However if there is **healthy populations of predators** the thrips population will grow more slowly or may decline over time.
- **Keep good records** of thresholds of pests in the crop.
- **An IPM 'manual' written for a crop**, eg potatoes will include **action levels**. Until that threshold is reached, growers can hold off spraying to let predators and parasites wage their war against crop pests. Computer systems, local radio and daily newspapers are used to warn growers of possible pest and disease risks and encourage better crop hygiene.
- **Action thresholds or levels** may be provided by the supplier of the monitoring traps, eg suppliers of codling moth lures used to monitor populations indicate when to spray, provide population thresholds.
- **If thresholds are not available** then growers may have to:
 - **Prepare their own tolerance levels** with information provided by their traps, etc.
 - **Establish realistic thresholds.** Zero tolerance is wonderful but unattainable.
 - **How many weeds can you tolerate?** This will depend on such variables as the weed's growth cycle (annual, perennial), habit (tall, short, spreading) and where it is located (public garden, road edge or school playground), its positive (nectar source for beneficials) versus its negative roll (burrs in a children's play area).
 - **Make a best estimate** until action levels for all pests have been established.

Fluctuating thresholds

ETs values are not static but vary within a system.





On a golf course, thresholds for the same pest will be different on different areas, eg tees, greens and fairways

Most thresholds fluctuate depending upon a number of factors. Monitoring and sampling of crops is essential to determine these factors and their influence on where the threshold lies. Farmers who maintain a close watch on pest activity through regular crop inspections and thorough sampling are in a better position to decide if and when treatments are needed. The following factors should be monitored and considered when using thresholds and making spray decisions:

- **Thresholds may vary** according to the crop, variety and susceptibility of the host.
- **The condition of the crop** and the degree of damage caused under various environmental conditions.
- **Extent and severity of the infestation** and how quickly the population increases.
- **Prevalence of natural enemies** such as parasitic wasps, predatory shield bugs, ladybirds and diseases.
- **Type and location of pest damage** and whether it affects yield directly or indirectly.
- **Stage in life cycle** of the pest and the potential for damage.
- **Crop stage** and ability of the crop to compensate for damage.
- **Amount of damage** which has already occurred and the additional damage that will occur if the crop is not sprayed.
- **Anticipated crop yield or value** (high value crops cannot sustain too much damage as a small loss in yield or quality could mean a large financial loss), the cost of the spray and its application and the likely yield or quality benefit granted from control.
- **The market**, eg bedding plants for local market, export market of fresh cut flowers.
- **The cost and effectiveness of control measures** and their availability.

Step 7. Curative measures





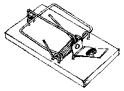
The 4th step of an *IPM* program is to **prevent or suppress** the pest, weed or disease (page 342). If prevention is not satisfactory, then further control may be necessary, this may occur during **establishment, maintenance, harvest and post harvest stages of the crop**. Once monitoring, identification, and action thresholds indicate that action is required; *IPM* programs then assess and evaluate pest management options.

<p>Threshold has been reached</p>	<p><u>Threshold has been reached for a particular pest.</u></p> <ul style="list-style-type: none"> • How serious is the threat? Is the damage economic? www.rirc.gov.au • Is management necessary? Is it a key pest? Is damage sufficient to justify control measures? Is it aesthetic? • Make a decision about whether the pest(s) needs to be controlled.
<p>Considerations</p> <p></p>	<p><u>Decision-making is based on the information</u> available from monitoring, previous experience, knowledge of the area, estimate of crop volume, market value and the current season. Control options include an understanding that:</p> <ul style="list-style-type: none"> • Legislation must be complied with. • When control is necessary, choices should be made which do not damage beneficials and the surrounding environment, or impact of control on other potential pests. • Control methods which encourage biodiversity should be used where possible. • If using pesticides, use Best Practice and Resistance Management Strategies (RMS). • Attempt to anticipate unforeseen developments resulting from control actions. • Select and implement a control option, record details. • Have the chosen control method(s) on hand ready to go.
<p>Decision support systems (DSSs) Warning services Better decisions</p> <p>Warning services Predictive services</p> <div style="border: 1px solid black; padding: 5px;"> <p>Predicting:</p> <ul style="list-style-type: none"> • Timing of certain growth stages • Harvest dates of crops • Disease, pest or weed development </div> <div style="border: 1px solid black; padding: 5px;"> <p>Remote sensing is already in use in many districts – mapping disease outbreaks, vigor, implanting's or missing vines as well as water table issues and soil temperatures. Soil moisture and multigrain moisture tester PM 4000 (2010)</p> </div> <p></p>	<p><u>Decision-support computer systems</u> for <i>IPM</i> and other management systems, eg</p> <ul style="list-style-type: none"> • <u>Interpret field-trapping data (monitoring).</u> <ul style="list-style-type: none"> • Timing of fungicides to spore release. • Spore traps have been developed that allow rapid and accurate detection using DNA techniques of fungal spores in the wind (a GRDC disease-management program and TREND, a Transect for Environmental Monitoring and Decision-Making). Data from these projects will be used to create disease predictive models and support the development of strategic disease management programs. • <u>Warning services of weather-driven diseases and pests</u> help decision making, eg <ul style="list-style-type: none"> • There is now a thorough understanding of the weather conditions under which most disease and pests of economic crops develop. Computer models take weather parameters and assess the crop risk. Apple scab is the main apple disease in most areas of Australia. Warning services are conducted in the principal apple growing districts so that the application of fungicides can be timed more effectively using post-infection curative fungicides rather than on a calendar basis. • Indicate when the pest, disease or weed is to be around. Historical records indicate seasonal variability in crop quantity and quality, indicating when to monitor. • District maps of specific weather parameters or disease risk are now a reality and can forecast individual regions. • Data can be fed from automatic stations in crops, into Decision-Support Systems (DSSs) that model the relationship between stages of development of pest insects and their surrounding temperatures for specific crops and conditions. DSSs collect, organize, analyze and interpret all types of information related to the production of the crop and eventually recommend the most appropriate action or action choices. • Spraywise Decisions (Nufarm) predict weather up to 14 days in advance for choosing when and how to spray to achieve optimum results. • Weather station / Disease Predictor (The ModelT Met Station – SARDI) can help growers make better decisions in the control of weather-driven diseases and pests in various crops. • Expert systems. DSSs for plant disease management may be a very simple data processing device or fairly complex, eg including automated weather and combinations of decisions aids and expert systems as well as multidisciplinary teams of experts. • The development of the AusVit DSS for grapes came about through the cooperation of several state departments of agriculture, universities, grower organizations and industry. • Development and usage of DSSs will become more regional rather than local. Pest outbreaks, analysis of pest outbreaks, assessment of the impact of climate change, timing of control measures and the interpretation of in-field trapping data can be forecast. • CLIMEX climate modeling pest risk analysis to underpin national and international management strategies current and control programs for pests and weeds. • TIMERITE™ RLEM for redlegged earth mite in WA predicts the optimum time for farmers to spray, to control the summer diapausing eggs. • <u>DSSs which model the relationship</u> between stages of development of pest insects and their surrounding temperatures are available for specific crops and conditions. <ul style="list-style-type: none"> • DSSs can collect, organize and integrate all types of information related to the production of the crop to subsequently analyze and interpret the information and eventually recommend the most appropriate action or action choices. • Pest outbreaks, analysis of pest outbreaks, assessment of the impact of climate change, timing of control measures and the interpretation of in-field trapping data can be forecast.

<p>Flexible decision-making Risk analysis</p>	<p>A grower's ability to adapt to climate change appears to be strongly linked to their capacity to cope with change, their social connectedness and how they use information.</p> <ul style="list-style-type: none"> • There is now a fundamental shift towards the need to manage risk better in our farming systems. • The skills emphasis has moved from a target of maximum productivity to one of setting up the crop for the potential the season provides – be that good or poor. • Flexible inputs means that fertilizer inputs depends on the expectation of crop yields that season. While crop choice is a primary management tool, on a short time scale it is inputs that must be managed carefully. <ul style="list-style-type: none"> • Nitrogen application is the most important factor for yield. Finishing rain determines the yield we have to be very flexible with Nitrogen – cautious with how much and when it is applied. If it is too wet there is the risk of denitrification and run-off, or if soil moisture is marginal.
--	--

Curative options

At each stage of the crop – Establishment, Maintenance, Harvest, Post harvest

<p>National Action Plan IPM</p>	<ul style="list-style-type: none"> • Monitoring pathogens. • Choose...BIOLOGICAL > PHYSICAL > NON-CHEMICAL > CHEMICAL • Limit chance resistance / virulence development. • No side-effects, eg try to anticipate unforeseen developments. <ul style="list-style-type: none"> • Do not damage beneficials and the surrounding environment. • Do a risk assessment on each control option as to their effect on neighbouring people and beneficial and non-target plants, insects and animals. • Sustainable pesticide application should not have a broad impact on the environment. • Appropriate, science-based measures.
<p>Cultural methods</p> 	<p>Many cultural practices (see page 29) are useful in IPM systems, eg</p> <ul style="list-style-type: none"> • Analyses of nutrients, as the crop is growing. • Irrigation scheduling and planning. • Providing optimum culture for the crop, but least favorable for the pest, eg stressed trees are very susceptible to borer infestations.
<p>Sanitation</p> 	<p>Sanitation (see page 65) is an ongoing essential part of nursery industry accreditation schemes, postharvest systems and biosecurity programs.</p> <ul style="list-style-type: none"> • Field sanitation to eliminate weed populations prevents potential migration of pests and viruses. • Roguing of diseases plants.
<p>Biological control</p> 	<p>Biological control (see page 83) should be the cornerstone of IPM where possible.</p> <ul style="list-style-type: none"> • Biocontrol programs do not have disruptive effects on the natural enemies present in the environment and so can be integrated with partially resistant varieties. • Integration of biocontrol programs with pesticides can be difficult but it can be done. • Releases of biocontrol agents must coincide with susceptible pest stages, eg eggs, larvae.
<p>Biosecurity</p> 	<p>Plant quarantine (see page 171) to keep pests out of crop areas can be one of the first avenues considered to reduce the need for other control measures.</p> <ul style="list-style-type: none"> • Do not introduce infested or infected plants, soil, etc. • Inspect and quarantine incoming plants for pest and other problems.
<p>Physical methods</p> 	<p>Physical methods (see page 229) include:</p> <ul style="list-style-type: none"> • Sticky traps to monitor some flying pests.

Pesticides



INTEGRATED PEST MANAGEMENT
At label rates and timing, CHORUS has minimal affect on predatory mites.

Beneficials can be encouraged by not spraying broad spectrum insecticides

Delay use of disruptive insecticides as long as possible.

Legal obligations regarding rates must be adhered to

Remember, though that the pesticides used must still be registered for use on that particular crop for that particular pest, and used according to label directions

Integration of pesticides with the action of natural enemies or biocontrol agents is an important part of **IPM** systems. Possible ways of selecting or applying chemicals so that they are least harmful to natural enemies include:

- Only applying pesticides when **needed**, eg after systematic monitoring of pests and their natural enemies. Be prepared to reconsider thresholds.
- Pesticides must play a **supportive** rather than disruptive role.
- Pesticides should **supplement** sound horticultural practice, not replace them.
- Only **compatible chemicals** must be used with predators. Check label.
- **Information** on which pesticides are non-toxic to the biological control agents is readily available from suppliers of biological control agents (page 130).

Preservation of natural enemy reservoirs OUTSIDE pesticide treated areas.

- **Ideally the natural enemies should be preserved within** the treated areas, but if broad spectrum pesticides such as Malathion[®] (maldison) are used, reliance may have to be placed on reservoirs **outside** treated areas. **The success of this depends upon the powers of dispersal** and searching abilities of the natural enemies, eg certain *Aphelinus* wasp parasites of scale insects are believed to disperse no more than a few yards annually. Maintain reservoirs in nearby crop environments or on weeds.

Preservation of natural enemy reservoirs WITHIN pesticide treated areas may be achieved by **incomplete spray coverage** of plants which may be obtained by:

- **'Spot' treatment of areas** with a high pest population causing economic damage.
- **Systematic treatment of the crop with 'staggered' treatments**, eg alternate pairs of trees or strips of field crops may only be sprayed.
- **Spraying only a portion of the plant itself**, eg only the upper or lower portion.

Complete spray coverage of plants. If all plants in a crop are to be sprayed, chemicals preferably should be **selective**.

- **Pesticide applications are usually dictated by the life history of the PEST.** Commonly pesticides are applied when pest eggs have hatched or when the pest is in the adult stage. Parasites are not usually active at this time but predators are. This method of preservation of natural enemies is more likely to work well when there is only one generation of pest a year or when there are not too many overlapping generations.
 - Do not spray at the first sign of mite activity, eg be prepared to suffer minor mite damage in the center of say orchard trees; this will not affect your present or future crops.
- **Pesticide applications and the life history of PARASITES AND PREDATORS.**
 - **Eggs are generally relatively resistant** to pesticides, even when in direct contact.
 - **Predatory insects** are not usually affected by **systemic pesticides** once they have entered the plant, though the initial contact can be harmful and they may be killed if their prey accumulates enough of the toxic material (uncommon).
 - **Adult stages of parasitic insects** are generally much more susceptible to insecticides than the larval and pupal stages which are often concealed and protected from **non-systemic (contact) pesticides**.
- **Characteristics of the pesticide.**
 - **Label directions** may indicate the effect on predators and parasites.
 - **Persistence.** Even when 2 chemicals are non-selective in a physiological sense, the less persistent one will be preferable. This applies not only to the crop sprayed but also to any adjacent areas if drift is likely. Natural enemies are susceptible to accumulations of persistent insecticides which drift into their habitats.
 - **Contact pesticides** such as soaps and oils are relatively safe to beneficials if used as spot sprays.
 - **Selective chemicals specific towards a particular pest** which have a narrow spectrum of activity but not harmful to natural enemies and other insects are ideal. **Broad spectrum chemicals** can be responsible for resurgences of established pests and upsurges of previously unknown or unimportant pests.
 - **Insect growth regulators are generally friendly towards beneficials.** Their target is immature stages so they have little effect on adult beneficials, eg azadirachtin, kinoprene.
 - **Lowering the rate** could reduce the period during which the crop retains residues harmful to natural enemies, **BUT** as parasitic and predatory insects are usually more susceptible to pesticides than are the pests, it would be possible to eliminate the natural enemies with lowered rates but not the pest. Pest flare-up may occur quickly.
 - **Some formulations** may be more toxic than others to natural enemies, eg granulated formulations and seed dressings, where appropriate, are less harmful than most other formulations. Wettable powders are safer than emulsifiable concentrates.
 - **Most wetting agents** are like soaps and can turn non-toxic products into contact killers.
 - **Bio-pesticides** have minimal effect on beneficials and are an important part of **IPM**, eg *Bacillus thuringiensis* (Dipel[®]), superior horticultural oils, petroleum spray oil.
 - **Chemicals have been rated for their environmental impact**, eg water solubility, persistence and potential impact on non-target organisms, eg bees, birds and fish. **Public Release Summaries** produced by the **APVMA** for new chemicals registered in Australia include such information (see also page 130).
 - **Pesticide applications** can be timed to optimize effect on pests but minimize effects on natural enemies, eg apply petroleum oils in winter on deciduous trees to control scales.
 - **Application equipment** must be well maintained and calibrated so that the correct amount of spray is applied and wastage prevented.

Step 8. Evaluation (3rd party audit)

Key Performance Indicators (KPIs) Audit criteria



A KPI is simply a measure of performance, eg it defines and evaluates how successful a program is in terms of progressing towards its long-term goals. So the **KPIs** depend on the type of organization and its strategy, but if they are to be of any value there must be a way to **accurately define and measure them**. What are you going to measure? Their measurement must be controllable by the organization and individuals.

Evaluation of an IPM system is essential. Was it effective?

- **Audit the IPM system using a checklist** compiled from what it is that you want to achieve from the **IPM** program (Table 24). Each part of the **IPM** program must be audited. What are you going to measure?
 - **An audit** is an evidence gathering process. Audit evidence is used to evaluate how well audit criteria are being met. Audits must be objective, impartial, and independent and the audit process must be both systematic and documented. There are several different types of audits, check which one you want (see page 322).
 - **Audits** on their own, may not be sufficient to indicate that an organization's performance not only meets, but will continue to meet, its legal and policy requirements.
 - **Audits and reviews** need to be conducted within a structured management system and integrated with overall management activity.
- **Management review and improve**, eg
 - If everything is satisfactory then no action is required.
 - If some items are unsatisfactory, then action is required and **IPM** strategy may need adjusting. Discuss with other farmers what control or management they may have used and how it worked. Review goals of IPM.
- **Recommendations for improvement next time round** may include:
 - More training of pest scouts, or using professional pest scouts.
 - Better communication between growers, pest scouts, researchers and others in industry.
 - Improving community / public knowledge.
 - Seeking expert help.
 - **The pests**. Ongoing research is essential to the success of **IPM** as pests and natural enemies are part of a complex and dynamic process. **New pests** appear from time to time and the **status of existing pests** may alter with changes in growers' practices, varietal selection and so on.
 - **Control methods**, eg use disease-tested seed, grow a different crop or different variety, or treat seed. Plant later, stagger planting dates and varieties with different maturity dates to spread risks.

Table 24. A summary sample checklist for evaluating your **IPM** system.

IPM COMPONENTS	YES	NO	ACTION
1.PLANNING Was a plan of IPM prepared? Records kept of details of action. Training, resources, etc. What can be audited?	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
2.CROP Is the crop all the same variety?	<input type="checkbox"/>	<input type="checkbox"/>	
3.IDENTIFICATION Were key pests, diseases, weeds and beneficials identified? Were soil, water and other tests carried out?	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	
4.PREVENTION Preventative control measures at each crop stage	<input type="checkbox"/>	<input type="checkbox"/>	
5.MONITORING Was monitoring done as scheduled? Was monitoring repeated on occasion to ensure accuracy?	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	
6.THRESHOLDS Are thresholds of weeds, pests, diseases or beneficials available?	<input type="checkbox"/>	<input type="checkbox"/>	
7.CURATIVE DECISION-MAKING Was the release of biocontrol agents / timing of sprays based on thresholds? Were sprays selected non-toxic to biocontrol agents?	<input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/>	
8.EVALUATION – all stages Was the quality and profitability of the crop evaluated? Were the control measures effective? Was the evaluation appropriate?	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	

EXAMPLES OF INTEGRATED MANAGEMENT

Crops and situations

Sometimes this is called **Integrated Crop Management (ICM)** but there is no official definition. However, in almost all cases these programs includes specific objectives such as **IPM**, **Best Management Practice (BMP)** and the use of beneficial organisms for the control of various diseases, insect pests and weeds; fertilisers are applied only after testing and pesticide use is limited. They are considered to fit somewhere between conventional and organic production (page 376, Agra Consulting 2002).

Most States and Territories have online **management** programs for **field crops, ornamentals, nursery production, fruit and vegetables**. Industry Biosecurity Manuals are also available online for key industries (page 187).

<p>Apples & pears A Biosecurity Industry Manual is also available</p>	<p>An excellent IPM program for Australian Apples & Pears compiled by Hetherington (2009) and published by NSW Industry & Investment and Apple and Pear Australia is available online. There are colored plates and illustrated Fact Sheets for specific pests and pathogens providing identification, the damage, prevention and management. A section gives information for reducing the impact of specific pests. There are 6 steps to controlling diseases and pests of apple and pears:</p> <ol style="list-style-type: none"> 1. Prepare and prevent. Prepare the orchard, eg machinery, soil, water and other tests, cultural requirements and sanitation, resistant and disease-tested varieties and rootstocks, fertilizers and pesticides available. 2. Have a pest management plan for the season. 3. Monitor. 4. Take action only if you need to. 5. Evaluate the season. 6. Plan for the next season.
<p>Vegetables Integrated crop management (ICM) Also available: Pest and Disease Management (DAFWA) Vegetable Integrated Pest Management (NSW Industry & Investment.)</p>	<p>ICM is becoming increasingly important for vegetable production to control diseases and insect pests. ICM includes the principles of IPM including the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:</p> <ul style="list-style-type: none"> • Minimise the impact of pesticide resistance developing. • Satisfy the consumer's desire for minimum residues in food. • Reduce environmental impacts. • Limit possible restrictions in trade (domestic and export).
<p>Nursery crops A Nursery Production Integrated Pest Management program and Biosecurity Industry Manual are available</p>	<p>IPM strategies are difficult to develop for nurseries because so many different types of plants are grown. Strategies include:</p> <ul style="list-style-type: none"> • Identifying the key economic pests, eg black fungus gnats, shore flies. • Monitoring, eg using sticky traps to monitor for pests, checking / changing weekly. • Establishing thresholds, eg thresholds will be different for different hosts. • Decision-making, eg the option of implementing a range of non-chemical controls (Table 25 below), ie releasing biological control agents, applying bio-insecticides, as well as other pesticides non-toxic to the natural enemies and biological control agents. <ul style="list-style-type: none"> • Suppliers of biological control agents, bio-pesticides, lures and pheromones for various diseases and pests are listed on page 125. • Some growers might wish to implement organic standards (page 381) and / or BMP (Best Management Practice) (page 363). • Evaluating the IPM program.

Table 25. Some non-chemical control methods commonly used in nurseries.

CONTROL METHOD	EXAMPLES AND COMMENTS	
Cultural methods	<ul style="list-style-type: none"> • Monitor environmental conditions. • Ideal conditions for plant growth but not for pests. 	<ul style="list-style-type: none"> • Adequate ventilation to prevent fungal diseases. • Avoid wet plant surfaces for extended periods.
Sanitation	<ul style="list-style-type: none"> • Clean propagation facilities, sealed surfaces are preferable, well drained aggregate. 	<ul style="list-style-type: none"> • Remove all dead / diseased plant material to prevent damping off, Botrytis and other diseases.
Biological control	<ul style="list-style-type: none"> • Biocontrol agents are available for many pests. 	
Resistant varieties	<ul style="list-style-type: none"> • For rust and other fungal diseases. 	
Biosecurity	<ul style="list-style-type: none"> • Pests, disease organisms and weeds are introduced into nurseries with seeds, cuttings, plants, or in soil. 	<ul style="list-style-type: none"> • Inspect incoming plants for mites, mealybugs etc. • Isolate and treat infested or diseased plants.
Disease-tested planting material	<ul style="list-style-type: none"> • Only plant disease-tested planting material in disease-tested media, test water. 	
Physical methods	<ul style="list-style-type: none"> • Screen greenhouses to prevent insects entering. • Yellow traps attract whiteflies; blue traps attract WFT. 	<ul style="list-style-type: none"> • Pasteurize media to prevent damping off diseases or use soil-free media.
Pesticides	<p>If using herbicides, fungicides or insecticides check:</p> <ul style="list-style-type: none"> • Registration. • Toxicity and hazard to operators and staff, re-entry. 	<ul style="list-style-type: none"> • Toxicity to predators. • Persistence. • See also Selection Criteria, page 30, 349.

Integrated Pest Management (IPM)

<p>Virus vectors</p> <p>Sanitation Resistant varieties Disease-tested Biocontrol/insecticides</p>	<p>Tomato spotted wilt virus (TSWV) spread by thrips is among the 10 most damaging viruses infecting vegetable, legume and ornamental crops worldwide. The crops most frequently and severely affected are tomato, capsicum, lettuce, potato and peanut. IPM of TSWV aims to prevent or reduce the levels of disease in crops. Methods include:</p> <ul style="list-style-type: none"> • Crop and farm hygiene to destroy alternative hosts of the virus and thrips vectors. • TSWV resistant varieties are available for capsicum, tomato and potato. • Using virus-tested planting material including virus free vegetable transplants. • Manage thrips through insecticides or biological control, seek advice.
<p>Biorational insecticides</p> <p>Biorational IPM Organic IPM</p>	<p>Insecticides vary in their toxicity and in their potential ecological impact. Pest control materials that are relatively non-toxic to people with few environmental side-effects are sometimes called “biorational” pesticides (see also pages 438).</p> <ul style="list-style-type: none"> • The “biorationality” of an insecticide is almost always relative, i.e., the toxicity of one insecticide is compared to that of other insecticides, or is almost never broad spectrum, ie an insecticide can be non-toxic to one natural enemy or even some life stages of one natural enemy but can be toxic to another natural enemy or other life stages. • Traditionally, soaps / detergents, oils and botanicals (neem products made with azadirachtin extracted from neem tree seeds) have been termed biorational. • However systemic insecticides, insect growth regulators and products containing Bt (<i>Bacillus thuringiensis</i>) or its components would be included.
<p>Mice plagues</p> <p>IPM systems have been prepared for many other vertebrate pests</p> <div style="border: 1px solid black; padding: 5px; width: fit-content;"> <p>National Mouse Management Working Group, Invasive Animals Cooperative Research Centre and South Australian Mouse Working Party</p> </div> <p>GRDC Fact Sheet: Mouse Control. Sept 2011</p>	<p>Maturing crop damage by mice is most extreme around flowering and seed set.</p> <ul style="list-style-type: none"> • Monitoring for mouse damage in maturing crops is critical. Mouse numbers can change rapidly, monitor through and between seasons. • Baiting is the currently the only option for in-crop control of mice and is advised as soon as damage is noticed, particularly in areas where autumn mouse densities are high. <ul style="list-style-type: none"> • Zinc phosphide is the only active constituent registered for in-crop use. • Breeding usually begins when crops set seed and juvenile mice will emerge into crops 5 weeks later. • Mice can range over large areas, so monitoring 7-10 days after baiting is critical to identify damage from invading mice. • Baiting maturing crops is effective but kill rate may be lower. New research shows reduced mouse bait efficacy in mature crops, but results may be improved by baiting at night. However, ants may remove baits spread at night. • Baiting pre-sowing and at crop emergence achieves high levels of control but re-invasion can occur. • Hygiene at harvest includes setting harvesters to minimize grain loss and the control of summer weeds (the green bridge) are important if populations are to decline before next autumn. Availability of quality feed can drastically extend the breeding season.
<p>Stored grain</p> <p>Monitoring Exclusion</p> <p>Sanitation</p> <p>Physical</p> <p>Fumigation</p>	<p>Under favorable conditions a single pair of stored grain insects can become a raging infestation in 3 months and Australian conditions can be favorable for grain insects for much of the year. Recommended pest control include:</p> <ul style="list-style-type: none"> • Early identification and monitoring of pests, eg inspection, trapping. • Keeping new insects out of the store. Sealing the storage and maintenance of hygiene around storage. • Eliminate contaminating insects in harvesting, transport, handling and storage equipment. • Making the storage hostile to pests. Aeration-cooling, storage of dry commodity, white painted bins, grain protectant application, removal of insect refuges around store. • Killing all insects in the storage area and in the commodity. Fumigation is central to stored grain pest control. Phosphine is the only fumigant widely available for on-farm fumigation and will kill all species of all ages of grain insects (eggs, larvae, pupae and adults) if the phosphine is retained in stored grain long enough by adequate sealing the storage area. Before purchasing a storage facility check that it has adequate sealage.
<p>Be proactive</p>	<p>Be proactive, growing crops is becoming increasingly complex.</p> <ul style="list-style-type: none"> • Make sure you can document IPM strategies already in use in Australia. • Evaluate the actual and potential benefits of IPM to Australian agriculture and horticulture. • Seek advice and access guidelines on how to develop IPM programs for your crop. • Seek professional advice on how to reduce reliance on chemicals.

Integrated Disease Management (IDM)

<p>Fungal diseases in ornamentals</p> <p>Using only one method to control fungal diseases will not be effective</p>	<p><u>Disease control in ornamentals can be difficult for several reasons</u>, eg</p> <ul style="list-style-type: none"> • Many ornamentals are vegetatively propagated and so more prone to disease infestations than sexually propagated materials. Vegetatively propagated material has greater uniformity with a potentially greater severity of disease. • Often during production, ornamentals are grown closely together which means a greater potential for disease spread and more inoculum. Note that the effectiveness of a fungicide increases when the inoculum potential decreases. • Sometimes management practices like recirculated water can increase the frequency of <i>Phytophthora</i> and <i>Pythium</i>.
<p>Predicting soil borne diseases Test before you plant</p>	<p><u>Estimation of the risk of soilborne diseases</u> enables a grower to avoid disease by selecting another field, manage diseases by crop rotation, modifying the environment, select a resistant variety or use chemical control measures, eg seed treatments.</p> <ul style="list-style-type: none"> • Where risk of soilborne diseases exists, monitoring disease development of certain pathogens can permit control measures to be implemented to minimize disease development in the following crop.
<p>Invasive potential Irish blight</p>	<p><u>The invasive potential of Irish blight</u> (<i>Phytophthora infestans</i>) in different crop situations is characterized by:</p> <ul style="list-style-type: none"> • Proportion of potato cropping and proportion of susceptible potato varieties. • Field size, shape and orientation. • Clustering of potato fields. • Local epidemics in one field and regional epidemics across fields. • Strong interactions between weather and landscape configuration. • Major variation between years is to be expected. • R-gene preservation during the 20-odd years of breeding.
<p>Integrating sugarcane with vegetable crops Where these industries coexist</p> <p>Reducing nematode and soilborne disease problems</p>	<p><u>A sugarcane farming system based on residue retention, minimum tillage, a leguminous rotation crop</u> and controlled traffic using global positioning guidance is currently being adopted by the Australian sugar industry. It improves sugar yields, reduces costs and provides additional income from crops such as soybean and peanuts. There are beneficial effects on soil carbon levels and soil biological properties (Stirling 2008).</p> <ul style="list-style-type: none"> • <u>Breaking the sugarcane monoculture</u> with a soybean or peanut crops can reduce populations of lesion nematode (<i>Pratylenchus zaei</i>) and root knot nematode (<i>P. javanica</i>), the 2 most important nematode pests of sugarcane. • <u>The vegetable industry</u> currently uses a farming system for crops such as tomato, capsicum and rockmelon, where inadequate crop rotation, excessive tillage, low organic inputs and the fallowing and solarization effect of covering beds with plastic, leads to a situation where soil fumigations is seen as the only option for reducing losses from soilborne pests and pathogens. • <u>Developing minimum tillage practices for vegetable production</u> and integrating then with the sugarcane farming system could improve profitability in both industries, produce better environmental outcomes at a landscape level and provide more sustainable solutions to nematode and soilborne disease problems.
<p>Diseases of vegetables General principles of IDM</p> <p>Also consider:</p> <ul style="list-style-type: none"> • Avoid introducing contaminated soil etc • Conservation tillage? 	<p><u>Disease management aims to combines a range of suitable methods</u> to obtain effective, economically sound disease control with minimal environmental risk (Persley et al 2010).</p> <ul style="list-style-type: none"> • <u>Selection and establishment</u> <ul style="list-style-type: none"> • Diagnostics, carry out soil tests before planting. • Select resistant varieties, if available. • Source-disease-tested seed or transplants, otherwise heat treat seed if bacterial diseases are a major problem. • Chemical and physical treatments such as fumigation, solarization and mulching reduce levels of soilborne pathogens prior to planting. • Seed treatments with fungicides and insecticides or bioinoculants where necessary. • Rotate crops. Avoid double cropping or cropping after crops in the same family. • Manage weeds within crops and in surrounding crops, particularly those that host diseases that affect your crop. • <u>Maintenance</u> <ul style="list-style-type: none"> • Apply optimal water and nutrient requirement (confirm by water, soil and tissue analysis). • Practice good sanitation, eg chip or remove diseased plants. • Manage virus vectors when virus is present in the crop or in a neighboring area. • Use preventative fungicides when diseases are constantly a problem, otherwise apply fungicides after monitoring or when conditions are conducive and symptoms evident. • <u>Harvest and post harvest</u> <ul style="list-style-type: none"> • Minimize mechanical damage of growing plants and harvest produce. • Ensure good sanitation practices are followed when washing produce. Change wash water regularly to ensure that disinfectant efficacy is maintained. • Harvest crops in cooler conditions and rapid postharvest cooling will minimize post-harvest breakdown. • Plough in crop residues soon after harvest. Researchers are looking at ways of incorporating conservation tillage in IDM programs for vegetable growing.

<p>Nursery industry</p> <p>Sanitation</p> <p>Sanitation Disease-tested</p> <p>Monitor and record Biosecurity</p> <p>Biosecurity</p>	<p><u>The Nursery & Garden Industry Qld says that as growers are producing many plants</u> that are within the same genus as some of our major food and fiber crops, regulators are paying greater attention to biosecurity in the ornamental horticulture industry. There are some simple steps to preventing pests and diseases (Thomas, S. Aust. Hort. Dec 2004).</p> <ul style="list-style-type: none"> • Doing things differently can reduce the risk of diseases and pests, eg ensure high hygiene areas such as propagation houses are done first. Ensure staff wash hands thoroughly; that clothing is free of vegetative material, growing media, insects, etc before beginning work. Clear up rubbish at the end of each day. • Equipment hygiene. Disinfect secateurs, nursery trays. • Check you source. Source stock from known reliable nurseries. If buying from a new supplier it is recommended that you get customer references from them and verify them, visit them if possible, use industry contacts to find out who has dealt with them and if they are satisfied. Preferably deal with Nursery Industry Accreditation Scheme Australia (NIASA) accredited businesses. • Monitor and record to detect any problems, rots, pests, etc. • Some recommend applying a broad spectrum insecticide and fungicide upon stock entering the nursery – allow quarantine of 21 days rule of thumb. This is a bit draconian but some sort of quarantine and management is requirement if the source is unreliable. • Visiting other nurseries is good for networking and getting ideas but there is the risk of transfer of pests and diseases. Footbaths (clean boots first), control movement of staff and visitors, control vehicle movement, clean vehicles.
<p>Foliage diseases of cereals</p> <p>Environment</p> <p>When to intervene</p> <p>Fungicides</p>	<p>A <u>nationally accredited training workshop</u> for grain advisers on the management of cereal foliar diseases has been developed (GRDC Growers Report 2010-2011 <i>Training advisors for the fight against foliar diseases</i>). Course participants learn to:</p> <ul style="list-style-type: none"> • Identify and name key cereal growth stages and emergence of leaves. • Relate the impact of environment and day degrees on crop and disease development, to the economic management of foliage diseases in cereals. • Relate the impact of the environment on plant part contribution to yield and economic management of foliar disease. • Identify canopy management interactions and be able to relate this to the decisions on foliar disease management. • Identify key intervention points for disease management in cereals and relate this to environment and genetics to formulate cost-effective disease management plans. • Understand mode of action of key fungicide groups.
<p>Salinity No single solution can be applied everywhere</p>	<p><u>Monitor the ground water levels and the amount of salt in the land and water in areas</u> where a salinity hazard map has identified a high level of hazard. Encourage preventative action by landholders to stop salt moving to the surface, stop the further loss of deep-rooted native vegetation in both high hazard areas and in those areas that contribute ground water to them, etc.</p> <ul style="list-style-type: none"> • Some salinity problems can often only be prevented and managed on regional basis, eg a National Action Plan for Salinity and Water Quality to tackle salinity problems. People in 21 priority regions will be helped to develop regional plans to control salinity and improve water quality and will include measures appropriate for the local area and national objectives.
<p>Sugar industry and diseases – a bit of history but still useful today</p> <p>Biosecurity Disease-tested</p> <p>Rogueing</p>	<p><u>Between 1920-1950 the Qld sugar industry was troubled by many of the serious diseases</u> of sugar cane, often in serious proportions (Griggs 2008). The CSR and Qld Bureau of Sugar Experiment Stations (BSES) responded by researching the diseases and devising control strategies to reduce their impact which included:</p> <ul style="list-style-type: none"> • The establishment of quarantine districts and • Restriction on the movement of cane plants. • Use of disease-tested planting material. • Pre-treatment of planting material with hot water and / or solutions of fungicides. • And rogueing of diseased cane plants.
<p>Viral disease management in vegetables</p> <p>Prevent or delay infection</p>	<p><u>Surveys have found that virus diseases are an important cause of loss</u> to the vegetable industry. Crops which are often severely affected include cucurbits (papaya ringspot, watermelon mosaic, zucchini yellow mosaic viruses); capsicums and lettuce (tomato spotted wilt virus; lettuce big vein disease) (Persley 2011).</p> <ul style="list-style-type: none"> • Plants cannot be cured once infected. • Management of viral diseases requires an integration of several methods aimed at preventing or delaying infection of crops. • Best practice guidelines have been prepared by industry experts, as part of an IDM project. Information on best practice is being provided to growers and consultants through reference material, technical papers, regional information sessions, field days and personal networks.
<p>Myrtle Rust Management Plan</p>	<p>This plan (2012) provides a detailed framework for growers and retailers to apply on-site for the management of Myrtle Rust on all plants from the Myrtaceae family (this plan is available online on the NGIA website under publications). www.ngia.com.au</p>

Integrated Weed Management (IWM)

IWM is a system of managing target weeds over the long term, to stop them reproducing and spreading, and minimizing herbicide resistance in an economic and sustainable manner. Before deciding whether or not to include a herbicide in your control program you need some knowledge about herbicides and understand their relevance in an IWM program. The future of weed control is discussed by Guenther (2013).

<p>Planning</p> <p>There is never going to be one prescription that suits all situations</p>	<p>Like all successful IWM programs the plan must be:</p> <ul style="list-style-type: none"> • Flexible – able to respond to seasonal conditions. • Based on good understanding of the target weed’s characteristic and life cycle. • Uses a mix of weed control tactics which complement each other to maximize their effectiveness, eg a problem weed in a small area could be managed chemically (herbicide), physically (mow or hoe out), biologically (release control agents) and culturally (replant desirable vegetation). • Regularly implemented at the right time. • Based on knowledge of the site, climate, soil and history. • Cost-effective and linked to long term land management goals, so must be evaluated.
<p>Resistance and Integrated Management (RIM)</p>	<p>RIM evaluates the performance of different IWM practices over many crop cycles, eg the effect of early vigor wheat lines with different levels of suppression on the buildup of the weed seedbank. Early vigor achieves sustainable levels of weed control of ryegrass when used as part of IWM, eg using a wheat cultivar with 30-50% additional weed suppression, sowing at a high seeding rate and windrow burning.</p>
<p>IWM program for particular weeds</p> <p>General rules</p> <p>Plenty of programs</p> <p>What you need to know about herbicides includes:</p> <ul style="list-style-type: none"> • Toxicity. • Classification of herbicides. • Selectivity. • Mode of action. • Timing of application. • Persistence of herbicide. • Effectiveness. 	<p>Ensure compliance with legislation. Management includes:</p> <ol style="list-style-type: none"> 1. Prevention: Weed-resistant landscape, regular monitoring at good monitoring sites, training, hygiene with respect to persons, tools and machinery, disposal of weeds, animal feed and seed and planting stock (weed-tested seed). 2. Site assessment. Establish exact location with GPS, identify use of site, identify weeds and map them, why are the weeds present? Identify risks, local indigenous flora and fauna and seriousness of the threat, eg Weed Risk Assessment (page 181). 3. Strategies. Determine weed priorities (ability to establish), competitiveness once established, likelihood of long distance dispersal (wind, water, livestock, wildlife, machinery), extent of reduction in desired vegetation caused by the weed, potential losses or damages to agricultural and feasibility of control measures. 4. Implementation. Set measurable objectives, and maintain a long term perspective, eg priority, resources available, most effective management options, minimize environmental damage, make the site more resilient to weed invasion. 5. Monitor, evaluate and review performance. Identify the performance indicators, rate of spread or contraction of weed infestation, rate of establishment of desirable vegetation and identify any new weed threats that may affect site restoration. What monitoring needs to be done to measure the effect of the control measures?
<p>Tactical groups</p> <p>Weed life cycles</p> <p>Enhance the impact of weed management to optimize crop growth</p> <p>A tactic group is a plan for attaining a particular goal, for maintaining an advantage</p> <p>Biosecurity</p> <p>Biosecurity</p>	<p>Just as herbicides can be grouped by mode of action groups, weed control methods can be grouped according to their main aim. This concept of Tactic Groups creates new options for weed management and has been designed to challenge the focus from crop yield to weed life cycle (CRC for Australian Weed Management, Fact Sheet 2005).</p> <p>Using Tactic groups to manage weeds in NON-CROP situations (weeds around the place):</p> <p>Tactic 1. Deplete weed seed in the target area soil seedbank, by encouraging germination of seed, by burying, soil disturbance, burning, grazing, biocontrol, predation and physical removal.</p> <p>Tactic 2. Kill and remove weeds and weed seedlings from target area, eg physically removing, cultivating or applying herbicide to weed seedlings, burning or cutting older weeds. Increasing competition from desirable vegetation by planting desirable competitive species to replace weeds, improving competition by using appropriate plant densities, fertilizer, disease and insect control, mulching.</p> <p>Tactic 3. Stop weeds setting seed while minimizing the effects on desirable vegetation by herbicide techniques (wiping, selective spray, top spraying), hand rogueing, spray graze, strategic cutting or pruning).</p> <p>Tactic 4. Prevent viable seeds from existing weeds from being added to the soil seedbank by physical removal of viable propagules from the target area, eg seed heads or fruits by picking, cutting, burning.</p> <p>Tactic 5. Prevent introduction of viable weed seed from external sources by improving hygiene to prevent entry of new weeds, on vehicles, mowers, weed-tested seed.</p> <p>Using Tactic groups to manage weeds in IN CROP situations:</p> <p>Tactic 1. Deplete weed seed in the target area soil seedbank by burning residues, encourage insect predation of seed, inversion ploughing, autumn tickle, delayed sowing.</p> <p>Tactic 2. Kill weeds (seedlings) in the target area. Fallow and pre-sowing cultivation, herbicide, weed control in wide row spacing, spot spraying, chipping, hand rogueing and wiper technologies, biological control.</p> <p>Tactic 3. Stop weed seed set. Mow or graze before seed set. Also pasture spray topping, silage and hay, renovation crops and pastures, green manuring, brown manuring, mulching and hay freezing, grazing, actively manage weeds in pastures.</p> <p>Tactic 4. Prevent viable weed seeds in the target area from being added to the soil seedbank. Weed seed collection at harvest, grazing crop residues, etc.</p> <p>Tactic 5. Prevent introduction of viable seed from external sources by on-farm hygiene, clean farm machinery and vehicles and manage livestock feeding and movement. Washing mowers, tractors (is it practical?); weed-tested seed.</p>

<p>School grounds?</p> <p>Since most weed tolerance levels are subjective, have a representative group to reach a consensus. Weed tolerance levels can be re-evaluated on an annual basis</p> <p>Cultural methods</p> <ul style="list-style-type: none"> Select plants Plant competition, ground covers <p>Physical</p> <ul style="list-style-type: none"> Hand weeding Mowing Flaming <p>Herbicides (?)</p> <p>Evaluate effectiveness</p>	<p>The components of effective weed monitoring (Property Care Industry) include:</p> <ul style="list-style-type: none"> Mapping weed habitats. The first step in monitoring is to map areas where weeds are growing. This need not be a too detailed, time consuming process – a rough map will do. Identifying the most common weed species in your school grounds to determine appropriate management methods. Keep records of when a particular species appears or flowers, when to treat, etc. <ul style="list-style-type: none"> Which weeds and how many of each can be tolerated in a specific area without them impairing the function of the grounds? Are weed populations rising, falling or staying about the same each year. If new species of weeds are becoming a problem (this often happens as a result of weed control efforts), determine the long-term effectiveness of management methods. Establishing weed tolerance levels (thresholds). It is not necessary to suppress all weeds, even if that were desirable. Adjust aesthetic standards to take this into account. <ul style="list-style-type: none"> Facilitate long term plans and provide justification for weed management action - or lack of action. Identify areas where weeds pose potential health and/or safety hazards or threaten damage to facilities, assign low tolerance to weeds in that area and place a high priority on their management. Assign higher tolerance levels to weeds growing in shrub beds or along fence lines and lower priority for their management. Long-term weed management plans. Availability of herbicides has often helped perpetuate poor landscape designs and inappropriate maintenance practices. Better to change design specifications for landscapes etc. Evaluate long term costs, risks and benefits. Management options include: <ul style="list-style-type: none"> Plant selection. In shrubs you can include groundcover with rapid spreading growth habits that can out-compete weeds. Manipulate planting techniques and cultural practices so that desired vegetation grows densely and vigorously crowding out weeds. Competitive interplanting. When shrubs or groundcover are installed, the spaces between individual plants are often colonized by weeds before the ornamentals can spread and shade them out. Mulches are primarily used to exclude light from the soil thus limiting weed seed germination. Hand-pulling, cultivation, string trimmers and mowers are very effective for weed control. Groups can adopt a section of the school yard to maintain and beautify. Eliminate weed habitat. Creating a “mow strip” under and immediately adjacent of fence lines can solve a common weed problem. Flaming. Flamers are used by a growing number of parks and school districts to treat weeds in pavement cracks, under picnic tables, etc. to sear tops of young weeds. Flaming can be hazardous (page 242). Herbicides. There is a growing trend school grounds to be designated pesticide-free places. If considered necessary, apply during school holidays. Trained applicators should use colorant to mark treated areas and help passers-by see and avoid the treated area. Post a sign. Check toxicity, registration and legality. Seek professional advice.
<p>Salvinia – a WONS</p> <p>Biocontrol & herbicides Physical methods</p>	<p>Salvinia at one stage entirely covered a man-made lake near Bundaberg in Qld. Council began an eradication program including:</p> <ul style="list-style-type: none"> Introducing salvinia weevils and spraying which achieved some effective results. As a section of the lake became salvinia-free, a floating barrier of PVC piping was installed preventing salvinia from re-infesting the lake making it easier to spray remnant sections. Several 2 sq meter pontoons with mesh bases were built to float on the lake, plants including melaleucas were put on the pontoon with the base of the pots in the water allowing roots to draw nutrients from the lake making the water in the lake became less favorable for salvinia to grow.
<p>Depleting the seedbank</p>	<p>Brome grass is a persistent but manageable weed in some cropping areas. Control is achieved in break crops and by growing wheat varieties tolerant to imidazolinone (Clearfield) herbicides. Aim for 2 consecutive years of control to deplete the seedbank of this troublesome weed (Penfold 2011).</p>
<p>Six Practices on-farm biosecurity</p> <p>Disease-tested Sanitation</p> <p>Monitor</p>	<ol style="list-style-type: none"> Be aware of biosecurity threats – make sure you and your workers and contractors are familiar with the most important weed threats and grain pests. Conduct a biosecurity induction session to explain hygiene practices for people, equipment and vehicles. Ensure seed is weed and pest free and preferable certified. Keep records of farm inputs. Keep it clean – Sanitation. Practicing good sanitation and hygiene will help prevent the entry and movement of weeds and pests onto you property. Workers, visitors, vehicles and equipment can them so decontaminate before entry and leave the farm. Have a designated area and provide vehicle and personal disinfecting vehicles. Check your crop – monitor and check your crop frequently. Know the new weeds, pests, and diseases, etc that you have to keep a look out for. Abide by the law – legislation. Report anything unusual. What are the usual pests, diseases and weeds which in occur your crop? Exotic Plant Pest Hotline 1800 084 881.
<p>Invasive plants</p>	<p>The Nursery & Garden Industry Invasive Plants Position document sets out the industry's commitment to helping the community tackle the issue of invasive garden plants. It also outlines how governments and authorities can assist in this regard. www.ngia.com.au</p>
<p>Australian Weeds Committee (AWC)</p>	<p>AWC is a cross-jurisdictional committee with members from the Australian Government and State and Territory governments resolving weeds issues at a national level. It oversees the administration of the Australian Weed Strategy (AWS).</p>

PROS AND CHALLENGES

PROS

- **A new logo** for **certified IPM** has been developed.
- **IPM** offers long term management of pests, diseases and weeds with minimal off-target effects.
- **Adoption** and interest in adopting **IPM** has increased.
- Reduced risk of emerging secondary pests.
- Maintains a better balance between the pests and their natural enemies.
- **Reduced dependence on pesticides** which:
 - Reduces worker exposure to pesticides.
 - Reduces pesticide residues in fruit and vegetables.
 - Reduces environmental contamination.
 - Improves safety for the community.
 - Delays the development of pesticide resistance due to their less frequent use.
 - Greater customer confidence and social benefits.
- **Growers develop a thorough knowledge** of pests and beneficials present in their crop.
- **Potential marketing advantages** for 'clean and green' produce grown with minimum pesticide use.
- **IPM is a component** of organic and environmental standards and **BMP**.
- Unlike organic growing, **IPM** does not seek to eliminate all chemicals from control programs.
- **IPM is part of the national strategy** for the management of agvet chemicals in many countries.
- **IPM is available** for an increasing number of crops.
- **IPM** can result in production of high quality citrus fruit in Qld at less cost to the grower than the cost of chemical control programs.
- The problem may **not** require control. Below a predetermined threshold, control is not justified.

CHALLENGES

- **Software.** Farmers need to learn to use software by attending courses, etc. Software has reduced the time taken to plan inputs and retrieve key information re planting dates, etc. Record keeping is very simple.
- **Monitoring** must be accurate and carried out regularly. It takes time and can become onerous. The use of on the go recording of data on iPhones help. Remote recording of monitoring is almost a must.
- **A better understanding of pest thresholds** is important to support the uptake of **IPM**.
- **Growers need to remain economically viable** and at the same time reduce certain production inputs such as pesticides, fertilizers and growth regulators.
- **Training** is fundamental to uptake of **IPM** by **IPM** providers, growers, managers and employees:
 - Rapidly identify pests and natural enemies.
 - Monitor pests quickly, easily and accurately.
 - Provision of better information on alternative controls.
 - Motivating growers to change by providing them with new skills and knowledge, eg the National Invertebrate Initiative (NIPI), National Integrated Weed Management Initiative (NIWMI), National Cereal "Rust Bust" Program.
- **IPM programs must be designed** by experts for specific crops or situations or for specific pests.

- **For some situations**, eg nurseries where a range of plant species are grown, **IPM** can be difficult.
- **IPM** systems are dependent on knowledge. This is lacking for some crops, eg some minor crops.
- **Need for more research** into the effect of chemical and non-chemical control methods on the ecosystem and on how they can be combined in practice.
- **IPM** can be **less effective** when **pest pressure** is **high** and growers may occasionally need to "spray".
- **IPM programs are increasingly sophisticated**, eg **WFT** is likely to involve a combination of 3 complementary predators, other pests are often involved as well.
- **Growers will only accept IPM** if they have the necessary information to make decisions about the economic implications of the new strategies.
- **Cultural techniques** which relate to the management of the weed seedbank such as destruction of weed seeds at harvest and to summer weed control which play a part in removing the green bridge.
- **IPM** includes the strategic and effective use of chemicals to ensure long term efficacy of products such as glyphosate.
- **Research on crop rotations** and their role in providing the opportunity to rotate chemical mode of action groups to provide a pest and disease break continues.
- **Appropriateness of chemical selection**, cost, pesticide not toxic to predators, bees.
- **Secret of IPM** is to identify the pests and diseases, and predators, know life cycles and regularly monitor, etc.
- **Effect of pesticides** on reproduction of species by measurement of egg laying (fecundity) and offspring production (fertility) by adults.
- **The program against a particular pest not only varies** between crops but increasingly between varieties. In leafminer control in tomatoes, variety can be the major factor influencing buildup of a pest and must be reflected in the introduction rate and pattern of parasitoids.
- **Consumers are often unwilling to accept produce** with minimal damage, eg food and cut flowers. Golfers may not happily accept imperfect greens.
- **Some non-chemical methods** may be more time consuming than applying pesticides.
- **IPM is best described as a continuum.** Many growers, if not most, identify their crop pests before spraying. A smaller subset use less risky pesticides. The aim is to move growers along the continuum to using all appropriate **IPM** techniques.
www.epa.gov/pesticides/factsheets/ipm.htm
- **Time taken to register** some **products** suitable for use in **IPM** programs.
- **The adoption of CA practices** with minimum tillage and retention of crop residues has resulted in the need to look for alternative cultural control practices.
- **Genetically modified (GM) crops** can play a part in **IPM** programs reducing pesticide use; improving yield, water use efficiency, drought resistance, better weed suppression by crops and alleviating pressure to convert additional land into agricultural use.
- **A holistic approach by IPM** requires examination of important plant interactions with both detrimental and beneficial organisms in the environment in which they flourish.

REVIEW QUESTIONS AND ACTIVITIES

1. Explain to another grower the **meaning of IPM**.
2. Describe **legislation** that applies to **IPM**.
3. List the **8 steps** in **IPM**.
4. List **7 non-chemical methods** of disease, pest and weed control used in **IPM**. Give 1 example of each.
5. Name 5 reasons why **IPM was developed**.
6. List the **properties of a pesticide** checked when its use is being considered for an **IPM** program.
7. Describe one **IPM** program operating successfully in your locality, or one **IPM program** you could use at **work**.
8. Name **at least 2 businesses** which provide advice on **IPM** strategies.
9. Describe the **advantages and disadvantages** of **IPM** at the present time.
10. Perform a **practical exercise** in **IPM**.

SELECTED RESOURCES

- Agra Consulting. 2002. European Commission DG Environment. 2002. *Integrated Crop Management Systems in the EU* (Amended Final Report).
- Bajwa, W. I. and M. Kogan. 2002. Compendium of IPM Definitions (CID) - *What is IPM and how is it Defined in the Worldwide Literature?* IPPC Publication No. 998, Integrated Plant Protection Center (IPPC), Oregon State University, Corvallis, OR 97331, USA.
- Beer, A. 2007. *What Does Your Garden Grow?* CRC for Australian Weed Management.
- Bolkan, J., Casey, C., Newman, J. et al 2001. *IPM Works for Rose Growers*. GrowerTalks. Oct.
- Colla, P., Gilardi, G. and Gullino, M. L. 2012. *A Review and Critical Analysis of the European Situation of Soilborne Disease Management in the Vegetable Sector*. *Phytoparasitica* 40 515–523.
- Cooke, T., Persley, D. and House, S. 2009. *Diseases of Fruit Crops in Australia*. CSIRO Pub.
- CRC for Australian Weed Management. 2005. *Integrated Weed Management: Developing a Plan using Tactic Groups*. Factsheet, CRCAWM.
- Diver, S and Hinmand, T. 2008. *Cucumber Beetles: Organic and Biorational Integrated Pest Management*. ATTRA, AK.
- Dreistadt, S. H. 2004. *Pests of Landscape Trees and Shrubs: An Integrated Pest Management Guide*. 2nd edn. University of California.
- Dufour, R. 2001. *Biointensive Integrated Pest Management (IPM)*. ATTRA, AK.
- Goodwin, S., Steiner, M., Parker, R., Tesoriera, L., Connellan, G., Keskula, E., Cowper, B, Medford, A. and Rodriguez, C. 2000. *Integrated Pest Management in Ornamentals: Information Guide*. NSW Agric/HRDC, NSW Agric., Sydney. A companion book *Field Identification Guide* is also available.
- Griggs, P. 2008. *Defeating Cane Diseases: Plant Pathologists and Development of Disease Control Strategies in the Australian Sugar Industry, 1920-1950*. CSIRO Pub.
- Guenther, L. 2013. *The Future of Weed Control*. *GrainNews* 39, (9).
- Hetherington, S. 2009. *Integrated Pest Management for Australian Apples & Pears* (ed. A. Munroe). NSW Industry & Investment and Apple and Pear Australia.
- Hertel, K., Roberts, K and Bowden. P. 2011. *Insect & Mite Control in Field Crops: Primary Industries Management Guide*. NSW DPI.
- Horne, P. and Page, J, 2008. *Integrated Pest Management for Crops and Pastures*. Landlinks Press.
- Leonard, E. 2010. *Smarter Pest Management*. Ground Cover. May-June.
- Llewellyn, R. (ed). 2002. *The Good bug Book*. 2nd ed. Australasian Biological Control. www.bugsforbugs.com.au
- McNaught, I. 2008. *A Field Manual for Surveying and Mapping Nationally Significant Weeds*. Bureau of Rural Sciences, Canberra.
- Neal, J. C. and Gordon, I. 2004. *Weed Management in Woody Cut Flower Plantations*. Centre for Native Floriculture, Uni of Qld.
- Neylan, J. 2010. *Fail to Plan or Else Plan to Fail*. *Australian Turfgrass* Sept-Oct.
- Norwood, C. 2010. *Farmer Watch Provides Disease Freedom Confidence*. Ground Cover. May 2010.
- Penfold, K. 2011. *Brome Grass Needs Multi-pronged Attack*. Ground Cover. 91, Mar–April.
- Persley, D., Cook, T. and House, S. 2010. *Diseases of Vegetable Crops in Australia*. CSIRO Pub.
- Persley, D. 2011. *Integrated Viral Disease Management in Vegetable Crops*. Qld Daff.
- Radcliffe, E. B., Hutchison, W. D. and Cancelado, R. E. (eds). 2011. *Radcliffe's IPM World Textbook*. Uni. of Minnesota.
- Rainbow, R. 2010. *Unified Attack on Pests and Diseases*. Ground Cover Issue 86. Collaborative Supplement.
- Retallack, M. 2011. *Vineyard Biodiversity and Insect Interactions: Establishing and Monitoring Insectariums*. GWRDC Regional. SA Central.
- Rehwinkel, R. 2011. *Evaluation of the ACT Vegetation Monitoring Manual: A Step-by-Step Guide to Monitoring Native Vegetation in the ACT*. Molonglo Catchment Group.
- Rutherford, R. S. and Conlong, D. E. 2010. *Combating Sugarcane Pests in South Africa: from Researching Biotic Interactions to Bio-intensive Integrated Pest Management in the Field*. *Proc. Int. Sugar Cane Technol.* Vol 27.
- SemiosBIO Technologies Inc. (SemiosBIO). 2012. *State-of-the-art Network Applications put Information at Farmers' Fingertips*. SemiosNET, Van., BC. July 26.
- Sharp, S. and Gould, L. 2009. *ACT Vegetation Monitoring Manual: A Step-by-Step Guide to Monitoring Native Vegetation in the ACT*. Greening Australia/National Heritage Trust, ACT Parks, Conservation and Lands.
- Shea, K., Thrall, P. H. and Burdon, J. J. 2003. *An Integrated Approach to Management in Epidemiology and Pest Control*. *Ecology Letters* 3:150-158.
- Stirling, G R. 2008. *The Impact of Farming Systems on Soil Biology and Soilborne Diseases: Examples from the Australian Sugar and Vegetable Industries*. *Aust. Plant Path.* 37:1-18.
- Wale, S. J. 2004. *Integrating Knowledge of Soilborne Pathogens to Minimize Disease Risk in Potato Production*. *Aust. Plant Path.* 33:167-172.
- Wilson, B. A., Zdunic, K., Kinloch, J. and Behn, G. 2012. *Use of Remote Sensing to Map Occurrence and Spread of Phytophthora cinnamomi in Banksia Woodlands on the Ngangara Groundwater System, Western Australia*. *Aust. Jn. Botany* 60(6) 495-505.
- ICM programs are available on a wide range of CROPS**, eg Almonds, apples and pears, cole crops and lettuce, strawberries, tomatoes, walnuts, etc.
Qld DPI Information kits include: Citrus, onion, lettuce, potato, rockmelon and honeydew, strawberry, grape-vine, low-chill stonefruit, passionfruit, tropical banana, tomatoes.
Cornell Extension Publication. *Integrated Crop and Pest Management Guidelines for Vegetable Crops*. University of California –IPM manual series, *Alfalfa Almonds, Apples and Pears, Avocados, Citrus, Cole Crops and Lettuce, Cotton, Floriculture and Nurseries, Potatoes, Rice, Small grains, Stone Fruits, Strawberries, Tomatoes, Walnuts, etc.*
- IPM programs are available on a wide range of PESTS**, eg Fruit flies
Heliothis (Helicoverpa)
Twospotted mite
- IDM programs are available on a wide range of DISEASES**, eg *Phytophthora dieback*
- IWM programs are available for WEEDS**, eg Commonwealth of Australia. 2007. *The Australian Weeds Strategy: A National Strategy for Weed Management in Australia*. www.weeds.org.au
GRDC 2008. *Weeds seedbank Monitoring*
GRDC. 2000. *Weed Seeds: Breaking the Bank. Integrated Weed Management Manual*
Introductory Weed Management Manual
Integrated Pest Management for Weeds on School or Commercial Grounds. Property Care Industry.
Noxious and Environmental Weed Control Handbook: A Guide to Weed Control in Non-crop, Aquatic and Bushland Situations.
Vegetation Monitoring Using Weed Mapping Weed Mapping checklist (Gov. of SA).
Weeds in Australia www.weeds.gov.au/
WONS www.weeds.org.au
Workshops on individual weeds, eg African love grass
Australasian Biological Control www.goodbugs.org.au
AusVeg. *Best Practice for Vegetables*.
Biological Services SA www.biologicalservices.com.au
Bugs for Bugs www.bugsforbugs.com.au
BioResources www.bioresources.com.au
Crop Consultants cropconsultants queensland.com.au
EcoGrow Australia www.ecogrow.com.au
Enhancing knowledge of pesticide effects on non-target invertebrates www.isppweb.org/nlaug11.asp
IPM in Ornamentals Information kit (DEEDI, 2002).
Integrated Plant Protection Centre (IPMnet) www.ipmnet.org/
IPM Technologies [ipm technologies](http://ipmtechnologies.com.au)
Journal of IPM (Entomological Society of America) www.entsoc.org/Pubs/Periodicals/jipm
Organic Crop Protectants www.ocp.com.au/

ENVIRONMENTAL MANAGEMENT



INTRODUCTION	360
LEGISLATION, STANDARDS, CODES, ETC	362
ENVIRONMENTAL MANAGEMENT	363
Best Management Practice (BMP)	363
Environmental Management Systems (EMS)	364
Tool kits for EMS / QA programs	365
Environmental Assurance (EA) for horticulture	366
Ecohort	367
Enviroveg	368
Freshcare	369
SUSTAINABLE AGRICULTURE / HORTICULTURE	370
Ecologically sustainable development (ESD)	370
Precision agriculture (PA) and horticulture (PH)	372
Conservation agriculture (CA)	374
Resilient systems	375
Biological farming, organic farming, permaculture	376
INTEGRATING EMS WITH OTHER SYSTEMS	377
CHALLENGES	379
REVIEW QUESTIONS AND ACTIVITIES	379
SELECTED RESOURCES	379

INTRODUCTION

Complex management systems are emerging to accommodate the demands of people of the advanced world who are over-fed, not scientifically informed and comprise only 15% of the world's population. We must not lose sight of the need to feed, clothe and house the whole world and to do this we will need to use our advancing technologies to continuously improve productivity on an affordable and sustainable basis.

- **By the year 2050, there will be 9.3 billion people living on this planet** (current population is 6.5 billion).
- **Crop land and population are not uniformly distributed**, eg China has 20-25% of the world's population but only about 1.4% of the world's productive land while Australia has roughly 0.3% of the world's populations but roughly 1.7% of the world's arable land.
- **Human activities have led to a steady increase in carbon dioxide levels**, resulting in global warming. It is predicted that the average global temperature will rise by 1.4 - 5.8°C by 2100, with increasing fluctuations in weather conditions. Climate change can radically alter rainfall patterns prompting the migration of people and shifts in agricultural practices. Further, an increasing human population will be responsible for wilderness destruction, water quality problems and diversion of water. Loss of habitat has resulted in many species being displaced.
- **Food security is regular and sustainable access to safe, nutritionally adequate and affordable food.** It is not sufficient to be able to supply the food; **it must be affordable.**

Grower benefits	<p>Benefits are numerous and include:</p> <ul style="list-style-type: none"> • Better understanding of the impact of horticulture and agriculture on the environment. • Possibility for improved marketing (some industries more than others). • Environmental certification may be required for some markets. • Improved management skills, communication and productivity. • Improved planning, record keeping, monitoring business performance, and auditing. • Provides a systematic way of managing an organization's environmental affairs.
Confusing terms	<p>The number of terms used to brand environmental systems overseas is incredible (Table 26). In Australia there are an equal number, some of which are defined in Table 27.</p> <ul style="list-style-type: none"> • Terms are confusing even within the same industry. • There is no one solution for everywhere or for every crop. Many different management programs have been established to develop and promote more productive, profitable and sustainable methods of agriculture and horticulture. • Decisions will depend on the region, the crop, the cost of inputs (water, fertilizer), regulation, seed, pesticides and certification. Crops and situations include cane growers, floriculture, production nurseries, fruit and vegetables, turf, grain, cotton and national parks, forestry and landcare. • There is a range of programs already in place at different levels of sophistication for agriculture and horticulture across most commodity sectors.





Table 26. Related terms (Gold, M. V. 2007).

<p>Agrarianism, agroecology Alternative Farming / Alternative Agriculture Best Management Practice (BMP) Biodiversity, Agrobiodiversity Biodynamic Agriculture / Biodynamic Farming Biointensive Gardening / Mini-farming Biological Farming / Ecological Farming Biotechnology Carbon footprint Carbon sequestration Conservation Agriculture Conservation buffer strips Conservation Tillage Ecological Footprint (EF) Eco-label Eco management Environmental Indicators Environmental management Farmland Preservation / Protection Good Agricultural Practices (GAP) Holistic Management (HM) [formerly Holistic Resource Management (HRM)] Integrated Farming Systems (IFS), Integrated Food and Farming Systems (IFFS)</p>	<p>Integrated Pest Management (IPM) Biointensive IPM Biological Control / Bio-control Intensive / Controlled Grazing Systems Related terms: Rotational Grazing, Management Intensive Grazing (MIG), High-Intensity Low-Frequency Grazing (HILF), Time-Controlled Grazing (TCG), Holistic Range Management, Grassfarming, Pasture-Based Farming and Voisin Management Grazing Landscape management Local / Community Food System Related terms: Foodshed concept, Food Circle concept / model / vision, Food Miles, Low Input Agriculture Low-Input Sustainable Agriculture (LISA) Natural Farming, Nature Farming, Kyusei Nature Farming Non-pesticide management (NPM) of crops is increasing in different parts of India and data shows that the incomes of farmers improve when they eliminate pesticides from their crops. Nutrient Management Organic Farming, permaculture, biodynamic Precision Farming / Agriculture, also called Prescription Farming, Site-specific Management Regenerative Agriculture Resilient Agriculture Sustainable Agriculture Research and Education (SARE) Sustainable Development Whole Farm Planning</p>
---	--

Table 27. Some Environmental Management Systems in Australia

<p>Environmental management system (EMS)</p> <p>Environmental Assurance</p>	<p>Environmental management system refers to the management of an organization's environmental programs in a comprehensive, systematic, planned and documented manner.</p> <p>ISO 14001 is the international certification for EMS; it is a systematic approach for identifying and improving environmental performance tailored to the business.</p> <p>The EMS may be externally audited by a third party to an international standard demonstrating the use of management practices that achieve the level of environmental protection expected of itself and its domestic and overseas customers, the community and other interested parties (Environmental Assurance), eg Environmental Assurance for Horticulture, EcoHort, Freshcare, Enviroveg.</p>
<p>Code of practice</p>	<p>A Code of Practice is a practical guide on how to comply with something, eg Code of Practice for Leucaena Growers.</p>
<p>Standard</p>	<p>A standard is a published document which sets out the minimum requirements to ensure that a material, product or method will meet certain standards of performance, eg the Australian Forestry Standard.</p>
<p>Accreditation, certification</p>	<p>Accreditation is certification of competence in a specified subject or areas of expertise and of the integrity of a business, group, or person, awarded by a duly recognized and respected accrediting organization, eg Nursery Industry Accreditation Scheme Australia (<i>NIASA</i>).</p>
<p>Best Management Practice (BMP)</p>	<p>A best practice is a method or technique that has consistently shown results superior to those achieved with other means, and that is used as a benchmark. In addition, a "best" practice can evolve to become better as improvements are discovered. Best practices are used to maintain quality as an alternative to mandatory legislated standards and can be based on self-assessment or benchmarking.</p> <p>Best practice is a feature of accredited management standards such as ISO 9000 and ISO 14001, eg</p> <ul style="list-style-type: none"> • Integrated Disease Management for Wine Grapes in Tasmania. • Fireweed: A Best Practice Guide for Australian Landholders.
<p>Integrated pest management (IPM)</p>	<p>A decision-making process using multiple pest management tactics to prevent economically damaging outbreaks while reducing risks to human health and the environment (Rutherford and Conlong 2010). The crop is managed as a whole and the management of the diseases, pests and weeds is part of the more complex system of producing the crop, eg</p> <ul style="list-style-type: none"> • Integrated Pest Management for Australian Apple & Pears (Hetherington 2009). • Integrated Disease Management of late blight of Potato. • Serrated tussock and Integrated Weed Management.
<p>Conservation agriculture (CA)</p>	<p>Conservation agriculture is a combination of reduced tillage, adequate retention of residues on the soil surface and crop rotation resulting in a soil with good physical and chemical qualities. It preserves, protects, or restores the natural environment, natural ecosystems, vegetation, and wildlife.</p>
<p>Sustainable</p>	<p>"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).</p>
<p>Resilient agricultural systems</p>	<p>Resilience is the ability of a system to absorb and manage changes without changing into another qualitative state with other defining characteristics (Folke, 2006). The capacity to recover quickly from difficulties, stress.</p>
<p>Biodiversity</p>	<p>The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.</p>
<p>Precision agriculture (PA)</p>	<p>PA is the precise placement of inputs to reduce costs, optimize efficiency of operations and the prevention of environmental damage – matching inputs with crop requirements.</p>
<p>Biological farming, biological agriculture</p>	<p>A whole system approach based upon a set of processes resulting in a sustained ecosystem, safe food, good nutrition, animal welfare and social justice. Biological, ecological or organic agriculture / farming means mild, environmentally friendly farming with no use of chemical pesticides and fertilizers. More specifically organic farming could be defined as a production system based on crop rotation, recycling of crop residues and animal manure, green manure, reasonable use of agricultural machinery and biological control methods.</p>
<p>Organic standards</p> <p>Organic Certification</p>	<p>Organic standards are sets of definitions, requirements, recommendations and restrictions regarding the practices and materials that can be used in certified organic production and processing systems.</p> <p>Organic certification is an audit and inspection process which allows agricultural and other enterprises to have their status as organic producers, processors, packers and exporters verified by an independent organization.</p>
<p>Farmer markets Fresh Food Local markets Locally grown Zero food miles Leisa (Low External Inputs Sustainable Agriculture)</p>	<p>Desire to connect with their food and sources, eg unprocessed, seasonal, family-farmed, sustainable, nutritious, naturally raised, hormone free, organic and artisanal (made in a traditional or non-mechanized way). Increasing numbers of shoppers opt for locally grown over organic alternatives. Consumers want verifiable sustainability standards. They want to know how their food is produced, how it is grown.</p> <ul style="list-style-type: none"> • Food should be fresher, but may not be subject to conventional testing. • Food miles is a term which refers to the distance food is transported from the time of its production until it reaches the consumer. Food miles are considered when assessing the environmental impact of food, including the impact on global warming.
<p>Holistic Management</p>	<p>Holistic Management does not yet have a well-established, precise meaning and probably never will. It is a process of understanding how things influence one another within a whole.</p> <ul style="list-style-type: none"> • It is large, complex and dynamic and is only possible due to the development of technology (computers) and increase in scientific knowledge. Holistic Management will only supply us with the information we want if we feed in the appropriate material.


LEGISLATION, STANDARDS, CODES, ETC

<p>Legislation</p> 	<p>The <i>Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act)</i> and its amendments (Environment Protection and Biodiversity Conservation Amendment (Invasive Species) Bill 2002), provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places, defined in the <i>EPBC Act</i> as matters of national environmental significance.</p> <ul style="list-style-type: none"> • <i>EPBC Act reform also allows the Commonwealth to accredit</i> State and Territory assessment and approval processes. • The <i>National Strategy for Ecological Sustainable Development</i> promotes ecologically sustainable development and environmental <i>performance reporting</i>. • <i>There are links</i> to the Australian Biodiversity Conservation Strategy, National Climate Change Action Plans and to <i>International agreements and bodies</i>, eg such as the Convention on Biological Diversity, Ramsar Convention on Wetland, The World Heritage Convention, United Nations Commission on Sustainable Development and the OEDC (Organization for Economic Cooperation and Development).
<p>Standards</p> <p>AUSTRALIAN STANDARDS</p> <p>Proposed standard for sustainability in wheat</p>	<p><i>AS/NZS ISO 14001:2004. Australian / New Zealand Standard™ Environmental Management Systems (EMS)</i></p> <ul style="list-style-type: none"> • <i>The overall aim of this standard</i> is to support <i>environmental</i> protection and pollution prevention in balance with socio-economic needs. • <i>EMS should encourage organizations</i> to consider the best available technology, where appropriate and where economically viable. • <i>EMS is a voluntary standard</i>. It does <i>not establish absolute requirements</i> for environmental performance beyond a commitment to compliance with applicable legislation and regulations and to continual improvement. The adoption of this standard does not in itself guarantee optimal environmental outcomes. • <i>This Standard is the most recognized EMS</i> standard internationally.
<p>Codes of practice</p> <p>CODES OF PRACTICE</p>	<p><i>There are many Environmental Codes of Practice</i> including:</p> <ul style="list-style-type: none"> • Code of Practice Leucaena growers (Oil). • Mallee Cropping Code of Practice (Oil) (WA).
<p>Environmental assurance (EA)</p> <p>Certification, Vendor declarations</p> <p>Some EAs are mandatory and must be audited by a 3rd party</p>	<p><i>An EMS is a systematic approach</i> that can be used by any enterprise or organization to continuously improve its business management to achieve efficiencies and better environmental outcomes.</p> <ul style="list-style-type: none"> • <i>An EMS is only one of the tools available to help a business</i> improve environmental performance and deliver <i>Environmental Assurance (EA)</i> certification, eg <ul style="list-style-type: none"> • A business would need a comprehensive <i>EMS</i> in place to demonstrate compliance with an <i>EA</i> standard (certification). • Both <i>EMs</i> and <i>EA</i> involve assessment and environmental impacts or risk and both advocate appropriate actions to address environmentally significant issues. • <i>Reasons for seeking ISO 14001 certification</i>, include: <ul style="list-style-type: none"> • To gain or retain market share via a green corporate image. • To attract more ethical investment. • To reduce insurance and prosecution risks. • To reduce costs. • Focuses on continual improvement of the system. • Improve planning, record keeping, monitoring business performance and auditing. • Provides a systematic way of managing an organization's environmental affairs. • Serving as a tool to improve environmental performance. • <i>The limited uptake of EMS certification</i> is probably because best practice environmental systems are <i>currently voluntary</i>. This is changing because: <ul style="list-style-type: none"> • Many horticultural markets are beginning to demand that their suppliers demonstrate an acceptable level of environmental management. • There are entry requirements for irrigation water allocations, catchment management restrictions, proximity to urban development and retail customer requirements. • <i>Voluntary Environmental Management Arrangements (VEMAs)</i> can improve Natural Resource Management in agriculture. Accreditation of a voluntary arrangement provides an avenue for recognition and encouragement without the need to regulate.
<p>Training</p> 	<p><i>There are formal courses in environmental management</i> provided by TAFES, universities and private providers, eg Certificate, Diploma and Degree levels. Guidelines are available for both growers and service providers.</p> <p>http://www.eianzsteps.org/ www.sustainability.edu.au/ http://environmentltas.gradschool.edu.au/</p>  
<p>Biodiversity Resource Guide</p> <p>Invasive species are one of the greatest threats to biodiversity and primary production</p>	<p><i>The Australian Government has developed a Biodiversity Resource Guide</i> as part of the national <i>Environmental Management Systems (EMS)</i> training kit (2012). It contains:</p> <ul style="list-style-type: none"> • The main National and State level legislative requirements and policy objectives. • A listing of available biodiversity resources, information, contacts, support services. • A listing of sector and policy Codes of Practice and BMP guidelines. • The <i>Introduction to Environmental Management Systems in Agriculture Biodiversity Resource Guide</i> is available online with links to State / Territory biodiversity resources.

ENVIRONMENTAL MANAGEMENT

Best Management Practice (BMP)

Best Management practice is a self-explanatory, descriptive phrase; it does not refer to a specific practice.

<p>Definition Evolves, systematic, consistent, practical</p> <p>AUSTRALIAN STANDARDS</p>	<p>A BMP is a method or technique that has consistently shown results superior to those achieved with other means, and that is used as a benchmark. A “best” practice can evolve to become better as improvements are discovered.</p> <ul style="list-style-type: none"> • BMP can be used to maintain quality as an alternative to mandatory legislated standards and can be based on self-assessment or benchmarking. • BMP is a feature of accredited management standards such as: ISO 9001 Quality Assurance Management Systems (QA) ISO 14001 Environmental Management Systems (EMS)
<p>Features of BMP</p> <p>Some BMPs are mandatory and must be audited</p>	<p>BMP was originally developed in the USA to reduce pollution. Today BMP is a usually applied to environmentally conscious management practices:</p> <ul style="list-style-type: none"> • It is based on the Standard AS/NZS ISO 14001: Environmental Management Systems - Specification with Guidance for Use. • It is site-specific and management intensive (rather like IPM). Adapting agricultural and horticulture systems to the local environment. • Uses IPM techniques (page 333). • Conserves resources. • Is not a specified set of rules but rather a set of common systematic guidelines on how to develop BMP, imposing a sense of order and ordered change in an enterprise. Many organizations have these characteristics but many fall short of the ideal. • Is often a problem-solving exercise. • Can be objectively audited for certification / registration purposes and / or self-declaration purposes. • Is a changing process as new technologies develop, eg the advent of herbicides in the late 1940’s was revolutionary because no machine invented in the past 200 years had allowed the control of weeds growing within rows rather than between rows.
<p>Legislation</p> 	<p>Legislation and associated regulations.</p> <ul style="list-style-type: none"> • BMPs can be developed through legislation, eg Environment Acts, Clean Water Acts, Duty of Care, Pesticides Acts and Environmental Codes of Practice. • However, regulatory agencies prefer improvements in environmental performances to be initiated by industry, rather than enforced by government. • If self-regulation does not work, industry may ask for government regulation, eg cotton industry and certain pesticide safety requirements. • Where environmental harm is thought to have occurred by failing to follow advice as set out in an approved Regulation, Code of Practice or Standard, legal proceedings may be brought under various Environmental Protection Authorities. • EMS is a basis for establishing ‘due diligence’. If an environmental problem should arise liability would be lessened if a business could demonstrate that it had such a system in place to minimize risk to the environment.
<p>Environmental BMP</p>	<p>The concept of BMP has been employed extensively in environmental management. For example, it has been employed in forestry to manage riparian buffer zones and in particular, it has been important to improving water quality relating to non-point source pollution of fertilizers in agriculture, as well as the identification and adoption of best practice for controlling salinity.</p> <ul style="list-style-type: none"> • However, there are significant challenges in defining what is best in any given context, eg in the complex environmental problems such as dryland salinity. • In these contexts, it is more useful to think of BMP as an adaptive learning process rather than a fixed set of rules or guidelines. This approach to best practice focuses on fostering improvements in quality and promoting continuous learning.
<p>Guidelines are available</p> <p>Weeds in Australia www.weeds.gov.au</p>	<p>Environmental Best Practice Guidelines for Weed Management includes:</p> <ul style="list-style-type: none"> • Developing a weed action plan. • Volunteer group weed control programs. • Sourcing certified seed and fodder. • Imported fodder management. • Sanitation, eg vehicle and cleaning protocols.
<p>Examples of BMP</p>	<p>There are many examples including:</p> <ul style="list-style-type: none"> • Fireweed: A Best Practice Management Guide for Australian Landholders. • Best Practice Guidelines for the Management of <i>Phytophthora cinnamomi</i>. • Nursery Industry Water Management Best Practice Guidelines. • Best Management Practice in the Australian Cotton Industry.

Environmental Management Systems (EMs)

An **EMS** is a systematic approach that can be used by any enterprise or organization to continuously improve its business management to achieve efficiencies and better environmental outcomes.

**EMS Standard
AS/NZS ISO
14001:2004**

The overall aim of this standard is to support environmental protection and prevent pollution in balance with socio-economic needs.

- **The standard contains only those requirements that may be objectively audited** for certification / registration purposes and / or self-declaration purposes. Many of the requirements may be addressed concurrently or revisited at any time.
- **EMS should encourage organizations** to consider the best available technology, where appropriate and where economically viable.
- **This standard does not establish absolute requirements** for **environmental** performance beyond a commitment in the policy to compliance with applicable legislation and regulations and for continual improvement. The adoption of this standard **does not in itself guarantee** optimal environmental outcomes.

**Complying with
the EMS standard**

**AUSTRALIAN
STANDARDS**



Which audit do you need and what criteria are to be audited? (page 322)

AS/NZS ISO 14001:2004, Australian/New Zealand Standard™ Environmental Management Systems—Requirements with Guidance for Use is a model for continual improvement.

1. **Environmental policy.** Specify the environmental management system to be complied with, eg **AS/NZS ISO 14001:2004**.
 - **All legal obligations must be met**, eg Environmental Acts, regulations, standards, codes of practice, trade requirements, duty of care, etc.
 - **ISO 14001 applies to those environmental aspects** identified that can be controlled and influenced. It does not state specific environmental performance criteria.
2. **Planning** includes putting in place **systematic methods** to establish the objectives and processes necessary to deliver results in accordance with the organization's environmental policy – numerous packages are available, eg
 - Appoint a coordinator of the EMS.
 - Identify legislative and regulative requirements relevant to the organization's environmental objectives.
 - Establish environmental objectives and targets. Have a checklist of obligations.
 - Training.
 - Documentation is the basis of a traceable performance.
3. **Implement programs** to achieve those objectives and targets. **Documentation** involves preparing a manual intended to be a comprehensive set of written instructions, which is the basis of a documented traceable performance. For many crops there are already programs available, eg citrus, cotton.
4. **Check and review.** Monitor and measure progress towards achieving those objectives and targets in a systematic way. Then evaluate by **auditing** which can be for self-declaration or for certification (which is the process of having an independent third party confirm that you are doing what you say you are doing), then comparing that to the Australian standard (**AS/NZS ISO 14001:2004, Environmental Management Systems - Specification with Guidance for Use**). Document and assess the results.
5. **Continual improvement** is ensured by the review. Introduction of new processes and technology is an ongoing essential activity. Strategically review the continuing effectiveness an **EMS** within the organization.

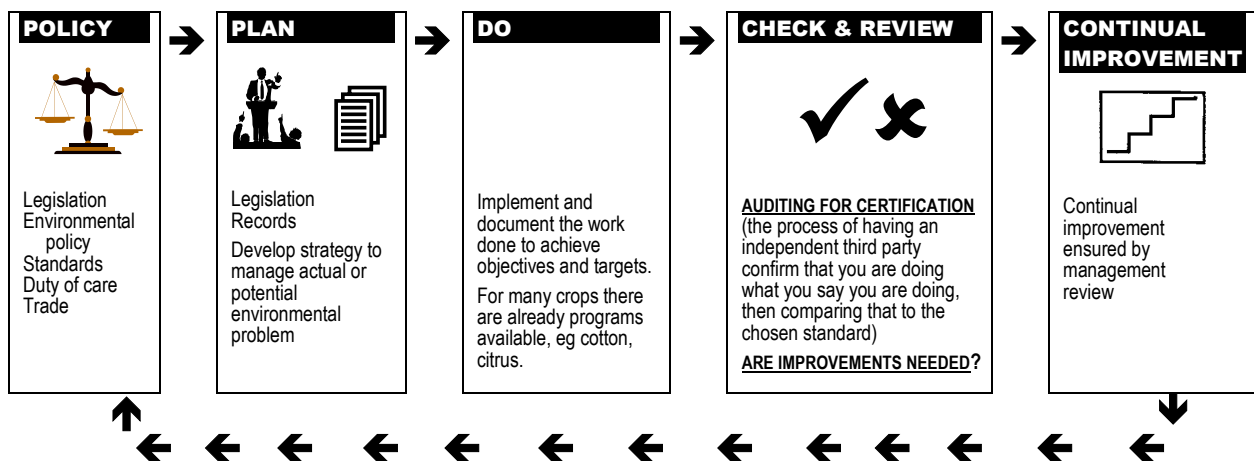



Fig. 31. Steps for compliance with AS/NZS ISO 14001:2004. *Environmental Management Systems*.

Tool kits for EMS / QA programs

There are many guides to Environment / QA Programs already in place at different levels of sophistication for growers across most commodity sectors.

<p>Industry specific EMS programs Commonwealth and State websites</p>	<p>The EMS industry policy is now focused on the outcomes that industry, growers and government are seeking to achieve:</p> <ul style="list-style-type: none"> • The adoption of profitable and sustainable farming practices. If farms are not profitable, investing in improved natural resource management is more difficult. • Improved natural resource management and environmental outcomes. • An ability to demonstrate environmental stewardship to domestic and international markets. • The Industry EMS program recognizes that industries are best placed to develop and implement an approach to environmental assurance that meets member's needs. • This approach also recognizes that governments' need to be flexible in their support, as different industries are at different stages in the development and implementation of environmental assurance approaches. The Australian government acknowledges that industry has already developed and implemented many excellent programs that provide information and management tools to farmers to improve their practices. • Various government funded programs have assisted uptake of EMS to enable industry to take the next step via the: <ul style="list-style-type: none"> • EMS Incentives Program and • The Pathways to Industry EMS programs. • Both are available as Fact Sheets on the Australian Department of Agriculture website. www.agriculture.gov.au (under construction, previously www.daff.gov.au)
<p>National Framework for EMS Plan Do Check Review Improve</p>	<p>A National Framework for EMS in Australian agriculture was developed to:</p> <ul style="list-style-type: none"> • Provide a set of principles that describe the broad parameters needed to achieve consistency and acceptance across the agricultural sector. • Describe the relationships and roles of the range of participants in environmental management in agriculture, including landholders, industry groups, community groups, and governments at the local, State and Federal scale. • Ensure that the details and content of an EMS will be determined by the individual business. • Emphasises that the adoption of an EMS by a business is voluntary and that the roles of government and industry groups are to facilitate the provision of information and assistance. Available online. • An EMS Implementation Plan was developed to assist Australia's National Framework for EMSs in Agriculture.
<p>MERI Monitoring Evaluating Reporting Improvement)</p>	<p>The MERI framework is a broad, overarching document for Natural Resource Management (NRM). It provides a generic framework for monitoring, evaluating, reporting on and improving Australia's approach to managing key assets. The key asset classes in the (NRM) context include human, social, natural, physical and financial assets (online).</p> <ul style="list-style-type: none"> • The MERI toolkit provides project managers with tools and guidelines to assist in measuring and reporting on outcomes from Caring for our Country investments. The toolkit should be used together with the Caring for our Country MERI strategy which was based on the conceptual framework established in the NRM MERI Framework.
<p>INFFER™ Investment Framework for Environmental Resources</p>  <p>Agriculture and environmental trade-offs in the Gippsland Lakes. 2012. INFFER™</p>	<p>INFFER™ is a tool for developing and prioritizing projects to address environmental issues such as water quality, biodiversity, environmental pests and land degradation.</p> <ul style="list-style-type: none"> • INFFER™ is designed to help environmental managers achieve the most valuable environmental outcomes with available the resources. • Provides a strong basis for preparing a case for funding. • Highlights the funding required to achieve particular environmental outcomes. • INFFER™ consists of a seven-step process, which begins with identifying significant assets and works through project development, project assessment and selection, implementation and, finally, monitoring, evaluation and adaptive management. Details are available online. www.inffer.org/
<p>WONS Weeds of National Significance</p> <p>These programs may change with time</p>	<p>Programs in place to help tackle WONS (now 32) and other land problems. eg</p> <ul style="list-style-type: none"> • Caring for our Country. • Natural Resources Management regions. • CERF (Commonwealth Environmental Research Facilities). • Weed Warriors is a national program for schools, administered and supported by Federal and State / Territory governments. • Managing Commonwealth land, eg defense establishment, national parks. • The National Landcare Program.

Environmental Assurance (EA) for horticulture

Environmental Assurance (EA) for Growers & Industry

(Horticulture for Tomorrow 2006)

AS/NZS ISO 14001:2004

Voluntary but there is potential for certification

EA is a means of demonstrating the use of management practices that achieve the level of environmental protection expected of itself and its domestic and overseas customers, the community and other interested parties. **Environmental Assurance:**

- **Provides a generic checklist of Environmental Best Practice**, ie **HOW TO DO IT**
- **Assesses performance against known industry best practices** and regulatory requirements to assure customers that environmental issues are being managed to an acceptable standard.
- **Assessment / auditing.** A business can demonstrate management of environmental issues through self-assessment, by seeking assessment from submissions or an independent (third) party (see page 322).
- **ISO 14001 is the international certification for EMS**, it is a systematic approach for identifying and improving environmental performance tailored to the business, this may be externally audited to the international standard.
- **GlobalGAP** (a global program) focuses on safe and sustainable agriculture production; a section on environmental management is recommended but **not mandatory**.
- **Some horticulture industries, such as the vegetable and nursery industries** have developed and begun implementing their own industry specific environmental management programs. However, these existing schemes **integrate** and were considered in the development of the **Horticulture for Tomorrow** program.
- **By comparing the EA guidelines to the international GlobalGAP** standard as part of the grower trials, Horticulture for Tomorrow was ensuring that horticulture's environmental practices, once adopted, would be at least the equivalent of this acknowledged standard.
- **Guidelines and the corresponding auditable code are voluntary.** However, there is potential for horticultural businesses to adopt these practices and become competitive on international markets otherwise not accessible to them.

Environmental Assurance for Growers and Industry
 Horticulture for Tomorrow www.horticulturefortomorrow.com.au/

Guidelines for Environmental Assurance in Australian Horticulture

Guidelines for environmental assurance in Australian horticulture have been developed by Horticulture for Tomorrow for growers and industry. The Guidelines aim to:

- **Establish a national industry-wide approach** for recognizing sound environmental and natural resource management in the horticulture sector.
- **Be practical**, flexible and user-friendly to suit growers at various stages of implementing environmental management practices and assurance programs.
- **Target horticultural enterprises** with a basic understanding of production and environmental issues. Businesses further down the formal **EMS** path may need to seek more crop-specific information. www.horticulturefortomorrow.com.au/
- **More closely manage inputs** for financial, food safety, WHS and environmental reasons. The document includes key management chapters, a self-assessment checklist and expectations for environmental management, eg
 - Soil / growing media.
 - Water.
 - Nutrition, fertilizers.
 - Pest, disease and weed management, pesticides.
 - Air quality, energy.
 - Waste management.
 - Biodiversity.
- **Publications are available online**, eg
 - Environmental Management in Horticulture 2006.
 - An Introductory Guide to Environmental Management in Horticulture.

Brand names

Many different management systems have been established to develop and promote more effective and less environmentally dangerous methods of agriculture (Francis 2006). Brand names include:

- Ecohort.
- Enviroveg.
- Natures Choice.
- Montague Fresh.
- Freshcare.
- The Australian Landcare Management System (ALMS).
- Growcom Farm Management System. www.growcom.com.au
- Zero food miles, Locally Grown, Fresh Food Markets.
- Nursery Production Farm Management system (FMS).
- Farmcare Code of Practice for Sustainable Fruit and Vegetable Production in Qld.

Ecohort

What is Ecohort?

EcoHort is the national environmental management system for production nurseries, growing media manufacturers and greenlife markets. It is the **industry specific Guidelines** or **Environmental Management System (EMS)** equivalent to **ISO 14001**, by which a grower can demonstrate to industry, government and the community their sound environmental and natural resource stewardship. Adopting the process of **EcoHort** will allow you to show that your business:

1. **Has utilized a recognized system** for assessing likely environmental and natural resource impacts.
2. **Is managing these impacts** in a responsible and sustainable manner.
3. **Covers key areas** including:
 - Efficient energy use.
 - Water management.
 - Waste management.
 - Pesticides and chemicals.
 - Noise, air and odor.
 - Land, soil and biodiversity.

Ecohort Guidelines and Certification



The EcoHort Guidelines detail the nursery industry's Environmental Management System that provides businesses with the resources to ensure they can demonstrate to industry, government and the community, their sound environmental, natural resource stewardship and compliance with the diverse range of environmental legislation.

Ecohort certification is a business management tool. It is a reliable method of documenting environmental management practices. It is a **continual cycle** of planning, implementing, checking and reviewing to meet business and environmental goals

- **Policy** (standard equivalent to **ISO 14001**).
- **Plan**.
- **Do**, implement actions.
- **Check**, audit, effective monitoring and recording.
- **Continually improve**.

Nursery Production Farm Management System (FMS)

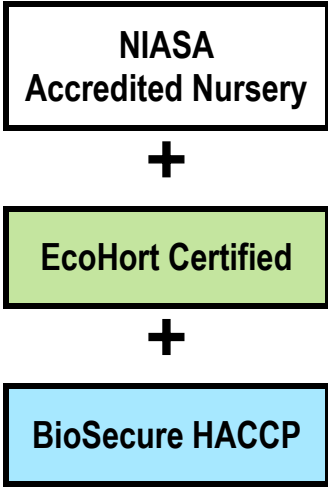
Nursery Industry Accreditation Scheme Australia (NIASA)

AUSTRALIAN/NZ STANDARDS

The Nursery Production Farm Management System (FMS) enables you to critically evaluate each component of your production nursery, identify areas of concern and manage the identified risks. It allows you to validate your business's integrity within the supply chain through an independent auditing process across the disciplines of best practice, environment and biosecurity.

The Nursery Production FMS includes 3 key programs, one of which is **EcoHort**:

- **NIASA-Accredited Nursery** ensures maintenance of a benchmark standard and assists in continuous improvement (AS/NZS ISO 9002).
- **EcoHort Certified** demonstrates have sound environmental stewardship and natural resource management (AS/NZS ISO 14001).
- **BioSecure HACCP** manages biosecurity risks for both imported and exported material.



EnviroVeg

What is EnviroVeg?

EnviroVeg is the vegetable industry's own environmental program developed specifically for vegetable growers (AUSVEG is the peak industry body for the Australian Vegetable and Potato Industries).

- **EnviroVeg provides growers with guidelines and information** on how to manage their business in an environmentally responsible manner.
- **It provides a visible way of demonstrating a responsible attitude** towards the environment. It also assists growers by showing the community that they are responsible environmental managers.
- **Growers achieving environmental certification** also benefit from a marketing edge.
- **EnviroVeg** is an industry owned and developed environmental program for vegetable growers.
- **It is free to all levy paying** vegetable growers.
- **EnviroVeg** assists growers by showing the community and consumers that Australian growers are producing high quality vegetables in a responsible environmental manner.

Why join EnviroVeg?

There are many reasons for joining Enviroveg including:

- **To have** your environmental practices recognized and acknowledged.
- **To identify** the farming practices that you already have in place which have a beneficial environmental impact.
- **To demonstrate to the community** and retail partners that you are actively engaged in environmentally responsible vegetable production.
- **To gain access** to exclusive member only areas of the website including learning resources and information about upcoming events.
- **To get information** about any subsidies, grants or funding this is available to growers wishing to make environmental improvements on farm.

EnviroVeg Self-assessment is available online

The EnviroVeg program has been specifically designed by vegetable growers to meet the requirements of both the industry and the broader community. Key outcomes guiding the **EnviroVeg** Program are to help growers:

- Improve environmental practices on-farm.
- Identify the risks of potential environmental impacts through farming practices.
- Adopt best environmental management practices on-farm.
- Demonstrate their commitment to the implementation of best environmental practices to the community and other stakeholders.

These outcomes are supported by the EnviroVeg Manual and Self-Assessment checklist which is an easy-to-use tool for growers to use on-farm to assess progress in various areas of on-farm management. The **EnviroVeg** Manual draws together the latest research and practice in one easy to use publication, that is supported by Natural Resources Management agencies as being in line with best practice recommendations for on-farm environmental management.

- **EnviroVeg** members are required to undertake the Self-Assessment checklist on a yearly basis.
- **Undertaking the Self-Assessment** allows growers to benchmark practices against previous years and continue to make improvements on-farm.
- **Once the Self-Assessment checklist has been downloaded and completed**, return to AUSVEG.

Freshcare

Freshcare Food Safety Code of Practice	<p><u>Freshcare is the name of the national on-farm assurance program for the fresh produce industry.</u> It is an industry-owned on-farm assurance program and not-for-profit organization.</p> <ul style="list-style-type: none"> • Freshcare provides a practical effective mechanism for Australian growers wishing to demonstrate the on-farm management of risk. • More than 3500 Australian growers have implemented the Freshcare Food Safety Code of Practice on their properties. • An annual independent audit process provides an assurance to customers of the practices in place to deliver safe, quality produce. • Freshcare is an example of one of the many safety systems and standards in the industry.
Freshcare Environmental Code of Practice	<p><u>The Freshcare Environmental Code of Practice</u> provides a practical, grower-friendly mechanism through which compliance against environmental elements can be demonstrated. The environmental code is an optional element of the Freshcare Program. The “Green Code” is designed to integrate with the existing Freshcare Food Safety Code of Practice or function as a stand-alone program.</p> <ul style="list-style-type: none"> • The <u>Guidelines for Environmental Assurance in Australian Horticulture</u> (the Guidelines) is the guiding reference document for the environmental practices used in the auditable Green Code. Each chapter within the Guidelines are covered in the Green Code. • <u>Together the Guidelines and the Green Code provide the resources for the grower</u> to understand, implement, assess and audit their environmental activities. <ul style="list-style-type: none"> • The Guidelines provide a practical resource to guide growers in meeting the requirements of the Freshcare Code. • The Guidelines will be extensively used in Freshcare Environmental training. • <u>Horticulture for Tomorrow is also linking these on-farm practices</u> with catchment scale activities through the establishment of Industry National Resource Management (NRM) Groups across Australia.
CODE OF PRACTICE	
The “Green Code”	
Integration with other programs	<p><u>The Freshcare environmental code is designed</u> to be used both by existing Freshcare Food Safety members and as a ‘stand-alone’ environmental module for those with alternate food safety/quality programs, eg HACCP food safety / quality.</p> <p><u>Freshcare has been working closely with the Enviroveg team</u> to ensure that the two programs complement and support each other. The Enviroveg manual provides an important implementation tool for vegetable growers, whilst the Freshcare Code provides a mechanism for certification.</p>

SUSTAINABLE AGRICULTURE / HORTICULTURE

Ecologically sustainable development (ESD)

The next green revolution must also consider sustainability not just productivity (Pritchard 2011).
Increased yields must not reduce sustainability – the sustainable revolution has begun (Drew 2013)

Some terms are difficult to define

Sustainable agriculture is one of them

ESD



Improving plant health, yield and quality



In such a quickly changing world, can anything be sustainable? What do we want to sustain? How can we do it? Is it too late? (Gold 2007).

- **Sustainable development was defined in the Brundtland Report** as: "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Put more simply, **ESD** is development which aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future to:
 - Enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations.
 - Provide for equity within and between generations.
 - Protect biological diversity and essential ecological processes and life-support systems.
- **Definitions of ESD change with time and knowledge.** Common features include:
 - In the commercial world, sustainable enterprises must be **profitable**.
 - Integrating global environment and economic objectives, as well as local ones.
 - Conservation and maintenance of soil, water and air resources.
 - Working towards reliance on renewable resources, decreasing reliance on fossil fuels.
 - Protection of biological diversity of native species and their habitat.
 - Avoiding or minimizing any adverse effect of agricultural activities, eg cultivation, pesticides and fertilizers, on the environment and human health.
 - Improving nutrient, irrigation and waste management, modifying salination and water table problems, controlling algal bloom outbreaks.
 - Implementation of **IPM** strategies for disease, pest and weed control.
 - Consideration of making ESD a legal responsibility of every producer.
- **Sustainable horticulture** in Australia is progressing slowly (Newley and Treverrow 2008).
 - This is due to the smaller scale of farms and the variability in growing systems, eg regions, climate, seasonal variability, orchards, plantations, field crops, protected cropping.

Sustainable frameworks and standards

AUSTRALIAN/NZ STANDARDS

Many organic standards

These include:

- **A National Framework for Sustainable Agriculture in Australia** focused on sustainable food and fibre production, resource management, resilient rural communities and has identified **eleven** key principles:
 1. Shared Leadership
 2. Partnerships and collaboration for change
 3. Aligned policy, programs and structures
 4. Clear roles and responsibilities
 5. Brand Australia
 6. Aligned standards and regulations
 7. Address issues and drivers
 8. Practice change
 9. Information / communication / decision support tools
 10. Define farm to catchment to market linkages
 11. Build and maintain capacity
- **The National Sustainable Agricultural Standard LEO-4000 2012** (Leonardo Academy, USA for all industries which is available online).
- The **National Standard for Organic and Bio-dynamic Produce (NSOBP)** which requires the nurturing and maintaining of land for future generations and the conservation of energy, soil and water resources and the maintenance of environmental quality and **The National Association for Sustainable Agriculture, Australia (NASAA)** (pages 381-396).

Technologies

which have contributed towards ESD

Many technologies have contributed towards ESD including:

- **New herbicides are more environmentally benign** than their predecessors because they act on enzyme pathways exclusive to plants. Glyphosate herbicides affect **cell division** in plants, have low toxicity to humans and are short-lived in the soil.
- The **combination of minimum tillage** and **herbicides** has been revolutionary. Minimum tillage is the most energy-efficient form of agriculture.
- **Conservation agriculture** which is a combination of:
 - Reduced tillage.
 - Adequate retention of residues on the soil surface.
 - Crop rotations that mitigate weeds, disease, insect problems, provide alternative sources of soil N, reduce soil erosion and reduce risk of water contamination by agvet chemicals.
- **Today sustainable farming practices** may include:
 - **Pest control strategies** that are not harmful to natural systems, farmers, their neighbors or consumers. This includes **IPM** techniques that reduce the need for pesticides by practices such as scouting, use of resistant cultivars, timing of planting and biocontrols.
 - **Use of natural or synthetic inputs** in a way that poses no significant hazard to man, animals or the environment.
 - Precision agriculture / horticulture.
 - Resilient agriculture and biological farming.

Land degradation

Ecologically sustainable crop production must be the aim of all production systems

Land degradation is a serious environmental problem confronting Australia. Whilst soil erosion and salting have the greatest visual effect and attract the greatest attention, others are just as serious if not more so, eg changed moisture regimes due to climate change, declining soil fertility and weeds.

- **Australian agriculture aims to develop:**
 - More resilient, viable and sustainable systems,
 - Focus on higher water use efficiency (WUE),
 - Groundcover throughout the year, and
 - Encouraging faster adoption of management practices and new technologies.
- **Nutrient depletion.** In growing crops and pastures, nutrients are removed from farms; they can also be lost by run off and soil erosion. If this continued demand for nutrient is not replaced soil fertility declines.
 - **Extent of nutrient depletion varies** depending land management practices, eg type of fertilizers used, yields, tillage, retention of organic matter, etc.
 - **More than 2 million tonnes of nutrients** are removed from our agricultural soils each year in farm produce alone, about one million tonnes are shipped overseas with exported goods. Maintaining the productivity capacity of the soil is central to sustainability.
 - **While some agricultural soils have high levels** of natural fertility, most Australian soils are old and largely infertile in their state.
 - **Many soils in Australia have long-term soil nutrient run-down problems.**

GEO Certified™ Golf Club

6 key sustainability action areas:

- Water
- Nature
- Energy
- Supply chain,
- Communities
- Pollution control



The National Golf Club near Melbourne, Victoria was Australia's first club to attain golf's international ecolabel, GEO Certified™, recognizing the club's sustainability achievements.

- **The National Golf Club achieved GEO Certified™** by signing into the free, on-line OnCourse™ sustainable golf support program.
 - Based on the program content, they recorded and refined their management practices across golf's six key sustainability action areas.
 - The club's performance and forward planning were then evaluated against the GEO certification criteria during a site-visit from **an accredited 3rd-party verifier**, who also provided the club with practical ideas for further improvement **during the three-years** before re-certification.
- **Some examples of the sustainability work underway at The National** include:
 - Investment in irrigation and turfgrass management reducing water use by 35%.
 - Recycled wastewater transferred to on-site storage for back up irrigation water.
 - Dedicated bush management team and native plant nursery using seed collected on site.
 - Increased vegetation cover of more than 15 hectares with indigenous grasses and scrub.
 - Archaeology surveys guide management of historically and culturally important sites.
 - LED low wattage bulbs reduced clubhouse lighting consumption by over 90%.
 - Investment in facilities and training to minimize risks associated with hazardous substances.

Research priorities, training



Courses are offered at TAFES and Universities in Australia.

- **University of Sydney's Institute of Sustainable Solutions** engages in training, policy, public engagement, development and community outreach.
 - **Research into land and water sustainability,** renewable energy, energy conservation, carbon capture and emission management, sustainable building design, urban planning, public health and well-being, economic development, environmental and international treaty law.
 - **Soil-plant-microbe systems** focus on interactions to control the amount and availability of water, carbon and nutrients in soil and their partitioning with plants.
 - **SUNfix Centre for Nitrogen Fixation** promotes research and teaching in Biological Nitrogen Fixation, eg
 - Apply the benefits of biological nitrogen fixation to provide **sustainable** systems for agriculture and forestry.
 - Maximize the economic application of *Rhizobium* inoculates to pasture and crop legumes and provide growers with leguminous and other nitrogen-fixing crops.
 - Research applications of biological nitrogen fixation to the growth of cereals and other crops currently requiring soil fertilizer as sources of N.
- **CSIRO's Sustainable Agricultural Flagship (2010)** explores ways of reducing the environmental impact of Australia's agricultural and forestry sectors (Stapper 2006).
- **The Society for Ecological Restoration International** has produced generic guidelines for conceiving, organizing, conducting and assessing ecological restoration projects. Restoration must also be **technically feasible** (Wade et al 2007).
- **Integrating** the principles of sustainable development, preventative measures for crop protection are aimed at managing pests and their natural enemies, first through action on their habitats both in crop fields and in the non-cultivated part of the farm (Ferron and Deguine 2005).
- **Environment and Farm Management (EFM) programs** should be less production-driven and more market-driven (Rowland 2005).
- Information on some courses is available online <http://www.eianzsteps.org/> <http://www.sustainability.edu.au/> <http://environmenttas.gradschool.edu.au/>

Precision agriculture (PA) and horticulture (PH)

A revolution brought about by information technology

What is PA or PH?

The basic tenet of PA is that all areas within a field are generally NOT the same

PA

Check that there is variability

Compatibility

PA is the precision placement of inputs to:

- Match **inputs** with **crop requirements**, eg better fertilizer management.
- Reduce costs, either by increase of the output and / or reduction of the input which increases efficiency, eg lowers the cost of nitrogen fertilization.
- Optimize efficiency of operations, eg better time management.
- Prevent environmental damage, eg reducing nitrogen run-off, etc.

PA enables targeted management of subsections of large areas. Just as crop management and marketing varies between paddocks, **PA** enables within paddock variation to be managed and capitalized on.

PA is about better decision-making based on data that is linked to the location in the paddock. **PA** relies on an **increasing level of detailed information** acquired with technology to improve decision-making in crop production.

- **Consists of observation, evaluation and interpretation**, targeted management and review.
- **Level and area of variability needs to be large enough to justify adopting PA.** Before adopting **PA** growers can optimize their chances of better returns by running simple on-farm trials manually or by using **PA** equipment.
- **PA enables nutrient, soil, water and weed variation in a paddock to be tested**, mapped and managed leading to reduced inputs of fertilizer, water and herbicides.
- **Measurements of yield, quality, soil and plant characteristics** identify areas of a paddock or property where yield or quality could be improved or inputs decreased.
- **By using global positioning (GPS) and a range of sensors**, eg soil, plant, weather, satellites or aerial images and **information management tools** (GIS) to assess and understand variations. Information can be collected enabling a grower to **more precisely evaluate** optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.
- **Real-time sensing of soil and crop variables**, near real-time accessing remotely sensed data.
- **Precision treatment is compatible with minimum tillage** and controlled traffic in association with zero till.
- **Don't forget growers have years of experience** in problem diagnosis and precise placement of treatments. In small-scale farming and horticultural systems, this includes differential plantings on hills and ridges to optimize soil moisture and sunshine.
- **Remember wastage** occurs even in normal years.

Mechanization, precision horticulture and robotics



The **Australian Centre for Field Robotics** (University of Sydney) researches possible uses, eg

- **Classifying different vegetation** and soil types.
- **Aerial surveillance** of locust swarms improves swarm modelling and therefore control.
- **Automatic detection**, mapping, classification and quantification of **woody weeds**, using sensors to discriminate between weed species, eg Parkinsonia, prickly pear and mesquite.
- **Aquatic weed detection and eradication** using robotic aircraft and a surveillance system can detect aquatic weeds in inaccessible habitats.
- **Spraying heights** of 2 metres are less likely to drift on to surrounding areas.
- **In almond orchards**, moving footage of tree canopy can pick out almond flowers, soil conductivity and yield, when to harvest and know what they have to forward sell.
- **UAVs are highly regulated**, fit into a suitcase, and are generally leased. In Australia, numbers are forecast to increase dramatically.
- **An International symposium on "Mechanization, Precision Horticulture, and Robotics in Fruit and Vegetable Production"** held in Brisbane (2014) featured presentations from international experts covering the latest technological innovations and the integration of these technologies into production systems.

Training



PH

IPNI (International Plant Nutrition Institute), 2011. *Precision Horticulture: Some Perspectives*. IPNI.

Providing education and training on the use of PA is considered to be central to achieving greater adoption of **PA**. Training is provided in most States by industry and government.

- **Australian Centre for Precision Agriculture (ACPA)** at the University of Sydney offers 2 levels of training.
- **Narrabri-based Precision Cropping Technologies (PCT).**
- **Farmscape Training** at Toowoomba presents simulations (the Agricultural Production Systems Simulator (APSIM)). Using **PA** in fertilizer management can significantly reduce costs per hectare just by accurately distributing phosphorus.
- **Precision Agriculture Manuals** and Fact Sheets available from GRDC.
- **Workshops** to help take **PA** beyond mere guidance. Adoption of other **PA** technologies such as yield mapping and variable rate inputs has been lower.
- **New projects in Precision Horticulture (PH)** and the automated measurement of the environment, plant and soil characteristics, fruit and vegetable quality to assist industry achieve greater productivity and quality with reduced inputs, eg water and fertilizer and with less impact on the environment (IPNI 2011)
- **The Precision Agriculture Research Group (PARG)** is located at the University of New England and offers a dedicated Graduate Certificate in Precision Agriculture.

Data collection



Drones, robotics and other new technologies have revolutionized the collection of data, resulting in enhanced crop yield and quality.

Geophysical surveys have proven their worth by allowing inputs to be targeted on a site-specific basis.

CCCI (Canopy Chlorophyll Content Index)
ECCI (Eucalypt Canopy Condition Index)
EMI (Electromagnetic Induction)
GPS (Global Positioning System)
GIS (Geographic Information Systems)
NDVI (Normalized Difference Vegetation Index)
NIR (Near-Infrared)

Infrared Thermal Imaging can define a frost event.



PlantScan
(High Resolution Plant Phenomics Centre
(CSIRO) www.csiro.au/)

Precision is exercised at many levels, eg seed, fertilizer and spray placement; permanent wheel placement to stop random compaction; individual weed killing with spot-spraying rather than field spraying, etc. There are many ways of collecting data needed for **PA**, eg

- **Variable rate application (VRA) of fertilizer** is the most common use to date of **PA** and has allowed the grower to vary the rate of fertilizer across a field according to the crop's need identified by **GPS-guided Grid Sampling**.
 - **Fertilizer can be spread only in areas that need it**, thereby optimizing its use.
 - **Overlaps are minimized**, inputs accurately placed and efficiency increased.
 - **VRA of N and P inputs** delivers cost benefits and improved yields. There are nutrition gains to be made from variable rates of N and P fertilizing.
 - **In-paddock soil tests for nutrients** could soon be quicker and easier, eg MIMS (Multi-ion Measurement System) samples, analyses and records results and locations on-the-go.
 - **Improving fertilizer efficacy**. Tailor advice to local conditions. Test first, and then match fertilizer to the potential to make a profit.
 - **The IPNI (International Plant Nutrition Institute)** identifies plant nutrition information needs and nutrient management improvement opportunities to improve crop nutrition management, fertilizer use efficiency and profits. www.ipni.net/
 - **Normalized Difference Vegetation Index (NDVI)**. The use of in-crop sensors to understand and manage the nutrition of the growing crop in relation to needs and the season is already being used on-farm.
 - **Wetlands**, water bodies, habitats, and stream courses in agricultural areas can be better protected from pollution.
- **Soils**.
 - **Analyze soil samples on the go**.
 - **Soil GPS and GIS** can make precise maps of **changes in soil properties** as they occur in a single paddock, orchard block or over a whole farm.
 - **GIS is not intuitive**. The ability to rapidly gather and map detailed **soil** information will soon become a reality, with prototype equipment and new methods moving to paddock scale trials. Electromagnetic induction (EMI) is used for mapping salinity, soil water and clay content in some soils. **Precision Agronomics Australia (PAA)** undertakes geophysical surveys of soils and ground-truths the results with tests to confirm the physical and chemical characteristics of the soil, eg **PAA** can produce maps to determine which areas are likely to respond to gypsum, etc (Baxter 2011).
 - **Quicker soils tests**, salinity mapping, soil water and clay content in some soils eg Sodium Green™ Imaging for salinity.
- **Irrigation**.
 - **EMI** for mapping salinity, soil water and clay content in some soils. In irrigation there is improved application and water use efficiency and yield monitoring.
 - **GPS, in-ground soil sensors and computer-based GIS irrigators** can make precise maps of changes in soil properties as they occur in a single paddock or orchard block or over a whole farm. Soil surveys and high-resolution soil-sensing underpin **PA** in Australia's irrigation areas, which account for **more than 40%** of agricultural production.
- **Weeds**.
 - **Develop accurate weed maps** so Variable Rate Technology (VRT) sprayers can specifically hit weed patches using GPS in **PA** systems to reduce herbicide use. It is a bit like a mechanized spot spraying of weeds.
 - **However, to target specific weeds with specific herbicides and / or rates**, a more detailed understanding of weed distribution across a paddock is required, eg paddocks need to be more precisely zoned using new technology to drastically reduce herbicide use.
 - **Normalized Difference Vegetation Index (NDVI)**. GreenSeeker[®]-fitted machinery assesses whether the target being observed contains live green vegetation or not and so can be used to target live weeds.
- **Disease control**.
 - **Crop sensors can read wavelengths** outside the range of the human eye to provide quantifiable information about crop canopy.
 - **Separating next year's crop from last year's stubble** has been considered a control option for some diseases. **PA** tools such as GPS guidance and autosteer offer the ability to sow a crop on or in between last year's crop residues and can be used in **IDM** programs. Note precision row placement **will offer little or no benefit with soilborne diseases** that are long lived and widely distributed in the paddock.
- **Yield monitoring**.
 - **Typically yield mapping** using **GPS** and aerial photography, water and nutrient levels in soil and plants can be measured. **PA** can be used to fine-tune planting rates, fertilizer applications, pest and disease control and irrigation.
 - **Raptor crop sensor** is attached underneath a low-flying aircraft and enables rapid scanning of **crop biomass** over entire paddocks. This active system directs rapid pulses of red and near infrared light onto crop plants and measures the light reflected back to the aircraft, providing an indicator of plant vigor (biomass or water or nutrient status).
- **Canopy management**.
 - **The Canopy Chlorophyll Content Index (CCCI)** is designed to measure and predict canopy **N** nutrition in some crops.
 - **The ECCI is used to categorize the forest or plantation canopy** into classes of unhealthiness to support targeted and cost-efficient forest health diagnosis and treatment.
- **Analyses of plant growth and structure by PlantScan** analyses plant structure (number of leaves, etc), morphology (leaf size, shape, color, area, etc).
 - **Plant Scan** using **3-D lasers** and other tools takes images of a single plant and measure its growth and other achievements enabling scientists to gain a better understanding of the complex interactions between plant architecture, the physiological processes driving plant development in time and space, and the physical plant environment.

Conservation Agriculture (CA)

CA is a combination of reduced tillage, adequate retention of residues on the soil surface and crop rotation

<p>What is CA?</p>	<p>Conservation agriculture (CA) is an application of modern agricultural technologies to improve production while concurrently protecting and enhancing the land resources on which production depends (Mezzalama et al 2011).</p> <ul style="list-style-type: none"> • CA attempts to optimize yields and profits while achieving a balance of agricultural, economic and environmental benefits. • Farming communities become providers of more healthy living environments for the wider community through reduced use of fossil fuels, pesticides and other pollutants. • CA is gaining acceptance in many parts of the world as an alternative to both conventional agriculture and organic agriculture. • Key characteristics include: <ul style="list-style-type: none"> • Minimum or no tillage which can be practiced in both large and small farming systems. • Full stubble retention maintenance of a mulch of carbon-rich organic matter covering and feeding the soil (e.g. straw and / or other crop residues including cover crops). • Diverse crop rotations or sequences and associations of crops including trees which could include nitrogen-fixing legumes. • Improves soil health and increases microbial activity. Soil microflora communities and their effect on plant growth promotion and the suppression of soil-borne diseases. • Flexibility. CA must constantly evolve to meet the changing needs of cropping systems. • CA is an integrated concept: <ul style="list-style-type: none"> • Implementation will depend on the local agro-ecological environment. • A holistic approach is needed as CA integrates ecological management with modern, scientific, agricultural production using modern technologies that enhance the quality and ecological integrity of the soil. • Don't forget the application of these is tempered with traditional knowledge of soil husbandry gained from generations of successful farmers.
<p>Reduced tillage plus residue retention See also page 54</p>	<p>The favorable effects of the combination of CT or ZT with residue retention include:</p> <ul style="list-style-type: none"> • Increased soil aeration. • Cooler and wetter conditions. • Less fluctuations of temperature, moisture and higher carbon content in surface soil. • Increased organic matter in the soil. • These favorable effects are responsible for increased microbial activity which creates an environment which is more antagonistic to pathogens due to competition effects.
<p>Strategic tillage</p>	<p>The reality facing many mixed farming systems across Australia is the requirement sometimes for strategic tillage due to wet weather, weeds, root diseases and productivity restraints (Collis 2012).</p> <ul style="list-style-type: none"> • Adoption rates for no-till practices in Australia had exceeded 90% in some regions and less than 5% in some other regions. Less than 5% of growers now practice multiple cultivations. • However, most no-till growers still cultivated up to 30% of the cropped area and 88% used points for sowing instead of discs. • Strategic tillage and residue reduction has proven necessary to overcome productivity constraints in mixed systems (see also page 55).
<p>Diverse crop rotations</p>	<p>Diverse crop rotation plays a major role in controlling soilborne diseases and weeds. There is a diverse range of these pathogens and of biological and physical characteristics of different soils, therefore it was necessary to investigate how to adapt CA principles and to find out the responses in each environment.</p>
<p>Detractions</p>	<p>Factors that detract from the benefits of conservation agriculture in Australia include:</p> <ul style="list-style-type: none"> • Weeds. • Root diseases. • Inhibitory soil organisms that could slow early crop growth and reduce yields. • The need to incorporate lime in acid soils. • The need to improve soil structure and water infiltration. • Resistance to glyphosate.
<p>Crops</p>	<p>CA, including agroforestry, specialty crops, and permanent cropping systems, promotes food sufficiency, poverty reduction and value added production through improved crop and animal production.</p>

CA relates directly to the United Nations Framework Convention on Climate Change, the International Convention on Biodiversity, the United Nations Convention to Combat Desertification and the various agreements on international waters.

Resilient systems

<p>What is resilience?</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Contemporary academic discussion of urban resilience focuses on three distinct threats:</p> <ul style="list-style-type: none"> • Climate change, • Natural disasters and • Terrorism </div>	<p>Resilience is the ability of a system to absorb and manage changes without changing into another qualitative state with other defining characteristics (Folke, 2006), eg</p> <ul style="list-style-type: none"> • Amount of change that a farm system can undergo and still function under its current basic structure, eg flood, drought, market conditions. • Degree to which a farm systems is capable of adaptation to stress. • Can effectively manage variation in climate, water availability, feed costs, etc. • Ability to build and support farmer learning and flexibility and still be profitable. • Is sustainable for natural, animal and people resources. • Resilience centres have been set up, eg the Stockholm Resilience Centre. • Indicators of resilient systems (Wilson 2000-2001). • Urban Resilience is defined as the “capability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to public safety and health, the economy, and security of a given urban area.
<p>Resilient farmers</p>	<p>Resilient farmers in WA have 6 common characteristics (Baxter 2012):</p> <ul style="list-style-type: none"> • Scanning the business environment for opportunities, changes and trends. • Engaging in contingency planning (to identify potential floods, droughts, adverse weather, and climate change). • Building flexibility into the business. • Actively building relationships with others, eg growers, agronomists, suppliers. • Continually experimenting and making innovations. • Resilient farmers are part of a family business with shared goals and values.
<p>Strategies to build resilience</p>	<p>Resilience can be learned, eg</p> <ul style="list-style-type: none"> • Learn to live with change and uncertainty. • Combine knowledge and learning. • Link with others, eg maintain connectedness to industry and social networks. • Nurture diversity.
<p>Climate-smart agriculture</p>	<p>More productive and resilient agriculture will need better management of natural resources, such as land, water, soil and genetic resources through practices, such as:</p> <ul style="list-style-type: none"> • Conservation agriculture. • Integrated pest management. • Agroforestry. <p>This transformation of agriculture is being promoted by FAO along with other partners under the term “Climate-smart agriculture” to maintain that sustainably increases productivity, resilience (adaptation), reduces / removes greenhouse gases (mitigation), enhances achievement of national food security and development goals (FAO 2010). Agriculture in developing countries must undergo a significant transformation in order to meet the related challenges of food security and climate change.</p>
<p>Resilient landscapes</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>The National Urban Forest Alliance promotes a thriving, sustainable and diverse Australia urban forest that creates a healthy ecosystem that is valued and cared for by all Australians as an essential environmental, economic and community asset.</p> </div>	<p>Melbourne has close to 60,000 trees in the city. Many were planted at the same time and now are reaching the end of their life at the same time. The Urban Forest Strategy and Open Space Strategy will ensure healthier, greener and more resilient landscapes and open spaces over the next 100 years.</p> <ul style="list-style-type: none"> • More than decade of drought, severe water restrictions and periods of extreme heat combined with ageing tree stocks have put Melbourne’s trees under stress and many are now in a state of accelerated decline. • Research shows that 27% of the current tree population will be lost within 10 years and 44% within 20 years. • Key targets of the Urban Forest Strategy include: <ul style="list-style-type: none"> • Increasing the Melbourne’s canopy cover from 22% to 40%. • A canopy made up of no more than 5% of one tree species. • Achieving a tree population that is 90% healthy by 2040. • The Future Melbourne (Eco-City) Committee said diversifying the city’s tree stock was essential to minimize future vulnerability to threats such as extreme weather and attacks from pests and diseases.
<p>Resilient wheat</p> <p style="text-align: right; margin-right: 10px;"> Risk insurance Improved varieties </p>	<p>Wheat production systems are coming under intensifying pressure from a combination of stresses, eg heat stress, rising transportation costs, dwindling groundwater resources and disease pressure. The International Maize and Wheat Improvement Centre (CIMMYT) oversees efforts to build capacity for farming systems to 2050 (Braidotti 2011).</p> <ul style="list-style-type: none"> • Programs are underway to lift agricultural productivity, sustainability and resilience. • Innovations through alliances with public and private sector breeders, in conservation agriculture and socioeconomic services such as risk insurance. • Past benefits to Australian wheat growers from links with CIMMYT are estimated at \$150 million a year from improved varieties alone.

Biological farming, organic farming, permaculture

Biological agriculture, organic farming	<p><u>Organic agriculture is seen to be part of a sustainable farming system</u> and a viable alternative to the more traditional approaches to agriculture. Since the EU regulations on organic farming came into force in 1992, tens of thousands of farms have converted to this system as a result of consumer awareness of, as well as demand for, organically grown products.</p> <ul style="list-style-type: none"> • By biological, ecological or organic agriculture / farming we mean mild, environmentally friendly farming with no use of chemical pesticides and fertilizers. • More specifically, we could define organic farming as a production system based on crop rotation, recycling of crop residues and animal manure, green manure, reasonable use of agricultural machinery and biological control methods. Appropriate combinations of such practices ensure: <ul style="list-style-type: none"> • Conservation of soil fertility and adequate crop nutrition. • Crop enemy, disease and weed control. • Organic farmers may achieve the above with no need to resort to synthetic chemical pesticides and fertilizers. • Product labeling. <p><u>Biological farming includes but is not limited to:</u> Ground Grocer www.groundgrocer.com/</p> <ul style="list-style-type: none"> • Organic farming. • Bio-dynamic farming. • Permaculture. • Sustainable farming. • Natural sequence farming. <p><u>Produce from biological or organic farming may not be subject to conventional testing</u>, eg residue testing or certified as organic.</p>
Locally grown, farmers' markets	<p><u>Increasingly shoppers are opting for locally grown over organic alternatives.</u></p> <p>The consumer has a desire to connect with their food and sources, eg unprocessed, seasonal, family-farmed, sustainable, nutritious, naturally raised, hormone free, organic and hand processed.</p> <ul style="list-style-type: none"> • Rise of the farmers' markets, direct marketing, missing out the middle man, food may be fresher, but food may not be subject to conventional testing, eg residue testing or certified as organic.
Permaculture Agricultural ecosystems are intended to be sustainable and self-sufficient	<p><u>Permaculture</u> is a contraction of <u>permanent agriculture</u> which extended to <u>permanent culture</u>, as cultures cannot survive for long without a sustainable base and land use ethic (Australians Bill Mollison and David Holmgren and Masanobu Fukuoka's natural farming philosophy). See also page 388.</p> <ul style="list-style-type: none"> • <u>Permaculture is about designing sustainable human settlements.</u> It is a philosophy and an approach to land use which weaves together microclimate, annual and perennial plants, animals, soils, water management, and human needs into intricately connected, productive communities (Mollison 1994). • <u>"Permaculture is a philosophy of working with, rather than against nature;</u> of protracted and thoughtful observation rather than protracted and thoughtless labor; and of looking at plants and animals in all their functions, rather than treating any area as a single product system." Bill Mollison.
Considerations	<p><u>Other considerations</u> include:</p> <ul style="list-style-type: none"> • Legislation, resources. • Threatened species and ecological communities. • Biodiversity conservation. • Invasive species, eg weeds, feral animals, diseases, fungi, insects. • Migratory species.
Training	<p><u>Training Courses are available</u> at various levels and in workshops for agriculture and horticulture, including:</p> <ul style="list-style-type: none"> • Bachelor of Ecological Agriculture Systems. • Agriculture (Organic Production). • Diploma of Sustainable agriculture, Certificate in Sustainable Agriculture. • BioNEW offers solution-oriented services for biological agriculture, including a level of nutrition, natural plant disease resistance, yield, and pesticide-free crops which are beyond the scope of agro-chemical and organic methods. www.bionew.com.au <ul style="list-style-type: none"> • BioNEW is positioned to support growers on a journey, whether from agro-chemical growing or organic through to biological farming. • Additionally, the unique positioning of BioNEW with a systemic focus on the 'bionome' that bridges the two traditional worlds of agriculture and BioTECH which brings an awareness to creating healthy soils, plants, animals and humans.
An example of one company that offer courses	

INTEGRATING EMS WITH OTHER CONTROL METHODS

The *EMS* standard can be integrated with other management systems within a business to assist with achieving environmental and economic goals. *EMS* is one of many Resilient Agricultural Systems being researched

<p>National Action Plan (NAP) IPM 2012 EU directive</p>	<p><u>The EMS easily integrates into The National Action Plan (NAP)</u>, eg</p> <ul style="list-style-type: none"> • Prevention (rotation, sanitation, host resistance, healthy seed, landscaping). • Monitoring pathogens. <p style="text-align: center;">BIOLOGICAL > PHYSICAL > NON-CHEMICAL > CHEMICAL</p> <ul style="list-style-type: none"> • Limit chance resistance / virulence development • No side-effects. • Sustainable pesticide application. • Appropriate, science-based measures.
<p>Invasive species</p> <p style="text-align: center;">EPPO</p>	<p><u>The International Union for Conservation of Nature (IUCN)</u> describes invasive species as “animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species”. The main strategies of the European and Mediterranean Plant Protection Organization (EPPO) are:</p> <ul style="list-style-type: none"> • To protect plant health in agriculture, forestry and the uncultivated environment. • To develop an international strategy against the introduction and spread of pests (including invasive alien plants) that damage cultivated and wild plants, in agricultural and natural ecosystems and protecting biodiversity. • To encourage harmonization of phytosanitary regulations and all other areas of official plant protection action. • To promote the use of modern, safe, and effective pest control methods. • To provide a documentation and information service on plant protection.
<p>Decline in pollinating bees worldwide</p>	<p><u>Thirty-five percent of global production from crops</u> including at least 800 cultivated plants depends on animal pollination (Nicholls and Altieri 2013). For many fruit and vegetable crops suitable pollinators must be available. Transformation of agriculture in the past half-century has triggered a decline in bees and other insect pollinators.</p> <ul style="list-style-type: none"> • <u>In North America, losses of bee colonies have accelerated since 2004</u>, leaving the continent with fewer managed pollinators than at any time in the past 50 years. • <u>A number of factors linked to industrial agriculture affect bee colonies</u> and other pollinators around the world, including: <ul style="list-style-type: none"> • Habitat degradation due to monocultures resulting in a decline of flowering plants. • Cold, heat or rain may prevent pollinators from ‘working’. • Climate change. • Use of insecticides toxic to bees. • Bee pests, eg varroa mite and diseases. • <u>Incentives could be offered to farmers to restore pollinator-friendly habitats</u> by adopting agro-ecological production methods, including: <ul style="list-style-type: none"> • Providing appropriate flowers within or around crop fields. • Eliminating the use of insecticides toxic to bees. • Conventional farmers should be extremely cautious in the choice, timing, and application of insecticides and other chemicals.
<p>Riparian native vegetation</p>	<p>Riparian management, preventing stock access to fragile areas, fencing channels and drains, windbreaks and shelter belts, wetland management, retention and management of remnant vegetation.</p>
<p>Grow-Me-Instead (GMI) Nursery & Garden Industry Association</p>	<p><u>The Nursery-led GMI campaign might just have prevented</u> an environmental problem caused by flooding in Qld.</p> <ul style="list-style-type: none"> • <u>The likelihood of any transported weeds</u> becoming environmental problems was reduced. • <u>The GMI campaign identified</u> 27 invasive urban plants in each State / Territory along with a range of suggested superior alternatives for nurseries to grow. • <u>Movement by flooding or other means of non-native species of plants</u> into the natural environment at any time is serious as these plants may naturalize and have an environmental impact, eg degrade natural vegetation and impact on biodiversity generally.
<p>Erosion control</p> <p style="background-color: yellow; text-align: center;">AUSTRALIAN STANDARD</p> <p>Proposed standard for turf as an erosion control measure (TU12202)</p>	<p><u>The turf Industry is developing an Australia Standard for turf as an erosion control measure</u> at Redlands Research Station in Qld to provide a permanent demonstration site to conduct workshops and training to the various construction industries and local and state government representatives. (Turf Industry: Maintenance and Operation of the Erosion Control Demonstration Facility).</p>

<p>Revegetation projects Local or non-local genotypes?</p>	<p>King's Park and Bold Park in WA are both significant bush areas in the Perth area which have been contaminated by invasive species and are the subject of restoration programs (Berney 2007), using local genotypes or introducing non-local genotypes into the sites.</p> <ul style="list-style-type: none"> • In general, more often than not, results suggest we should be collecting as locally as possible and wherever possible, from the local population itself. • However the reverse hypothesis has to be tested, eg researchers are looking at the performance of home versus introduced genotypes on both rehabilitated mined areas and undisturbed sites.
<p>Biological diversity changing all the time</p>	<p>Biological diversity is not static but undergoing changes all the time. Do we want to maintain the current biodiversity species as a status quo or instead look at the overall changing biodiversity?</p> <p>Biological diversity can be recognized at 3 levels:</p> <ul style="list-style-type: none"> • Ecosystem diversity, • Species diversity and • Genetic diversity. <div style="border: 1px solid black; padding: 5px; text-align: center; margin: 10px auto; width: fit-content;"> <p>2010 was International Year of Biodiversity</p> </div>
<p>Biodiversity and GM crops</p>	<p>The Convention on Biological Diversity (CBD) is an international legally binding treaty. Its objective is to develop national strategies for the conservation and sustainable use of biological diversity. The main goals include conserving biological diversity, using components sustainably and the equitable sharing of benefits arising from genetic resources.</p> <ul style="list-style-type: none"> • The impacts of genetically modified crops (GM) crops on biodiversity have been considered at crop, farm and landscape levels (Carpenter 2011, also page 417). <ul style="list-style-type: none"> • It also considered the potential effects of the introduction of GM crops on: <ul style="list-style-type: none"> • Crop diversity. • Non-target soil organisms. • Weeds. • Land use. • Non-target aboveground organisms. • Area-wide pest suppression. • The study concluded that "Overall, currently commercialized GM crops have reduced the impacts of agriculture on biodiversity through": <ul style="list-style-type: none"> • Enhanced adoption of CT practices. • Reduced insecticide use and reduced use of the more hazardous insecticides. • Use of more environmentally benign herbicides. • Increased yields that alleviate pressure to convert additional land into agricultural use.
<p>The Systemwide Program on Integrated Pest Management (SPIPM)</p>	<p>The Systemwide Program on Integrated Pest Management (SPIPM) is a global group of scientists and institutions that spearheads forward-looking collaborative research and outreach programs on crop pest and disease management.</p> <ul style="list-style-type: none"> • SPIPM aims to develop knowledge and technologies for innovative crop protection to increase and secure the production of safe food in an environmentally and economically sound way: <ul style="list-style-type: none"> • Adapting IPM to climate variability and change. • Improving agro-ecosystem resilience. • Managing contaminants in food, feed, and the environment. • In these areas IPM research strives to gain a better understanding of the biotic and abiotic interrelationships between the different components of agricultural biodiversity. • A holistic approach is taken which requires examination of important plant interactions with both detrimental and beneficial organisms in the environment in which they occur.
<p>Challenges for cotton crops</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Field-based case studies of Precision Agriculture in cotton farming systems and could include:</p> <ul style="list-style-type: none"> • Nutrition • Irrigation, • Plant growth regulators • Yield monitoring </div>	<p>Strategies for BMP for cotton, include:</p> <ul style="list-style-type: none"> • Develop and evaluate the use of attractants and repellants for <i>Helicoverpa</i> spp. • Identify and evaluate effective biocontrol agents for soilborne pathogens of cotton. • Investigate the use of biofumigation and "systemic induced resistance" for improving the efficacy of disease control strategies. • Develop more effective and user friendly diagnostic kits for rapid detection of pests and diseases in plant tissues and soil and for pesticide residues and pest resistance. • Investigate bioremediation techniques for pesticide contamination on cotton farms. • Wider use of biocontrols for pest, weed and disease management, to reduce environmental impact. • Progress sustainable farming systems using IPM and BMPs in commercial cotton. • Seek alternative management tools that minimize dependence on disruptive pesticides. • Also the need for innovative solutions to pest, weed and disease problems and the need for new tools to remediate or monitor environmental impacts. • Fundamental work on the molecular genetics of cotton will aid breeding for various characteristics including pest and disease resistance and fiber quality.

CHALLENGES

- Using **Roundup brand herbicides** in such a way that it can continue to be a perfect fit with the vision of sustainable agriculture and environmental protection.
- It is important to have **general bipartisan agreement** on what is to be done based on solid scientific research, otherwise a lot of money and time will be wasted.
- The **way water is used in agricultural production** has led to widespread degradation globally.
- Generally, **commercial drivers** are more effective in generating positive outcomes and compliance.
- Although a number of horticulture industries have implemented an **EMS**, this is not widespread. There is a need for industry to take the lead, eg
 - Informing / educating members of the supply chain.
 - Developing practical management systems that mesh with existing quality management systems.
 - Enabling compliance with market requirements.
- **One of the main aims of current farming** is to reduce chemical applications of disruptive applications but this is **not** necessarily the main problem.
- **It is important that biotech solutions be considered** as a means of reducing environmental impacts, eg GM crops, robotics, nanotechnology.
- **Many new technologies are not being implemented** by industry, possibly due to lack of skills and appropriate equipment. There is a need for increased uptake of:
 - Precision agriculture, horticulture and forestry of water, fertilizers and pest control products according to the season and the crop to reduce environmental contamination and conserve resources.
 - Programs to reduce use of disruptive insecticides, encouraging environmentally benign herbicides.
 - Extending the adoption of CT practices.
 - Traffic farming to reduce soil compaction.
 - Increasing crop yields to alleviate pressure to convert additional land into agricultural use by either traditional breeding or genetic modification.
 - Applying technologies can be complex and many growers cannot afford them.
- **Different countries** have different needs and systems.
- There is also the challenge of meeting the changing demands of society.
- **Projects** of the National Center for Appropriate Technology (NCAT) in the United States deal with sustainable energy/food/agriculture, farm energy, and climate change especially in **poor, rural areas**.
- **It is likely that solutions to many problems will need to be mandated**, eg reduced phosphorus in fertilizers.
- The **Invasive Species Council** in Australia has launched a proposal for the establishment of a national taskforce, **Environment Health Australia**, to stem the rising tide of environmental pests (Low 2012). Obviously the current approach to invasive species is not working. Australia needs a new approach to tackling its growing environmental pest problems. www.invasives.org.au
- **Revegetating affected areas** with either native or exotic species more able to withstand the ravages of fire, drought, salinity, etc, eg reseeding fire affected Mountain ash forests in Victoria with fire resistant eucalypts.
- **Green Marketing** and the Trade Practices Act. The practice of using 'green' claims as a marketing tool.
- **Ecolabels can also be a grey area**, but they may encourage the public to think about what they use. All are aimed at helping consumers make the right choice. They are a form of sustainability measurement. More than 50 different eco-labeling programs operate in Australia from energy, to water savings rating, to forests. Ecolabeling is usually voluntary but green stickers may be **mandated by law**, eg for major appliances and automobiles. Overseas certification standards with ecolabels exist for coffee, cocoa and tea, etc which are aimed at **sustainable food production and good social and environmental performance**. The main drivers for ecolabels have been **energy and fuel** consumption. **Three (3) types are defined** by the International Organization for Standardization whose ISO 14000 series of environmental assessment cover:
 - Environmental management,
 - Certification and
 - Eco-labeling.
- **Predictions for the next 25 years** suggest that Russia will become a global food superpower and humans will redefine nature (The Observer 2/1/2011).
- **Food production needs to increase**.
- The **CRC** for Contamination Assessment, Remediation and the Environment (**CRC CARE**) assesses, prevents and remediate contamination of soil, water and air.
- **Fertilizers**, eg N reduction decreases exotic cover; the most successful seed mix for **reducing exotic abundance** varied depending on the **invader functional type**, eg
 - **Exotic annual grasses were least abundant** when the native community was dominated by early active forbs, which matched the phenology of the exotic annual grasses.
 - **Nutrient availability** and the timing of biotic interactions can be manipulated in restoration to prevent invasion and minimize native species recovery (Cleland et al 2012).

REVIEW QUESTIONS AND ACTIVITIES

1. Explain the **difference** between environmental management and environmental assurance.
2. What are the **aims** of Ecologically Sustainable Development (ESD)?
3. Describe generic steps in any **environmental / QA** program.
4. What **EMS** applies to your industry?
5. Briefly list the types of **legislation, standards, and codes of practice and accreditation schemes** you have to comply with at work.
6. Name **3 other EMSs** for agriculture or horticulture.
7. Explain the meaning of and give one example of each:
 - Best Management Practice (BMP)
 - Standard
 - Ecologically sustainable development (ESD)
 - Sustainable agriculture
 - Precision agriculture / horticulture
 - Conservation agriculture
 - Resilient agriculture
 - Biological farming

SELECTED RESOURCES

Allison, S. K 2012. *Ecological Restoration and Environmental Change: Renewing Damaged Ecosystems*. Rutledge, Taylor & Francis Group.
Australian Biosecurity Group. 2005. *Invasive Weeds, Pests and Diseases: Solutions to Secure Australia*. Invasive Animals CRC; Weeds CRC; WWF Australia.

Ateyo, C. and Thackway, R. 2009. *Field Manual for Describing and Mapping Revegetation Activities in Australia*. Bureau of Rural Science.

Baxter, N. 2011. *On-farm Input Trials Show Where the Money is*. Ground Cover. Sept-Oct 2011. Variable Rate Technology (VRT).

- Baxter, N. 2012. *The Six Habits of Resilient Farmers: Study*. Ground Cover. Jan-Feb.
- Baxter, N. 2012. *Technologies Transfer a Must for Food Productivity*. Ground Cover. Jan-Feb.
- Berney, J. 2007. *The Tyranny of Distance*. Aust. Hort. Nov.
- Braidotti, G. 2011. *Our Future World Relies on Wheat*. Ground Cover. Nov-Dec.
- Bunting, S. W. 2013. *Principles of Sustainable Aquaculture: Promoting Social, Economic and Environmental Resilience*. Earthscan from Routledge.
- Carpenter, J. E. 2011. *Impacts of GE Crops on Biodiversity*. ISB Newsletter.
- Cleland, E. E., Larios, L. and Suding, K. N. 2012. *Strengthening Invasion Filters to Reassemble Native Plant Communities: Soil Resources and Phenological Overlap*. Restoration Ecology, 21.3. May 390–398.
- Collis, C. 2011. *Sustainable Certification for No-till Wheat*. Ground Cover. Sept-Oct.
- Collis, C. 2012. *Conservation Needs to be Practical*. Ground Cover. Jan-Feb 2012.
- Collis, C. 2013. *Strategic Cultivation shows On-farm Profit Potential*. Ground Cover. July-Aug.
- Commonwealth of Australia. 2007. *The Australian Weeds Strategy: A National Strategy for Weed Management in Australia*. Natural Resource Management Ministerial Council. www.weeds.org.au
- Drew, J. 2013. *Boldly Into the Future*. SMH Oct 21.
- Ferron, P. and Deguine, J. 2005. *Crop Protection, Biological Control, Habitat Management and Integrated Farming: A Review*. Agron. Sust. Dev. (25)1 Jan-Mar 17-24.
- Folke, C. 2006. *Resilience: The Emergence of a Perspective for Social-ecological Systems Analyses*. Global Environmental Change 16, 253-267.
- Francis, P. 2006. *Outstanding Horticulture EMS Package for Horticulture*. Australian Landcare. Oct.
- Gleeson, T. 2007. *Guide to the Australian Landcare Management System (ALMS)*. Australian Landcare Management System.
- Gold, M. V. 2007. *Sustainable Agriculture*. Alternative Farming Systems Information Centre, USDA.
- Gold, M. V. 2009. *Sustainable Agriculture: Information Access Tools*. Alternative Farming Systems Information Center, USDA.
- Gunningham, N. and Sinclair, D. 2002. *Environmental Partnerships: Combining Sustainability and Commercial Advantage in the Agricultural Sector*. RIRDC No.02/004.
- Gurr, G. M., Altieri, M., Miguel, A. and Wratten, S. D. (eds). 2004. *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*. CSIRO Pub.
- Gurr, G. M., Wratten, S. D. and Luna, J. M. 2003. *Multi-function Agricultural Biodiversity: Pest Management and other Benefits*. Basic Appl. Ecol. 2003. 4:107–116.
- Hetherington, S. 2009. *Integrated Pest Management for Australian Apples & Pears* (ed. A. Munroe). NSW Industry & Investment and Apple and Pear Australia.
- Ikerd, J. 2012. *The Essentials of Economic Sustainability*. Kumarian Press.
- IPNI (International Plant Nutrition Institute). 2011. *Precision Horticulture*. IPNI. www.ipni.net/
- Lindenmayer, D., Burns, E., Thurgate, N. and Lowe, A. 2014. *Biodiversity and Environmental Change*. CSIRO Pub.
- Low, P. 2012. *Invasive Species Council warns Australia needs a National Taskforce to Stem the Rising Tide of Environmental Pests*. WeedsNews 3477 / June 28.
- Masson, P. 2011. *Biodynamic Manual: Practical Instructions for Farmers and Gardeners*. Floris Books.
- Mech, T. and Young, M.D. 2001. *Voluntary Environmental Management Arrangements (VEMAs)*. RIRDC.
- Mezzalama, M., Govaerts, B., Sayre, K. and Verhulst, K. 2011. *Conservation Agriculture: A Solution to Soil Degradation and Soil-Borne Diseases?* Technical Innovation Brief 14 Sept 2011. www.spipm.cgiar.org,
- Newley, P. D. and Treverrow, N. L. 2008. *Sustainable Horticulture*. Primefact 144, NSW DPI.
- Nicholls, C. and Altieri, M. A. 2013. *Plant Biodiversity Enhances Bees and other Insect Pollinators in Agroecosystems. A Review*. Agron. Sus. Devel. 33:257-274.
- Norton, D. and Reid, N. 2013. *Nature and Farming Sustaining Native Biodiversity in Agricultural Landscapes*. CSIRO Pub.
- Pieri, C. 2006. *The Paradigm of Conservation Agriculture*. Proc. of World Assoc. of Soil and Water Conservation Paper No.P1-7.
- Rotherham, I. D. and Lambert, R. A. (eds). 2013. *Invasive and Introduced Plants and Animals: Human Perceptions, Attitudes and Approaches to Management*. Rutledge, Taylor & Francis Group.
- Rowland, P. 2005. *Environment and Farm Management (EFM) Program*. RIRDC, Canberra.
- Sharma, P. D. 2005. *Environmental Microbiology*. Alpha Science International.
- Sindel, B. and Coleman, M. 2011. *Fireweed: A Best Practice Management Guide for Australian Landholders*. University of New England.
- Smith, M. L., Smith, J. P. and Stirling, G. R. 2011. *Integration of Minimum Tillage, Crop Rotation and Organic Amendments into a Ginger Farming System: Impacts on Yield and Soilborne Disease*. Soil & Tillage Research 114: 108-116.
- Stapper, M. 2006. *Soil Fertility Management – Towards Sustainable Farming Systems and Landscapes*. CSIRO Sustainability Network Update 61E .
- Stirling G.R. 2014. *Biological Control of Plant-parasitic Nematodes: Soil Ecosystem Management in Sustainable Agriculture*. CAB International, Wallingford.
- Upadhyay, R. K., Mukerji, K. G. and Chamola, B. P. (eds). 2000. *Biocontrol Potential and its Exploitation in Sustainable Agriculture: Crop Diseases, Weeds, and Nematodes*. Springer.
- Wade, M. R., Gurr, G. M. and Wratten, S. D. 2007. *Ecological Restoration of Farmland: Progress and Prospects*. The Royal Society.
- Walker, B. and Salt, W. 2012. *Resilience Practice: Engaging the Sources of Our Sustainability*. Island Press, USA.
- Warburton, K., Pillai-McGarry, U. and Ramage, D. 2002. *Integrated Biosystems for Sustainable Development*. RIRDC No. 01/174.
- Wilson, G. 2000-2001. *Resilient Agricultural Systems*. RIRDC. Free online
- Wilson, J., Williams, J. and Shaw, D. 2008. *EMS Pathways Project*. State of Victoria.
- ACIAR. *Conservation Agriculture: Extent of No-tillage Adoption Worldwide for the year 2008-2009*. Acres Australia (Sustainable Agriculture)
- Aust. Gov. Dept of the Env. www.environment.gov.au/ Australia's National Framework for Environmental Management Systems in Agriculture
- Australian Nursery & Garden Industry Environmental Sustainability Position. 2014. NGLA.
- Australian and New Zealand Environment Conservation Council (ANZECC)
- Biodiversity and Integrated Pest Management
- Ecos – Science for Sustainability
- EMS Self-assessment Guide
- Environmental Best Practice Guidelines for Weed & Pest Management
- Environmental Code of Practice
- Environmental Management Introduction (Horticulture for Tomorrow) www.horticulturefortomorrow.com.au/
- Environmental Management Systems e-newsletter (DA)
- Growcom Farm Management Systems have produced the following Fact sheets: *Eco efficiency, Farm Management Systems, Farm Safety, Information Management, On-farm Energy Use, On-farm food safety, On-farm waste management, Water Use, Record Keeping, Sustainable Land Management, Sustainable Nutrient Management, Water Efficiency*.
- Horticulture Natural Resource Management Strategy: EMS Incentives Program
- International Service for the Acquisition of Agri-biotech Applications (ISAAA). www.isaaa.org/
- Introduction to Environmental Management Systems in Agriculture: Biodiversity Resource Guide
- Invasive Plant Risk Assessment Tool www.planrisktool.com.au
- Invasive Species Council National Center for Appropriate Technology (NCAT)
- Long Paddock Organic Solutions <http://longpaddock.net>
- National Framework for Sustainable Agriculture
- National Guide to EMS in Agriculture
- National Invasive Species Council (Washington) <http://www.invasivespecies.gov/>
- Natural Resource Management Ministerial Council
- Organic Farming Systems (WA)
- Practical Guide to Rural Land Management.
- The Weed's Network www.weedsnetwork.com

ORGANIC STANDARDS

EXAMPLE OF AN ORGANIC STANDARD

GENERAL REQUIREMENTS

- Legislation
- Planning
- Training

PRODUCTIONS REQUIREMENTS

- Soils
- Water
- Inputs (not permitted / permitted)
- Pests, diseases, weeds
- Specific crops
- Specific situations

CERTIFICATION REQUIREMENTS

- Certification process
- Documentation/records
- Auditing
- Type of certificate
- Allowed or approved products
- Labeling / packaging / logo
- Export

STANDARDS 382

CERTIFICATION 384

- General requirements 384
- Production requirements 385
- Certification requirements 386
- Approved Certifying Organizations (ACOs) 388
- Other organic and advisory groups 390
- A National Organic Logo / Mark 391

MANAGING ORGANIC STANDARDS 392

PROS, CONS AND CHALLENGES 394

REVIEW QUESTIONS AND ACTIVITIES 396

SELECTED RESOURCES 396

STANDARDS

<p>International Federation of Organic Agriculture Movements (IFOAM)</p>	<p>The IFOAM defines organic agriculture as:</p> <div style="border: 1px solid black; padding: 10px; text-align: center;"> <p>“a whole system approach based upon a set of processes resulting in a sustained ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production therefore is more than a system of production that includes or excludes inputs.”</p> </div>
<p>Certified organic</p>	<p>Certified organic food is produced to a set of standards and principles concerning such issues as chemical pesticides, food additives, animal welfare and sustainability. Descriptions of organic grown products are often over simplified and inaccurate, eg “in organic systems products are grown and processed without the use of synthetic chemicals, fertilizers or genetically organisms”.</p> <ul style="list-style-type: none"> • Currently there are no laws or regulations in Australia to protect the use of the word “organic”. Many products carry the word “organic” on their label but only if it is certified organic by a recognized certifier (accompanied with a logo or certificate) can consumers be sure that it is truly organic. • How do I know if organic food is really organic? www.organicfooddirectory.com.au
<p>Standards can be obtained from the Department of Agriculture (DA) website; they are updated regularly</p>	<p>Organic standards are sets of definitions, requirements, recommendations and restrictions regarding the practices and materials that can be used in certified organic production and processing systems. Standards are guideline and rules for those wishing to become producers, processors or retailers, wholesalers, exporters of organic products (Neeson 2010). Copies of standards are available either free online or for a fee from certifying organizations. Standards undergo periodic review to ensure they remain current and aligned with the requirements of the Commonwealth and State governments and overseas countries. There are many standards including:</p>
<p>STANDARDS</p>	
<p>Compulsory NSOBP</p>	<ul style="list-style-type: none"> • Export standard The National Standard for Organic and Biodynamic Produce (NSOBP) which stipulates minimum requirements for products placed on the market with labeling which states or implies they have been produced under organic or bio-dynamic systems is administered by the Australian Department of Agriculture (DA) and provides a framework for the organic industry covering production, processing, transportation, labeling and importation. Any person producing organic goods for export is required to have a quality management system that is audited by DA as part of a third party arrangement with certifying organizations. www.agriculture.gov.au/ (under construction, previously www.daff.gov.au). • Aims to enhance trade in certified organic produce through uniform standards. • Forms the basis of a national quality system for the preparation and production, certification, identification and labeling of all organic produce. • Outlines production requirements for: <ul style="list-style-type: none"> Soil and soil management. Plants and plant products, eg type of control methods permitted. Livestock - animal husbandry. Postharvest, processing, packaging, storage and transport. • Aims to be sustainable, eg NSOBP requires the nurturing and maintaining of land for future generations and the conservation of energy, soil and water resources and the maintenance of environmental quality. • Export Control (Organic Produce) Orders make it illegal to export organic produce without a government to government certificate.
<p>Voluntary ASOBP</p>	<ul style="list-style-type: none"> • Domestic and import standard The Australian Standard for Organic and Biodynamic Products - AS 6000-2009 (ASOBP) establishes an agreed set of procedures, transportation, marketing and labeling of organic and biodynamic products including food and processed food within the Australian domestic market and imported food. This standard is voluntary.
<p>Australia is still progressing towards having one standard and a compulsory domestic standard</p>	<ul style="list-style-type: none"> • Both the export and domestic standards are currently undergoing side-by-side comparison in order to determine which standard is the more appropriate for export. The Organic Industry Standards and Certification Council (OISCC) will maintain the standard DA deems is required for export. The OISCC will only recognize one standard which will be used for both domestic, import and export produce.
<p>International</p>	<ul style="list-style-type: none"> • International standards The international Codex Alimentarius Commission has adopted guidelines for the production, processing, marketing and labeling of organic foods from plants and plant products, from ‘Farm to Fork’. <ul style="list-style-type: none"> • Guidelines cover all aspects of production, processing and internationally agreed farm and processing inputs for organic foods. • Measures for consumer protection, including inspection, certification and labeling of organic products. Inputs may only be used if they are essential for the purpose. <ul style="list-style-type: none"> No recombinant DNA techniques, ie not genetically engineered. No synthetically derived chemicals, eg fertilizers and pesticides. No irradiation as a postharvest or storage treatment. No substance that could result in or contribute to, harmful effects to the environment.

Approved Certifying Organizations (ACOs)

Approved Certifying Organizations (ACOs) provide export certification, on behalf of the Australian Department of Agriculture (DA) for organic and bio-dynamic produce - as defined under the **Export Control (Organic Produce Certification) Orders** exported from Australia.

- **DA regulates Organic certification in Australia** and has the overall responsibility for certifying organic produce for **export** and administers its responsibilities through **ACOs**. It accredits independent organizations to operate organic certification schemes (Fig. 32).
- **Certification** is the procedure by which **DA-Approved Certifying Organizations** provides written assurance that an operator has been determined to conform to the **National Standard for Organic and Biodynamic Produce (NSOBP)**.
- **NSOBP provides the organic industry with nationally agreed guidelines** on the production and processing of export agricultural products that are labeled 'organic'.

Organizations must apply to DA in order to become a **DA-ACO**. **DA** then undertakes an audit of the organization against **NOSBP, legislation** and **Importing Country Authority** requirements.

- **Growers must be certified** through a **DA-ACO** to produce and market certified organic products. **DA** and **ACO** inspect and certify **exports** of Australian organic produce.
- **Certification protects producers** of organic produce against misrepresentation of other agricultural produce as being organic.
- **The role of ACOs** is to ensure that products marketed under their logo are produced according to specific standards.
- **Some certifying organizations have their own standards** in addition to the National or Australian Standard; some are also accredited by overseas countries to certify products in accordance with those country's standards which allow market access for Australian organic products accredited under those systems.
 - **While each Certification body has slightly different standards and procedures**, they have all been provisionally approved to certify for export and meet minimum national standards for organically produced products developed by a coordinating committee called OPAC (Organic Producers Advisory Committee).
 - **ACOs must then ensure that growers** maintain their Organic principles whilst overseeing both organic wholesalers and retailers.
 - **The following organizations are accredited**, are **Approved Certifying Organizations (ACOs)** and provide inspection and certification services for the range of organic and biodynamic commodities and production practices.
 - Australian Certified Organic (ACO)
 - NASAA Certified Organic (NCO)
 - Organic Food Chain (OFC)
 - Tasmanian Organic Dynamic Producers (TOP)
 - AUS-QUAL Limited (AUSQUAL)
 - Bio-Dynamic Research Institute (BDRI)
 - Safe Food Production Queensland (SFQ)
- **Soil, plant and other samples** are taken by **DA-ACOs** for testing.
- **ACOs** are audited **annually** by **DA** to ensure they meet **NOSBP** requirements.

For a current list of approved certified organizations see the Australian Department of Agriculture (DA) website

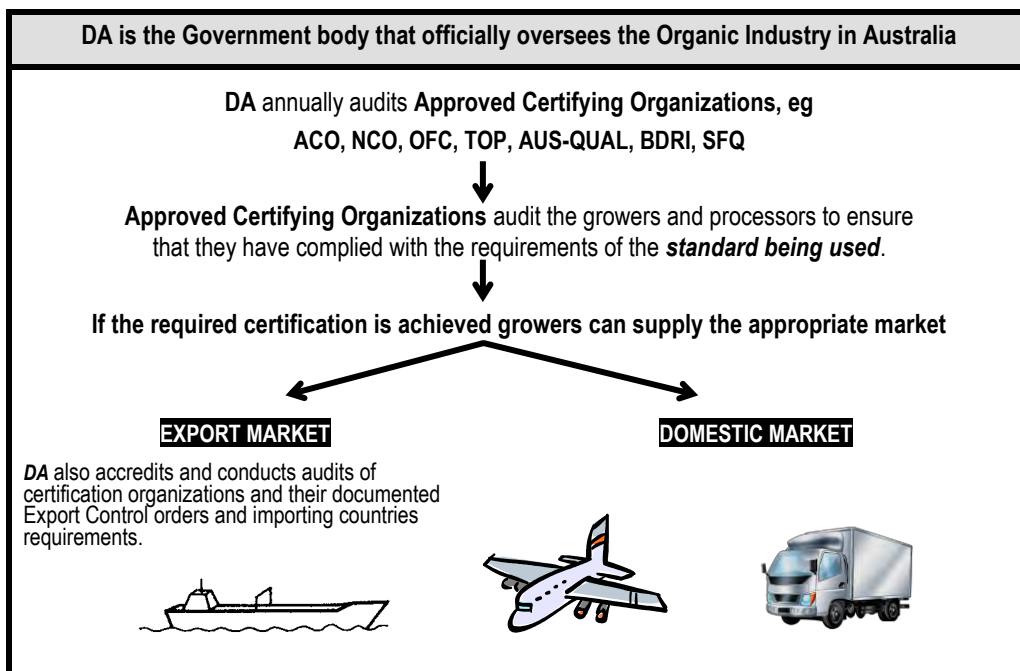







Fig. 32. Oversight of the organic industry by DA.

CERTIFICATION

General requirements

<p>Legislation Compliance</p>  	<p>Organic farmers and their produce must meet all relevant local, State / Territory and Commonwealth legislative requirements, standards and codes of practice, even if it means using a herbicide and in the process destroy the farm's organic status.</p> <ul style="list-style-type: none"> • NSOBP is complementary and additional to other health and agricultural regulatory requirements at local, State / Territory and Commonwealth level, eg reading pesticide labels, etc. • It is illegal to sell non-organic produce as organic produce. There are various consumer protection acts, Commonwealth and State, under which people can be prosecuted. • Inspections and testing can prove that produce is not organic. • Fees. Producers who are Certified Organic pay for the Certification as well as pay an on-going levy to maintain the certification systems.
<p>Planning Records Audit trail</p>	<p>To be certified you have to have an organic management plan, outlining your soil nutrition, what are your pest, disease and weed management strategies. You have to be able to identify them all and show how you will manage them organically.</p> <p>The standard at the ground level is the grower's responsibility</p> <ul style="list-style-type: none"> • Individual growers, processors, etc who produce or prepare products as specified in NSOBP and market. • It takes 3 years to become a certified organic producer. • Each of the organizations can supply you with specific information as to their particular standards. • Growers, producers, processors to wholesale and retail operations must comply with the standard for which they are seeking to certify their produce, etc. • Through the use of printed standards, on-site inspection and multi-stage review of their application, organic producers seek to verify that their farming or processing facility and system meet the agreed standards for organic production. This provides a clear audit trail from point of sale back to the exact farm of origin. • Producers are able to choose which certifier they wish to use. • Certifying organizations may indicate which clients are no longer certified with them.
<p>Training</p>   	<p>Students vary from herb, vegetable and fruit growers interested in retail and markets to broadacre crops and graziers, schools. All States and Territories offer courses for training people in commercial organic growing in TAFES and Universities, eg</p> <ul style="list-style-type: none"> • Certifying organizations offer training to their standards. • Some organic groups that do not certify enterprises (Table 29, page 390) assist with communication, training, domestic and export market development and general information. • Private consultants, eg TM Organics offers consulting, training, business advisory and publishing services in Australia and Asia Pacific, principally focused on the organic sector. TM Organics brings together the organic agriculture and environmental experience, knowledge and contacts of the partners. • The Diploma in Agriculture (Organic Production) is available to anyone wanting to make a living from the land or is already doing so. The curriculum takes 18 months to complete and is focused on developing plans to change or develop systems towards organic. Riverina Institute-TAFE NSW offers online and distance learning programs in organic farming and permaculture. Students are linked with a mentor in their region to help them. • Specialty subgroups include: <ul style="list-style-type: none"> • Some focus on areas such as soils, plant nutrition, plant protection and on units of competences that embrace a push into more sustainable practices also on fostering education, training and industry best practice. • Commercial organizations assist courses in TAFES, eg <ul style="list-style-type: none"> • NGIA / Brisbane North Institute of TAFE (BNIT). • Organic Crop protectants / BNIT build environmentally practices into learning activities. • Schools. Australia Certified Organic (ACO) has assisted with funding to promote organic gardening leadership programs in some primary schools to help them develop their own organic gardening programs. • Most cities, town and regions have non-commercial organic growing societies for home gardeners. • Organic Expos, workshops, networking. • General training is addressed on page 441.

Production requirements (example only)

Purchase standards from the certifying organization or obtain them online.

Soil management	<p>General principles include:</p> <ul style="list-style-type: none"> • Healthy soil is the prerequisite for healthy plants, animals and products. With organic farming the care of the living soil and consequently the maintenance or improvement of soil structure, fertility and nutrient cycling is fundamental. • Sufficient organic material should be regenerated and / or returned to the soil to improve, or at least maintain, humus levels. Conservation and recycling of nutrients is a major feature of any organic farming system. By and large Australian soils have low levels of organic matter.
Water	<p>General principles include:</p> <ul style="list-style-type: none"> • Water and agriculture are inextricably linked. The harvest, storage, use and fate of water are integral components of an organic farm. Management of water will include management of vegetation, soil and drainage on the organic farm. • Recycling of water should be carried out as much as possible. • Surface water leaving an organic farm should not contain greater level of nutrients, salts and turbidity than it did when the surface water entered the farm.
Inputs <i>Products for use in organic systems</i>	<p>The production cycle is as closed as possible: there is some use of external inputs permitted in various Standards. Emphasis is placed on renewable resources.</p> <ul style="list-style-type: none"> • Not permitted products or by-products include: <ul style="list-style-type: none"> • No synthetic chemicals (fertilizers or pesticides). • Not derived from genetic engineering technology. • Not treated with ionizing radiation for postharvest purposes. • No fertilization with sewage sludge. • Permitted materials for use in soil fertilizing and soil conditioning, for plant and animal pest and disease control and for processing, storage and handling, ensure the lowest possible risk of residues. <ul style="list-style-type: none"> • All standards contain lists of substances or processes which are permitted in organic farming or in the processing of organic products. • Inputs. Standards typically contain lists of materials that are permitted as farm and processing inputs such as fertilizers, pesticides and food additives. Other materials are prohibited unless the relevant certification organization approves their use. Organic standards generally emphasize the use of good management practices to minimize the need for inputs wherever possible. Expert panels regularly evaluate applications for the addition or removal of permitted substances to or from the standards. <p style="padding-left: 20px;"><i>Allowed input</i></p> <ul style="list-style-type: none"> • An Allowed input (AI) is a product registered with an organic body which is essentially an input that is allowed to be used in that particular certified organic system, eg a product to address a mineral deficiency in the soil. AIs are also used by conventional farmers and becoming more mainstream in Australia, eg horticulture (see also page 386). <p style="padding-left: 20px;"><i>Approved product</i></p> <ul style="list-style-type: none"> • An Approved product (AP) is a product registered with an organic body which can be used by the consumer such as a meat product, also covers sanitizers that might be used by certified organic processors or abattoirs. <p style="padding-left: 20px;"><i>In some organic systems certain additives are permitted</i></p> <ul style="list-style-type: none"> • Compliance. Under international and domestic standards only food and food grade product and fiber products that are 95% or more of agricultural origin can be certified as organic. This means that products used in organic systems, eg fertilizers and cleaning products can be registered as AIs, however, some do have restrictions limiting their use, so check with your certifier. • Biological chemical products. Chemicals which may be permitted for use in organic systems, eg Eco oil, Horti oil, Ecocarb (page 438).
Pests, diseases, weeds	<p>General principles include:</p> <ul style="list-style-type: none"> • Reliance on substances rather than management practices for the control of pests and diseases is not in accordance with the principle aims of organic agriculture. • Livestock are an integral part of broadacre organic farming systems. • Where used, mulches should be of natural materials.
Specific crops	<p>Programs for particular crops are available, eg</p> <ul style="list-style-type: none"> • Fruit crops, eg apples, olives, lychees, etc. • Vegetables, eg mung beans, sweetcorn, etc. • Field crops, eg rice, pasture, cotton, wheat, flour, oats, sunflower, etc. • Wines.
Specific situations	<p>Organic products are handled in a manner that prevents contamination or substitution with substances. There are programs for particular situations, eg</p> <ul style="list-style-type: none"> • Storage and transport. • Preparation and packaging. • Local markets, export markets, etc.

Certification requirements

Certification process	<p><u>Individual operators must be certified</u> through a DA Approved Certifying Organization to produce or prepare similar products and market such products as organic.</p> <ul style="list-style-type: none"> • Certification protects producers of organic produce against misrepresentation of other agricultural produce as being organic. • The process of certification itself will differ, depending on whether the applicant or operation seeking certification is based within Australia, or is an international operation, ie based outside Australia. • Whilst the steps to certification within Australia involve a common process of regular inspection and review, the time frame and requirements will vary dependent on whether the applicant is a primary producer, involved in manufacturing and distribution or retail trade. • All applicants to certification intending to export organic product must meet specific Export Requirements. Additional certification is required for product exported to Japan and US. Accreditation through these programs can be undertaken as a separate exercise, or in addition to existing NASAA certification. • There are a number of approved organic certifiers in Australia and many more internationally.
Documentation, records, traceability	<p><u>Records must be kept</u>. Certification of all producers and operators is contingent on keeping accurate records which must be available to inspectors.</p> <ul style="list-style-type: none"> • Certification provides a system of traceability ensuring the integrity of the organic product from “paddock to plate”.
Audits	<p><u>Organic certification is an audit and inspection process</u> which allows agricultural and other enterprises to have their status as organic producers, processors, packers and exporters verified by an independent organization (pages 322, 350). It provides some credibility to claims that certified enterprises make about the organic status of their products or services and gives consumers some confidence in the authenticity of organic products.</p> <ul style="list-style-type: none"> • Approved Certifying Organizations (ACOs) are audited annually by DA. • Producers and industries are audited annually by their ACO. Minimum requirements and precautionary measures include: <ul style="list-style-type: none"> • Inspections and tests ensure that all stages of production, processing and marketing are subject to inspection and meet requirements. • All certified operators, businesses and organizations must have a Quality Management Manual as an integral part of the organic production system. It must satisfy NSOBP, the Export Control (Organic Produce Certification) Orders 1997 and the Importing Country Authority requirements. • Sanctions must be applied to producers or operators who are found to contravene any provisions of the standard.
The type of certificate issued	<p><u>Organic certification is a regulatory and audit system</u> aimed at providing guidelines and rules (known as standards) for those wishing to become, processors, retailers, wholesalers, exporters or importers of organic products.</p> <ul style="list-style-type: none"> • Organic certification helps protect both consumers and producers of organic food from false claims and misleading labeling of organic products. All food sold must be what it is claimed to be (Neeson 2010). • Pre-Certification is a period in which the farmer must practice organic principles, although, sell his produce as ‘Conventional’. During this period, the farmer is given training by his Certification body of choice. • There are generally 2 levels of categories for Organic Certification: <ul style="list-style-type: none"> • In Conversion to Organic (previously known as ‘B Grade’) is a period (3 years) during which the farmer is recognized organically and able to sell his produce as Certified Organic, although the fruit and vegetables must be labeled ‘in conversion’. During this period the farmer is developing his systems under the supervision of his chosen Certification body. • Certified Organic (previously known as ‘A Grade’) is the highest level of Certification a Farmer can reach (unless Biodynamic). ‘Certified Organic’ growers are experienced, capable and have had many years growing organic produce. All certified growers are audited annually to ensure they are complying with their organic standard.
Allowed or approved products	<p><u>Some products</u>, such as agricultural inputs, bottled water, salt and cosmetics cannot be certified organic (they are not raised from soil) but can carry a “ACO Allowed Input” or “ACO approved product” label to indicate their suitability for use in organic systems and status as products which do not contain synthetic ingredients.</p>

**Labeling,
packaging**

**Organic produce
certificate logo**

**Green Marketing and
the Trade Practices Act**

Guidelines produced
by the ACCC educate
businesses about their
obligations under the
Trade Practices Act in
terms of using 'green'
claims as a marketing
tool.

NSOBP lays down minimum principles for labels which should indicate that products meet a **standard** which is subject to an inspection scheme.

- **Requirements for the labeling** and marketing of **imported products** protect consumers against deception and fraud in the market place and unsubstantiated product claims.
- **Food Standards Australia New Zealand (FSANZ)**. All food for sale or imported for sale in Australia and New Zealand, including organic food, must be labeled in accordance with the Food Standards Code developed by **FSANZ**, which aims to protect the health and safety of people in Australia and NZ by maintaining a safe food supply. If you intend to **produce or sell** food or fiber that claims to be organic or biodynamic, you should be aware of the minimum requirements for production, processing and labeling of organic produce specified in the **NSOBP standard**.
- **Every certified product is required to have** a label with the logo, grower / manufacturer number and other labeling requirements as required by Commonwealth, State / Territory law.
 - **Each DA approved accredited organization has a unique logo specific** to that organization for easy recognition of Certified Organic products in the market place. Each packaged product will also display the Farmers / Producers unique Certification Number, appointed by his Certifier for audit purposes, eg

Certified NASAA. Retailer No. [] Copyright © 2008.

- **Eventually there may be an Australian unique logo** displayed beside the **Certifier's logo on products** sold in the market place.
 - This will allow for easy recognition of Certified Organic produce at a glance. **1 logo with 1 organic standard upheld** and a **clear new national logo audit trail** via our 7 Certifiers for assurance, with use of the unique Certification Number.
- **It is illegal** to label export produce as organic unless it has complied with the **NSOBP standard**.
- **Although we have a domestic standard (ASOBP) there are no mandatory requirements** for labeling.
- **The Commonwealth Trade Practices Act 1974** and the various State / Territories' fair trading laws protect against fraudulent and misleading practices, including food labeling. It helps to ensure that products being sold as organic are in fact organic. The Australian Competition and Consumer Commission (ACCC) is responsible for enforcing the Trade Practices Act.

Export

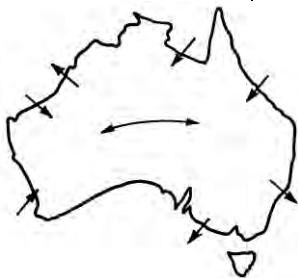
Approved Certifying Organizations (ACOs) issue **Organic Product Certificates (OPCs)** on **DAs'** behalf, for organic and bio-dynamic produce - as defined under the **Export Control (Organic Produce Certification) Orders**, exported from Australia. This certification provides assurance to the importing country that the product has been produced in accordance with Australia's organic export system and the importing country requirements.

- **Different Organic Produce Certificates** are required for different countries.
- **The export of certified organic produce** can be undertaken via:
 - The **DA export system** - all products must be made in accordance with the **NSOBP**, or
 - **A conformity assessment arrangement** between a certifying organization and the relevant importing country authority for certified product which is made strictly in accordance with the requirements of the approving overseas country. Products under this system must not be traded with other countries **unless prior DA approval has been given**.

**Variation
in certifying
criteria within
and between
countries**

The certifying criteria for products allowed for use in organic agriculture vary from country to country and even within a country where multiple certifying bodies exist.

- **Producers and exporters** of organic agricultural and horticultural products must be aware of the criteria specified for organic agriculture in the **local jurisdiction** or **destination country**.
- **Equivalency agreements** have been reached between some countries, eg between the Republic of China (Taiwan) and Australia on organic-labeled products imported into Taiwan. Organic-labeled foods exported to Taiwan include wine, beef, wheat, and flour, oats, sunflower oil and mung beans.



Approved Certifying Organizations (ACOs)

Table 28. Approved Certifying Organizations (ACOs) and the standards they certify.
Refer to the *DA* website for a list of *current ACOs*.

 ACO	AUSTRALIAN CERTIFIED ORGANIC (ACO) Formerly Biological Farmers of Australia (BFA)
	<p>ACO is one of Australia's leading certifiers of organic produce with operations both within Australia and overseas. ACO maintains conformance with most leading international organic standards for worldwide market access, and services can be provided to allow businesses to enter the Japanese, US, Canadian and European markets or any market worldwide. www.aco.net.au/</p> <p>Certification available includes: Australian Certified Organic Standard (ACOS) Organic Growers of Australia Small Producers Program (OGA) National Standard for Organic and Bio-dynamic Produce (Australian Export Standard) Australian Standard for Organic and Bio-dynamic Produce (Domestic and Import Standard)</p> <div style="text-align: center;">  </div>
 NCO	NATIONAL ASSOCIATION OF SUSTAINABLE AGRICULTURE AUSTRALIA (NASAA)
	<p>NASAA is one of Australia's leading certifiers of organic produce with operations both within Australia and overseas. www.nasaa.com.au NASAA Organic Standard is a holistic system built upon natural ecological processes, eg</p> <ul style="list-style-type: none"> • <i>It values the welfare of both the producer and the consumer of organic food</i> and fiber products, and is committed to conserving natural resources for the benefit of all future generations. • Healthy soil is the prerequisite for healthy plants, animals and products. • The maintenance of soil health by ecologically sound means is at the heart of organic production systems and consequently production systems not based on soil, eg hydroponic systems, are not acceptable under the NASAA Standard. • NASAA has extensive operation overseas, certifying production and processing operations in Nepal, Brazil, Papua New Guinea, Indonesia, Samoa, Malaysia, East Timor, Brazil, Solomon Islands and Sri Lanka – comprising over 12,500 small farmers. NASAA is also accredited through the International Federation of Organic Agriculture Movements (IFOAM) and the US National Organic Program (USNOP). • The scope of NASAA's certification service covers the organic supply chain – from input manufacturers to producers, processors to wholesale and retail operations - ensuring organic integrity 'from paddock to plate'. <p>Certification available includes: NASAA ('certified organic' or 'certified conversion') The NASAA Organic Standard (Primary Producers (incl. Biodynamic), Input Manufacturers, Processors, Packers, Wholesalers, Transporters, Exporters) NASAA Organic Trader Standard (retailers, restaurants, markets) NASAA Organic Standard Addendum Section (Cosmetic Labelling Standard February 2011) National Standard for Organic and Bio-dynamic Produce (Australian Export Standard) Australian Standard for Organic and Bio-dynamic Produce (Domestic and Import Standard) Trading standard for Organic and Bio-dynamic produce (Organic Retailers and Growers Association of Australia)</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  NASAA News </div> <div style="text-align: center;">  ORGANIC insights </div> </div>


Table 28. Approved Certifying Organizations (ACOs) and the standards they certify (contd).

	<p>THE ORGANIC FOOD CHAIN PTY LTD (OFC)</p> <p><i>OFC is an organic certifying body</i>, does not charge levies, or organic export certificate fees. Common-sense certification from the fastest growing body in Australia. www.organicfoodchain.com.au</p> <ul style="list-style-type: none"> • OFC is also accredited as an Organic Certifying Body in other countries, eg USA, Japan and the European Union, and by SGS International (JAS - ANZ AS/NZS ISO9001-2000 Quality Assurance Company), USDA NOP (USA), JAS MAFF (Japan) and are registered with the EU as an organic certifying body. <p>Certification available includes: Organic Food Chain Standard National Standard for Organic and Bio-dynamic Produce (Australian Export Standard)</p>
	<p>TASMANIAN ORGANIC-DYNAMIC PRODUCERS INC (TOP)</p> <p><i>The TOP producers' co-operative certifies organic and biodynamic food</i> grown in Tasmania. It is a regional body which aims to implement manufacturing and processing standards, promote certification, training and assist with marketing. www.tasorganicdynamic.com.au</p> <p>Certification available includes: National Standard for Organic and Bio-dynamic Produce (Australian Export Standard) TOP Manufacturing standard TOP Standards Certification Framework - Farms</p>
<p>AUS-QUAL</p>	<p>AUS-QUAL and its parent Company AUS-MEAT</p> <p>AUS-QUAL provides a vast array of services to industry including:</p> <ul style="list-style-type: none"> • Certification of Management Systems • Industry Accreditation Services • Program Management • Standards and Program Development • Auditing Services <p>www.ausqual.com.au</p> <p>Certification available includes: AUS-QUAL Organic Program Quality Management System certification, Nationally and Internationally against the International Standard ISO 9001:2000 Food Safety (HACCP) Management Systems certification against the Internationally recognized Codex Alimentarius HACCP Freshcare Horticultural Food Safety Program Safe food Quality (SQF)</p>
	<p>THE BIO-DYNAMIC RESEARCH INSTITUTE (BDRI)</p> <p>BDRI certifies biodynamic produce. <i>Bio-dynamic</i> means agricultural practices based principally on the work of Rudolf Steiner and subsequent developments derived from practical application, experience and research. www.demeter.org.au</p> <ul style="list-style-type: none"> • <i>Proponents describe it as</i> "a holistic understanding of agricultural processes." • <i>Our produce is grown from</i> Biological-Dynamic agricultural methods founded on a holistic perception of Nature. We use not only biological, but also dynamic practices that specially activate the life of soil and plants. • <i>The Australian DEMETER Bio-Dynamic Method</i> requires understanding of, and appreciation for, the appreciation of Nature and the need to work within the laws of Nature, as well as seeing the farm as a living individuality. • <i>Each and every farm and farmer is different</i>, therefore our Method has no single recipe to offer. <p>Biodynamic Certification available: Demeter standard for biodynamic produce (Products which carries our DEMETER Bio-Dynamic Mark meet The Australian DEMETER Bio-Dynamic Standard which incorporates the requirements of the National Standard for Organic and Bio-Dynamic Produce.</p>
	<p>SAFE FOOD PRODUCTION QUEENSLAND (SFQ)</p> <p><i>SFPQ is responsible for the day-to-day regulation</i> of primary production and processing. The legislation focuses on the food safety management of meat, eggs, dairy and seafood. It also provides a framework to address emerging issues that may impact on food safety. www.safefood.qld.gov.au www.safefood.qld.gov.au/index.php</p>

Other organic and advisory groups

Some organic groups do not certify enterprises (Table 29) but assist with communication, training, domestic and export market development and general information. Most cities, towns and regions have non-commercial organic growing societies for home gardeners.

Table 29. Organic groups which do not certify enterprises.

Organic Federation of Australia (OFA)	ORGANIC FEDERATION OF AUSTRALIA (OFA)
	<p>OFA is the peak body for the organic industry in Australia. The OFA is the only fully representative National Organic Body and represents the interests of all sectors of the industry, eg certifiers, horticulture, broadacre agriculture, meat production, wholesalers, exporters, retailers, consumers, processors, inspectors, regional organizations, education, research and the International Federation of Organic Agricultural Movements (IFOAM). It does not certify farmers. www.ofa.org.au Aims include:</p> <ul style="list-style-type: none"> • Ensuring that the same standards and compliance monitoring are adopted to certify organic produce for both domestic and export markets. • Representing and promoting the Australian Organic Certified Industry to all relevant bodies. • Fostering an industry that is committed to best practice in relation to the environment, sustainability, community and human resources. • Fostering education and training, industry best practice. • Facilitating research and development for the organic industry.
HDRA	HENRY DOUBLEDAY RESEARCH ASSOCIATION OF AUSTRALIA (HDRA)
	<p>HDRA is made up of organic gardeners and farmers who follow organic methods of farming, growing crops and tending livestock.</p> <ul style="list-style-type: none"> • Permaculture is a contraction not only of permanent agriculture but also of permanent culture, as cultures cannot survive for long without a sustainable base and land use ethic. • Permaculture is about designing sustainable human settlements. It is a philosophy and an approach to land use which weaves together microclimate, annual and perennial plants, animals, soils, water management, and human needs into intricately connected, productive communities (Bill Mollison 1994).
Organic Knowledge Hub	RIRDC is supporting the development of the Australian Organic Knowledge Hub , which will be a major resource providing single entry point to access a wide range of organic production information resources
Advisory bodies	DA is the Government body that officially oversees the entire Organic Industry in Australia with special recommendations where appropriate for involvement of government legislation relating to the ACCC and The NSW Department of Fair Trade. Advisory bodies include:
	<ul style="list-style-type: none"> • Organic Producers Advisory Committee (OPAC) advises DA on all matters organic. While each Certification body has slightly different standards and procedures, they have all been provisionally approved to certify for export and meet the minimum national standard (NSOBP) for organically produced products. • IFOAM is the industry's peak international body and oversees the global organic market and certifies the certifiers of each country if they wish to meet the stringent standards of the international organic market. IFOAM have produced a standard, ie Basic Standards for Organic Agriculture and Processing. • Organic Industry Standards and Certification Council (OISCC). • Organic Industry Export Consultative Committee (OIECC).

A National Organic Logo / Mark

Avoiding confusion

Australia is one of the few countries with a developed organic sector that does not have a national organic logo / mark. Most countries with organic sectors such as Canada, USA, India, Japan, China, Hong Kong, Korea and Taiwan, etc have national logos / marks. The European Union has just adopted **one logo for all of their member countries** which will take legal precedence over all the national and private labels and will be compulsory on EU certified products.

- Australia had a national regulatory mark used for Certifying Organic Products for Export but its use has ceased (30th of June 2011).
- The Organic Federation of Australia believes that the issue of one national organic mark needs to be considered and revisited.



Eco-Naturalure contains a yeast protein bait plus an insecticide spinosad. The protein bait lures fruit fly to feed on it and ingest the spinosad which kills them before they can mate and lay their eggs. Spinosad is from an actinomycete bacterium (*Saccharopolyspora spinosa*) with rapid activity on the target pest. It has a favorable environmental and toxicity profile, has little or no impact on most beneficial insects, not shown to be phytotoxic to crops, meets organic requirements, suitable for IPM programs. **Carefully follow information on the label on how to apply it.** It needs to be applied weekly and rotting fruit must be cleaned up as it is a source of protein.

Fig. 33. Examples of Certified Organic Products (**AgriBoost, MULTIGUARD and Eco-naturalure**). Note: BFA is now ACO (Australian Certified Organic).

CHECK CURRENT
REGISTRATION
STATUS OF
PESTICIDES
PRIOR TO USE

MANAGING ORGANIC STANDARDS

Organic growing is “a whole system approach based upon a set of processes resulting in a sustained ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production therefore is more than a system of production that includes or excludes inputs.”

<p>Integration with other programs</p>	<p>Organic standard certification may include:</p> <ul style="list-style-type: none"> • Best Management Practice. • Integrated Pest Management programs. • Environmental Management programs. • Risk management. • Nursery accreditation schemes. • Precision agriculture and horticulture.
<p>Biosecurity Manual for the Organic Grains Industry</p> <p>Farm Biosecurity Manual for the Organic Grains Industry</p>	<p>Biosecurity and the use of best practice is a high priority for the Australian grains industry. The Biosecurity Manual for the Organic Grains Industry aims to help organic grain producers deal with pest threats while complying with the Australian Standard for Organic and Biodynamic Products. www.planthealthaustralia.com.au/</p> <ul style="list-style-type: none"> • The manual provides invaluable advice on how to protect against unwanted pests which forms a key part of an organic grains farming operation. • By considering the key pest risks and implementing some simple practices detailed in the manual, biosecurity at the farm level can be greatly enhanced while also protecting the organic status of individual farms and benefiting the entire Australian grains industry. • Spelt (<i>Triticum aestivum</i> var. <i>Spelta</i>) is one of the oldest cultivated grains. Breeders are trying to improve the quality and yield of cultivars of spelt for organic production.
<p>Weed control</p> <p>A false seed bed involves creating a seedbed some weeks before sowing seed. Seeds that have been disturbed and brought to the soil surface during cultivation will germinate, and can be controlled before sowing the crop.</p>	<p>Certified organic growers need to be able to demonstrate that their produce is grown without the use of chemical herbicides. The challenge is to find combinations of weed management tactics that simultaneously provide acceptable levels of weed control, reduce weed seed return to the seed bank, are economically advantageous and can overcome variability in weather. To beat perennial weed problems without using herbicides, growers are using a range of non-chemical methods including:</p> <ul style="list-style-type: none"> • Reducing weed density, eg through use of a ‘false seedbed’. • Cultivation before and post sowing, selective weed control with inter-row cultivation. • Manual or hand weeding. • Grazing, hay cutting or silage. • Green manure crops. • Crop rotation, fallowing. • Increased seeding rates. • Competitive crops. • Increase interspecific competition promoting quick canopy closure. • Precise fertilizer placement for the growing crop. • Collection of weed seeds at time of harvest.
<p>Root and foliar diseases</p>	<p>Results are variable.</p> <ul style="list-style-type: none"> • Root diseases and pests were generally less severe or no more so in organic or reduced-input farms, than in conventional farms <ul style="list-style-type: none"> • Consistent reduction of root disease in organic systems and reduced input compared with conventional can be ascribed to longer rotations, regular organic amendments and complete absence or reduced pesticide use. Organic amendments reduce disease due to increased microbial activity. • Some foliar diseases were often more severe than in conventional farms. <ul style="list-style-type: none"> • The main reason for differences is probably determined by climate and weather factors and not by microbial activity. • It is generally more difficult to control foliar diseases than root diseases by biological or cultural means. There are some biological chemical products registered for use in organic crops. • Foliar diseases could be reduced by controlling overhead irrigation and reducing fertilizer use in some instances. • Weather forecasting systems would assist in timing of any action. • Lowered yield could be a problem.

Biodiversity, sustainability

Prohibition or reduced use of chemical pesticides and inorganic fertilizers, sympathetic management of non-cropped habitats and preservation of mixed farming are particularly beneficial for wildlife:

- **However it remains unclear** whether a whole farm organic approach provides greater benefit to biodiversity than careful targeted prescriptions applied to relatively small areas of habitat within conventional agriculture.
- **Generally** though, birds, predatory insects, soil organisms and plants respond positively to organic farming while non-predatory insects and pests did not.
- **Organic growing aims to be sustainable**. Sustainability generally benefits from organic technologies with high soil organic matter and nitrogen, lower fossil energy inputs and conservation of soil moisture and water resources.
- **There is some disagreement** over the merits of energy efficiency of organic versus conventional farming. Organic farming could increase the area needed for production and reduce the ability of a system to respond to problems such as dryland salinity in a flexible way.
- **Cultivation has a largely negative affect on soil biota**. Organic growers in Australia may make greater use of cultivation and fallow than conventional farmers.
- **Declining diversity under both organic and conventional**. **Arguably**, conventional crops are more sustainable than organic. Most sustainable systems will use some synthetic pesticides and liquid nitrogen instead of only manure.
- **Need to research:**
 - **The management** of soil phosphorus.
 - **Establishing the relative sustainability** of the alternative approach.
 - **Improve organic farming system performance** by increasing productivity and improving product quality and consistency of supply.
 - **Increase the knowledge of the roles of soil** in organic production systems.
 - **To improve the methods of production and protection of plants and animals** against pests and diseases in organic production systems.
 - Address supply constraints.
 - Evaluate organic farming system performance.

Organic, biodynamic, permaculture

Organic growing is a whole system approach based upon a set of processes resulting in a sustained ecosystem, safe food, good nutrition, animal welfare and social justice. Organic production therefore is more than a system of production that includes or excludes inputs.

Bio-dynamic agriculture is a method of organic farming originally developed by Rudolf Steiner that employs what proponents describe as "a holistic understanding of agricultural processes.

Permaculture about designing sustainable human settlements. It is a philosophy and an approach to land use which weaves together microclimate, annual and perennial plants, animals, soils, water management, and human needs into intricately connected, productive communities (Bill Mollison 1994).

No one system fits all!

Like all other systems of growing a crop, what is suitable for one area is not necessarily suitable for another. **No one system fits all!**

What is suitable for one area may not be suitable for another. It all depends on the crop, the soil, water, climate, etc.

Climate	Crop	Soil	Pests & disease
Grow a crop where the climate is not conducive to certain pests and diseases	It is comparatively easy to grow certified wine grapes as they there are varieties with some resistance to the main diseases	Check the soil for diseases, pests, weeds, etc that affect your crop	Grow a crop in an area which is free from certain pests and diseases (a pest- free area)

PROS, CONS AND CHALLENGES

PROS

- **Organic growing has a perception** of being good.
- **The reasons why interest** in certified organic produce should increase are many.
- Organic produce is attracting premium prices.
- **Weeds are developing resistance** to herbicides.
- **International legislation** now favors limiting the use of chemical inputs.
- **Research** is giving us a better understanding of integrated production and this will only increase.
- **Promotion of the concepts** of organic growing can influence public and political opinion to improve the standards of all types of crop management.
- **A perception by consumers** that crops grown in such a way are healthier.
- **Useful near urban situations.** Removing chemicals from production systems eliminates a main cause of concern and conflict between rural producers and urban dwellers living in the same area.
- **Soil.** Generally accumulative amounts of organic matter improve soil structure and the nutrient and water holding capacity of soil. The **slow release nature of organic materials** such as composted manure or blood and bone, means that soil health may continue to improve for several years.
- **Some crops are easier to grow organically than others.** For example, those that are susceptible to few diseases and pests or weed problems which require pesticide application, or those that mature early in the season before pests build up. Some varieties of grapes which can be conventionally treated with low toxicity pesticides may be readily grown organically.
- **Many markets for organic produce are niche markets** with some having a seemingly unlimited demand.
- **Organic growing aims to be sustainable.** Prevents soil erosion and builds healthy soils, eg less nitrogen leaching, etc.
- **Certification.** Even though certifying is time consuming and more expensive growers like it because it puts everyone on the same playing field.
- **Greenhouses** are prime situations for organic pest control. Sanitation and screening are the keys to organic pest control. Horticulture oils and insecticidal soaps and soil mixes must also meet the organic standard.
- **Organic groups provide training** to assist growers in their quest for certification.
- **Growers must be knowledgeable** about their crops, pests and environment
- **APVMA** assesses the safety and efficacy of biological chemical products.
- **Organic products won't feed the world** but they do have a place in small holdings especially in undeveloped countries. Simple community-based organic agricultural models such as some in Kenya can end rural poverty and starvation.
- **Organic growers still have to comply** with legislative requirements regarding the environment. Soil, nutrient and water testing are still required.
- **No hazardous chemical residues.**
- **Safer options are being developed all the time,** eg the Indian meal moth (*Plodia interpunctella*) is a headache for grain millers, manufacturers and retailers and a nuisance in home pantries throughout Australia and up until now there wasn't an effective organic option available for controlling it. Organic Crop Protectant's product PyGanic® has just received approval from the Australian Pesticides and Veterinary Medicines Authority (APVMA) to be used against Indian meal moth in silos, processing facilities and on shop shelves.

CONS

- **Cultivation has a largely negative affect** on soil microorganisms. Organic growers in Australia make greater use of cultivation as herbicides are not an option for weed control.
- **Complete elimination** of pesticides or chemical fertilizers could mean the economic collapse of farms engaged in intensive crop production.
- **Reduced outputs (yield)** through increasing adoption of organic systems may accelerate conversion of non-agricultural land into agricultural production.
- **It may be impossible to control some key diseases, pests and weeds** of some crops using only organic systems and still achieve the high yields required by population pressures today.
- **Benefits of genetically engineered crops** are foregone, eg pest resistance, improved grains with increased vitamin content or food crops which are unable to take up undesirable heavy metals. **GE** crops may increase yield and use less fertilizer, chemicals and fuel; they may be resistant to disease and drought.
- **Nutrient levels of organic fertilizers are often variable.** Higher application rates may be required than for conventional fertilizers. Nitrates in slurries, liquid manures and farm effluent are potential sources of water pollution. Some sewage sludges may contain heavy metals, eg arsenic, cadmium, copper, mercury, selenium. Some organic fertilizers have not yet undergone the standardization of synthetic fertilizers.
- **Not all permitted products** are harmless, eg **copper** persists in the soil, has a harmful effects on soil organisms and may inhibit growth of some crops.
- **Little evaluation of alternative products** is being undertaken in Australia to reduce the use of sulfur and synthetic fungicides (Savocchia et al 2011).
- **There is no national survey of organic produce** equivalent to the **national market basket** survey for all Australian agricultural produce. Unless produce is 'tested' regularly prior to purchase there is no guarantee that standards are adhered to.
- **Certified organic produce** may be more expensive to purchase because it costs more to produce and needs certification; more work, more expensive seed, fertilizer, sometimes smaller volumes which do not have economies of scale, eg organic certified soybeans.

CHALLENGES

- **The Co-Existence: of GM and Non-GM Crops** (Riddle 2004). Co-existence is the ability of farmers to provide customers with the choice between:
 - GM,
 - Non-GM
 - and organic crops and products
 Producers of GMO and NON-GMO crops should follow **BMPs BEFORE** the crop is planted:
 - Know your buyers, what does the market require
 - Know your risk
 - Know your crop
 - Know the regulations
 - Know your farm
 - Know your neighbours
 - Know neighbouring crops
 - Know your equipment
 - Know your transport
 - Know your crops storage
 - Know your harvest
 - Know your records

- **There is a need to clarify the levels and nature of permitted GM contamination.** Should the organic farmer bear the economic burden of the use of the GM crops by a neighbour while the GM farmer gets the economic benefit?
- **The USDA advisory committee** recommends organic and non-GE conventional farmers **pay to self-insure** against **unwanted GM weed contamination** (Weed News 29/11/2012). However, this would take GE contamination prevention out of the hands of the biotech industry and puts it back on organic and non-GM growers.
- **Making testing for low levels of GM material** in organic crops easier.
- **Regulation** in relation to inputs is considered by some to be excessive.
- **Input dependence** of both conventional and organic farming. Some organic systems may remain input dependent, eg merely replacing chemical fertilizers with dependence on organic nutrients. There is need to **reduce inputs** in all forms of agriculture and horticulture.
- **Labeling of organic food can be a grey area.** Consumers have a poor understanding of what constitutes organic food. You can only be sure that it is certified organic if there is a current logo attached. Consumers must be able to choose and have confidence of label claims. When buying “**Organic**” produce without a logo, you can always ask to see the Certification registration.
 - Standards allow the **ACCC** to prosecute under the Trades Practices Act but it appears that there have been no prosecutions to date.
 - Certified producers may be de-certified.
- **Locally grown, Farmers’ markets.** Increasingly shoppers opt for locally grown seasonal, fresh, local, family-farmed, sustainable, nutritious, naturally raised, hormone free, over organic alternatives. Direct marketing, missing out the middle man, but food may not be subject to conventional testing or not be “certified organic”.
- **The mandatory export standard** is enforced by **DA** for **export** organic produce; however, the domestic standard for certified organic produce is **voluntary** which confuses both the consumer and the organic producer. It was the intention of the industry and government for the export standard to apply domestically but this has not happened yet.
- **There is also still a confusing range of logos** and certification marks. **OFA** is pressing ahead on a national organic certification mark that would sit alongside the individual certifiers.
- **Substantial problems** associated with implementing organic crop production on a large scale, eg composting and spreading organic materials.
- **Declining biodiversity** under both conventional and organic production.
- **There is no evidence** that the average organic diet has a lower chemical load than the average Australian diet (food containing less than the legal Maximum Residue Limits (**MRIs**)).
- **More studies need to be carried out on** exposure to a mix of pesticides. The average household uses about 46, some of which may be more or less hazardous than many registered pesticides.
- **Organic production faces** essentially all the challenges of conventional agriculture plus additional ones, such as controlling weeds in a chemical-free manner.
- **Organic and conventional production systems have much in common.** Many conventional producers minimize the use of synthetic fertilizers, grow non-GM crops select low toxicity, non-persistent pesticides, practice **IPM**, **BMP** and **EMS** techniques and conserve the environment in the same way that proponents of organic growing advocate. They use **inputs** such as disease-tested seed, resistant varieties and mulches to control annual weeds.
- **Post harvest treatments** are difficult, eg controlling brown rot (*Monilinia fructicola*) on stone fruits.
- **Many growers follow organic standards** but don’t get accredited because of the:
 - Cost of auditing and
 - A one off spray can mean they lose their accreditation. Perhaps the organic industry could deliberate further on this.
- **Weed control is still a challenge for organic growers.** Organic growers do not use herbicides for weed control but use cultivation which disrupts soils and runs down soil nitrogen. There is a need to further explore other methods of weed control such as flammers, etc which do not disturb the soil.
- **Need to explore biocontrol and other products** for weed control, eg vinegar (acetic acid), pine oil, etc.
- **How sustainable is organic growing?** Minimum till with herbicides and GE crops should be more sustainable.
 - **No one knows precisely** at this stage of agro-economics, how other biotechnologies, including nanotechnology could improve or detract from sustainability.
- **Organic seeds and traceability** remain an issue for organic growers. Growers need to use certified seed and transplants to grow their crops. Has the seed been grown according to organic production methods, bred to organically accepted methods and / or seed varieties adapted to organic agriculture conditions with low-external inputs? Organic seeds should be purchased where available. Organic growers producing for **export markets** must realize there are differences in operations relative to the sourcing of seed that must be considered.
- **Despite its growth since the 1990s**, organic agriculture still only makes up a small proportion of all commercial agricultural production in Australia, US and Europe. There is scope to expand.
- **Marketing difficulties** include irregularity of supply, increased cost; rapid expansion in supply may lead to downward pressure on prices.
- **Produce may have minimal damage** which is not acceptable for biosecurity purposes.
- **There is some disagreement on energy efficiency** over the merits of organic versus conventional farming but it could increase the area needed for production and reduce the ability of a system to respond to some problems, eg dryland salinity in a flexible way.
- **The refusal to allow the fortification of flour** for making bread with folic acid (the cause of spina bifida) and iodine (wide spread deficiency in Australia resulting in serious diseases) and to recognize the advantages of some GM crops, etc is difficult to understand.
- **The general demand** is for more intense farming and better yielding crops.
- **Tough rules and labor intensive.** A perception that organics is by the rich for the rich.
- **People think if something is organic it is good** for the environment, but if too much water is put on, the organic matter will pollute just like anything else. Organic fertilizers may leach out of the soil.
- **Not as environmentally friendly** as projected, eg using cultivation to control weeds and plant crops, more lanes are needed.
- **APVMA registration and testing procedures** for biological chemical products. Time and costs of registering Ecocarb in Australia was unreasonable. It usually takes about 36 months and \$100,000 to get a new product registered though the APVMA. It hampers the uptake of IPM technology.
- **Public Health Regulations must still be met** for sprouts and other products. Cucumber sprouts may become contaminated with *Escherichia coli* (also called *E. coli*), a bacterium that can cause serious infections.
- **Some low toxicity pesticides** are only effective if insect or disease pressure is not high, eg spinosad baits to manage fruit fly.

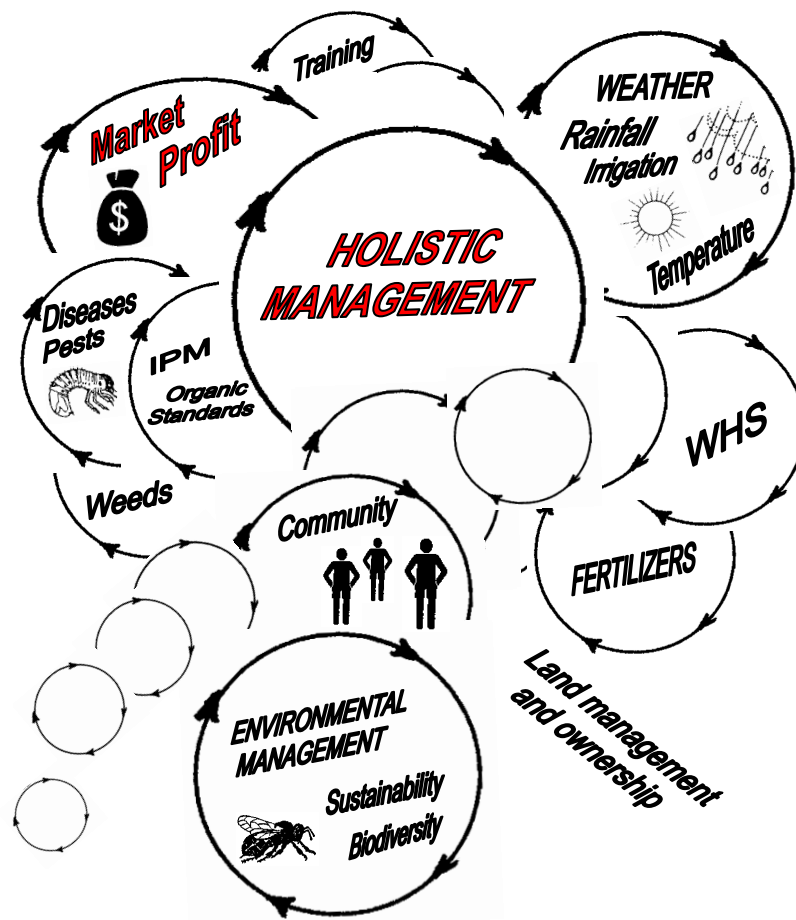
REVIEW QUESTIONS AND ACTIVITIES

1. Describe **6 control methods** used by both **conventional** and **organic growers**.
2. Explain the main differences between **conventional crop production** and **organic standards**.
3. Access the websites of the **7 DA-accredited websites** in Australia.
4. State whom you would contact if you wanted information on **domestic organic standards**.
5. List the **5** most important features of **NSOBP**.
6. Describe the requirements of the **Export Control (Organic Produce Certification) Orders 1997**.
7. Describe **2 fertilizers** which are permitted by **NSOBP** and **2** which are not. Give reasons for your answers.
8. Describe **2 pesticides** which are permitted by **NSOBP** and **2** which are not. Give reasons for your answers.
9. Describe at least **1** other treatment which is not permitted by **NSOBP**.
10. Describe the **regulations affecting labeling** of organic produce in Australia.
11. Recognize **4 logos** for organic produce in Australia.
12. Describe **methods of converting** to organic growing.
13. Describe the **advantages and disadvantages** of organic growing standards as defined by the **NSOBP**.
14. Perform a **practical exercise** in disease, pest and weed control using an organic standard.

SELECTED RESOURCES

- Apted, S. and Mazur, K. 2007. *Potential Economic Impacts from the Introduction of GM Canola on Organic Farming in Australia*, ABARE Research Report 07.11. Dept. of Agriculture, Canberra.
- AsureQuality provides food safety and biosecurity services to the food and primary production sectors worldwide. <http://www.asurequality.com/>
- Blakeney, M. 2007. *Managing the Change to Organics to Commercially Viable Organic Systems*. RIRDC. Canberra.
- Burke, D. 2009. *Organic: Don Burke's Guide to Growing Organic Food*. New Holland.
- Burnett, V., Neeson, R. and Wynen, E. 2005. *Should I Convert to Organic Farming?* RIRDC, Canberra.
- Cornell University. 2013. *Resource Guide for Organic Insect and Disease Management*. 2nded. Cornell University.
- Davies, G., Sumption, P. and Rosenfield, A. 2011. *Pest and Disease Management for Organic Farmers, Growers and Smallholders: A Complete Guide*. Crowood Press, UK...
- Pfeiffer, E. E. and Maltas, M. 2013. *The Biodynamic Orchard Book*. Floris Books.
- Hansen, A. L. 2010. *The Organic Farming Manual*. Story Pub., MA.
- Jones, R. 2010. *Green Harvest: A History of Organic Farming and Gardening in Australia*. CSIRO Pub.
- Kristiansen, P., Taji, A. and Reganold, J. 2006. *Organic Agriculture: A Global Perspective*. CSIRO Pub.
- Guthman, J. 2004. *Agrarian Dreams: The Paradox of Organic Farming in California*. Uni. of California.
- Lazor, J. 2013. *The Organic Grain Grower*. Chelsea Green Publishing Co., USA.
- Madge, D. 2009. *Organic Citrus: A Growers' Manual*. RIRDC, Canberra.
- McFarlane, A. 2011. *Organic Fruit Growing*. ABC Books.
- McKinna, D. 2006. *Export Potential for Organics: Opportunities and Barriers*. RIRDC 06/061/.
- Neeson, R. 2010. *Organic Standards and Certification in Australia*. NSW Primefacts 1047.
- NSW DPI. 2008. *Organic Farming: An Introduction*. Tocal College, NSW.
- NSW DPI. 2008. *Organic Farming: Crops, Fruit and Vegetables*. Tocal College, NSW.
- Riddle, J. 2004. *A Plan for Co-Existence: Best Management Practices for Producers of GMO and Non-GMO Crops*. University of Minnesota.
- Savocchia, S., Mandel, R. and Scott, E. S. 2011. *Evaluation of 'Alternative' Material to Sulfur and Synthetic Fungicides for Control of Grapevine Powdery Mildew in a Warm Climate Region of Australia*. Aust. Plant Path. Vol.40.No.1.2011.
- Stackhouse, J. and McDonald, D. 2012. *The Organic Guide to Edible Gardens*. Murdoch Books.
- Zwieten, van M., Stovold, G. and Zwieten, van Lukas. 2007. *Alternatives to Copper for Disease Control in the Australian Organic Industry*. RIRDC, Canberra.
- ### Journals, Newsletters
- Australian Organics Gardening Resource Guide
Australian Certified Organic Magazine
Organic Gardener: Essential Guide
Australian Organic Producers
Australian Organics Newsletter (RIRDC)
Natural Growing (Jn. of HDRA)
Permaculture International Journal
Seasons (Tas. Jn. of Organic Sustainable Agriculture)
Simply Living.
The Organic Farmer
The Organic Advantage
The Organic Knowledge Hub
Organic News
The Organic Update (OFA)
TM Organics (4/101 Mount Barker Road, Stirling SA.
Organic Certification Body Organic Farming: The Certification Process (Agriculture Notes Vic 2005
Organic Crop Protectants (OCP). Synergy Newsletter
Organic Crop Protection (OCP) is a leading manufacturer and distributor of organic soil and plant health products. www.ocp.com.au/
- ### States / Territory Fact Sheets, other leaflets.
- Each State / Territory has a website dealing with organic farming usually relating to particular crops, vegetables, eg lettuce, also for organic gardening.
- Guidelines for the Use of Sewage Sludge on Agricultural Land.
Organic Farming Systems (WA)
Organic Farming: An Introduction
Organic Fertilizers: An Introduction
Organic Grapevine Management Guide
Sewage Sludge and Organic Farms
Sustainable Vegetable Growing Projects, the Vegetable Research Station, Frankston, Vic.
- www.apvma.gov.au/ <http://portal.apvma.gov.au>
www.agriculture.gov.au (under construction, previously www.daff.gov.au)
www.ecoorganicgarden.com.au
www.organicfooddirectory.com.au
www.organicshub.com.au/OKH/Home.html
www.rirdc.gov.au

HOLISTIC MANAGEMENT



FEATURES 398

Holistic thinking 398

Features of holistic management 398

Development of pest control in holistic management 399

EXAMPLES OF HOLISTIC MANAGEMENT 399

CHALLENGES 402

SELECTED RESOURCES 402

FEATURES

Interconnectedness

Holistic Management (HM) is characterized by the belief that the parts of something are intimately interconnected and explicable only by reference to the whole. Sometimes it is sometimes called **Whole System Management (WSM)**. These management systems do not have a well-established, precise meaning and probably never will. They are systems that understand how things influence one another within a whole.

Most agriculture and horticulture holistic systems embrace **IPM, BMP**, conservation agriculture, biological methods, etc and their integration with modern, scientific agricultural and horticultural production.

Holistic thinking



Feedback loops are necessary for the system to operate predictably.

Holistic thinking incorporates several principles including:

- **Emphasizing the interdependence and interactive** nature of elements or disciplines and their attributes within and external to a system, eg pests, diseases and weeds are connected and joined together by a web of relationships, sometimes time-delayed, to climate, community relationships, biosecurity, trade, etc.
 - The interactions between the elements are **not static but dynamic processes**. The emphasis with systems theory shifts from parts to the organization of parts.
 - The more elements that are included the more complex the organization.
 - Holistic management integrates the units, disciplines and specialty groups into a team effort, forming a structured development process that proceeds from the concept to production to operation and disposal.
- **Goal seeking / aims**. Systemic interaction must result in some goal. What are **the business and the technical needs of all customers** so that a quality product that meets the user's needs; what are the needs of the workers, sociological health and environmental health.
- **Inputs and outputs** must be adaptable and flexible.
- **Regulation / Steps / Proper organization of the elements or disciplines** (pest control, irrigation, marketing, environment, etc.).

PLANNING

DO what you planned to do.

CHECK regularly audit.

IMPROVE

- **Hierarchy**. A complex whole made up of smaller subsystems, eg pest control, society's requirements, nature parks, etc.
- **Differentiation**. Specialized units, elements and disciplines can perform specialized functions, eg pest control, irrigation, water, resources, native vegetation, scientific knowledge, marketing, trade. In depth studies can identify the most critical interactions in the different parts of the system.

Features of holistic management HM



Holistic management is large, complex and dynamic and has only been possible by **IT** and increase in scientific knowledge, however, they will only supply us with the information we want if we feed in the appropriate material.

- **HM is a configuration of parts or elements connected** and joined together by a web of relationships, a family of relationships among members acting as a whole.
- **Interactions of parts are not "static" and constant but dynamic processes.**
- **In organizations, systems consist of people, structures and processes** that work together to make an organization healthy or unhealthy.
- **You have to examine the linkages and interaction** between the elements that comprise the entirety of the system.
- The **many circular interlocking, sometimes time-delayed relationships** among its elements are often just as important in determining its behavior as the individual elements themselves.
- **In nature, ecosystems have various elements such as water**, movement, plants and animals which work together to survive or perish. They seek equilibrium but can exhibit **oscillating, chaotic or exponential behavior**.
 - **In a crop situation**, elements such as the crop itself, pests, irrigation, soil, weather, fertilizers work together to produce a crop, or otherwise.
 - **Agricultural and horticultural systems** illustrate that small catalytic events can cause large changes in complex systems. An improvement in one area can adversely affect another element or area of the system, so it is necessary to promote **organizational communication** at all levels to avoid the **"silo-effect"** (lack of communication and common goals between departments in an organization).

Development of pest control in holistic management



Pest control was initially studied and viewed as an isolated entity, then it evolved into **IPM** for individual pests in a crop, then later into **Crop Management** for key pests, diseases and weeds and selecting varieties, and now it is part of **Holistic Management**.

- **With the development of IT**, large flexible and complex management systems have been developed to include not only pests, diseases and weeds, crop management but also climate change, biodiversity, markets, prices, human resources, etc.
- **Because of their complexity**, size and constantly changing nature, field workers in pest control must continually receive **soundly-based training in the basics of pest control** (and of course, soils, water, animals, biodiversity, etc) in order to quickly and confidently update their knowledge and skills.
- **In complex management systems**, basic systematic studies of pests, diseases and weeds, control methods, specific crops and diagnostics, etc can be diminished, so that the constant updating of such systems can be more difficult for participants.
- **Quality assurance issues**, chemical residues and changing market conditions all make decisions more difficult.

EXAMPLES OF HOLISTIC MANAGEMENT

Biosecurity

Biosecurity is about **maintaining market access, protecting the natural environment and securing the future of Australia's industries** and is a good example of holistic management (pages 171-204).

Integration of crops, livestock and forests

Plants, animals, soils, water, etc

Working against farmers are climate change, plant diseases and distribution problems.

Farmers currently grow enough food to feed 12 billion people according to the UN but transport and storage is a large problem.

- **Integrated farming or Integrated production** is a commonly and broadly used word to explain a more integrated approach to farming as compared to existing monoculture approaches. It refers to agricultural systems that integrate livestock and crop production and may sometimes be known as **Integrated biosystems**.
- **Management of landscape** rather than individual units is a future trend but is difficult.
 - **Encourage** integrated farm, forest and natural management planning approaches and systems, including property and catchment management planning through the provision of information and training for primary producers.
 - **Encourage** certification of integrated farm management systems and practices that incorporate and validate best-practice use of chemicals.
 - **Support the provision of landholder access** to improved diagnostic services to assist in informed planning and decision making.
- **One goal is to collaborate with other countries like Australia**, on researching the integration of crops, livestock and forests to explore productivity in the landscape.

Grassland management

It is generally recognized that only a holistic approach can improve our rivers

Holistic management is a decision-making framework which results in ecologically regenerative, economically viable and socially sound management of the world's grasslands (**Savory Institute** www.savoryinstitute.com/).

- **There are three components in a "holistic context"**:
 - The quality of life sought.
 - What needs to be produced to live such lives.
 - What their life-supporting environment must be like to sustain such lives into the future.
- **There are eight tools for managing natural resources:**
 - Money and labor.
 - Human creativity.
 - Grazing.
 - Animal impact.
 - Fire.
 - Rest.
 - Living organisms.
 - Technology.
- **Holistic management is based on four principles:**
 - **You can't control or change one thing in one area** without having an impact on something else in another area.
 - **All environments are different.** It is crucial to acknowledge nature's complexity and that an action can produce completely different results in different environments.
 - **Properly managed livestock can improve land health.** When domestic livestock is properly managed to mimic the behavior of wild herbivores interacting with grasslands, they can reverse desertification.
 - **Time is more important than numbers.** Overgrazing of plants is directly related to the amount of time the plants are exposed to the grazing animals and the amount of time that lapses between consecutive grazing events.

Bio-Holism	Bio-Holism™ aims to nurture, create and foster environments in which weeds, livestock, landscapes, in brief all human and non-human beings are taken into consideration.
RegenAg <i>Regenerative agriculture</i>	Regenerative agriculture is committed to helping regenerate Australia's farms, soils, communities and on-farm livelihoods. Workshops focus on improving soil health and biodiversity, increasing grazing and wildlife capacity, increasing annual profits and enhancing livelihoods, optimal rainfall usage, reversing desertification, increasing food and water security and enhancing family relations.
Organic Standards	Organic standards are a good example of holistic management (pages 381-396). NASAA's aims and principles include: <ul style="list-style-type: none"> • Organic agriculture is a holistic system built upon natural ecological processes. • It values the welfare of both the producer and the consumer of organic food and fiber products, and is committed to conserving natural resources for the benefit of all future generations. • Healthy soil is the prerequisite for healthy plants, animals and products. • The maintenance of soil health by ecologically sound means is at the heart of organic production systems and consequently production systems not based on soil (eg hydroponic systems) are not acceptable under the NASAA Standard (page 388).
Nursery Production Farm Management System (FMS) Accreditation schemes NIASA EcoHort Biosecurity HACCP	The FMS enables you to critically evaluate each component of your production nursery identifying areas of concern and to manage the identified risks (page 367). It includes 3 key programs: <ul style="list-style-type: none"> • The Nursery Industry Accreditation Scheme Australia (NIASA) Guidelines detail industry Best Management Practice (BMP) for crop hygiene, crop management, water management, and general site management. • The FMS EcoHort Guidelines detail the nursery industry's National Environmental Management System for production nurseries, growing media manufacturers and Greenlife markets. Demonstrates that you have sound environmental stewardship and natural resource management. • BioSecure HACCP Guidelines detail the industry specific on-farm biosecurity program designed to assist production nurseries, growing media manufacturers and Greenlife markets in assessing their current and future pest, disease and weed risks and to guide businesses in the implementation of management strategies at Critical Control Points (CCP).
Turf Industry	The MyResults online analytical resource for the turf industry is designed to simplify the science behind turf surfaces, by combining the benefits of fast and secure web-based access to improved reporting formats, novel management tools, eg disease predication models and efficient communication pathways suited to modern industry. <ul style="list-style-type: none"> • The primary outcome is the ability to make management decisions based on solid evidence derived from such analytical tools, within budget, etc. My-results covers soil chemistry, water chemistry, nematode counts, turf disease identification, plant tissue analysis, disease prediction models and associated information, tissue testing.
Cotton industry myBMP	A web-based management system for the cotton industry provides growers access to the Australian Cotton Industry's best practice standards. It provides growers with the tools required to improve production performance, better manage business risks, maximize potential market advantages and demonstrate responsible and sustainable natural resources management. <ul style="list-style-type: none"> • What's New? A new system of classification Level 1 is the entry level that covers legal requirements and Level 2 contains what is considered industry Best Practice. Together these two levels comprise the content required to complete myBMP certification. Levels 3 and 4 are aspirational levels that cover those practices that will be considered best practice in the next 5 and 10 years respectively. • mySystem allows you to work through the program in the order and to the levels that suit your business priorities. • myResources links every practice to its own reference source which provides information, definitions and other links to information. • myInsurance provides guidelines and practical advice on how to comply with legal requirements from storage to the use of chemicals to human resources management requirements. • myCertification allows those growers who choose to seek certification to find new and streamlined auditing processes easier to manage. • myBMP has the ability to cross reference BMP Practices against one another, automatically transferring those practices that you have completed from one system to another. • There is also a Cotton Pest Management Guide 2010-2011. <ul style="list-style-type: none"> • Insects, weeds and diseases. • Plant growth regulators and defoliant. • Cotton industry biosecurity plan. • Spray application best practice.

Phytophthora cinnamomi (Pc)

A summary of one project (2006)

©Commonwealth of Australia 2006.

Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia. Dept. of Environment.

www.environment.gov.au

The Protection and Biodiversity Conservation Act 1999 (EPBC Act) lists the disease in natural ecosystems of Australia, caused by the introduced plant pathogen *Pc* as a key threatening process. The Act requires the Australian Government to prepare and implement a threat abatement plan for nationally coordinated action to mitigate the harm caused by *P. cinnamomi* to Australian species, particularly threatened flora, fauna and ecological communities.

ERADICATION (2014)
Trials in WA indicate that *Pc* can be eradicated from bushland sites by completely removing living hosts



The Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia

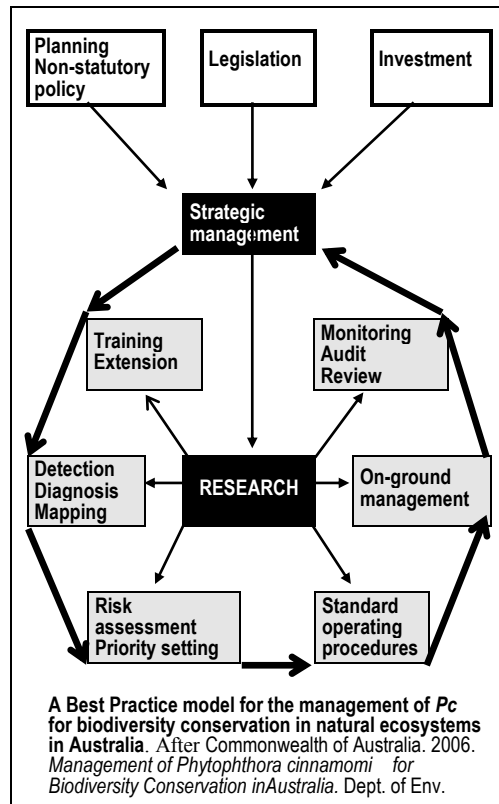
project was funded by the Australian Government Department of the Environment and implemented by **National Threat Abatement Plan** for Dieback Caused by the Root-Rot Fungus *Phytophthora cinnamomi* (NTAP). The aims were to review current management approaches identifying benchmarks for best practice and develop risk assessment criteria and a system for prioritizing management of assets that are or could be threatened by *Pc* and present the results in 4 parts.

Part 1. A Review of Current Management.

- **Best Practice Management of *Pc***
- **Review of current management:**
Legislation, policy, planning, cost
Research
Training and Extension
Detection, Diagnosis and Mapping
Risk Assessment and Priority Setting
Standard Operating Procedures (SOPs)
On-Ground Management
Monitoring, Audit and Review

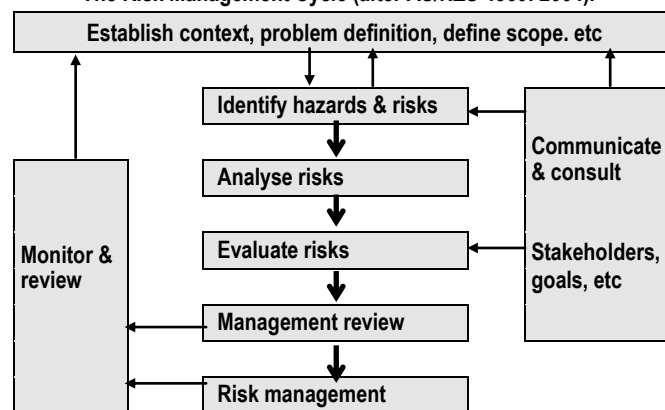
Part 2. National Best Practice Guidelines.

- **Determine need for managing *Pc*.**
Is the area favorable to *Pc*?
Is the site vulnerable to disease?
Are there species present for which the impact of *Pc* would be significant?
Is *Pc* present?
- **Are appropriate management options based on disease status of the site?**
Minimize spread by:
Access, hygiene, barrier system access (infection boundaries), non-vehicle activities, water, drainage, effluent, etc.
Minimize impact by:
Phosphite, extensive conservation, identifying areas vulnerable to disease, climate, isolate regions?
Response of Australian Native plant species to *Pc*. Threatened species and ecological community.



Part 3 - Risk Assessment for Threats to Ecosystems, Species and Communities: A Review.

The Risk Management Cycle (after AS/NZS 4360: 2004).



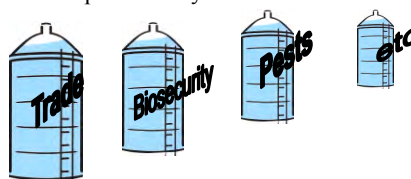
Part 4 - Risk Assessment Models for Species, Ecological Communities and Areas

The risk assessment models developed in the document, in the context of the broader strategy planning framework in which they should ideally operate.

Species & community models	<ol style="list-style-type: none"> 1. Identify vulnerable areas 2. Map <i>Pc</i> distribution 3. Identify threatened susceptible species and communities at risk 4. Identify potential management areas
Area model	<ol style="list-style-type: none"> 5. Assess likelihood of introduction to and establishment/spread within area 6. Determine likelihood of introduction to and establishment/spread with area 7. Assess the manageability of the risk to values, in the management area 8. Rank management areas for action

CHALLENGES

- **Are they becoming too complex?** The bigger the system the less accurate they may become. But they open up ideas and knowledge, etc and need to be seen within that framework.
- **Can we really do justice** to crops and surrounding landscapes?
- **Growers need to keep up to date with new software**, attending workshops, etc. Software has reduced the time taken to plan inputs, outputs and retrieve key information about planting dates, etc.
- **Land management and ownership.** Land management is increasingly complex and owners' responsibilities for what happens on their lands need to be clearly understood. It is increasingly common to use contractors for certain operations, for corporate ownership and collective management where a number of farmers pool their properties and employ a professional manager. **Managers** should have an understanding of the legislation and where their responsibilities lie. While **land owners** are responsible for most of what happens on their land, many others have an interest in their activities. Commonwealth, State and Local governments have a plethora of legislation and regulations aimed at preserving the wider community interest in the environment, health and safety, animal wellbeing, food quality, etc.
- **Quality assurance** will be a big part of growing crops in the next few years and software enables to record, when, where and what we spray, as well as chemical batch numbers, prevailing temperatures and wind direction. All commercial and domestic buyers and will soon request crop treatment records before products are purchased. This information should be available in a few mouse clicks.
- **Some growers still have some confusion** regarding biosecurity, integrated pest management, precision agriculture, etc so making the big the big leap to holistic management may be a big ask.
- **The Silo Effect** refers to a lack of information flowing between groups or parts of an organization. On a farm, silos prevent different grains from mixing. In an organization, the Silo Effect limits the interactions between members of different branches of the company, thus leading to reduced productivity.



SELECTED RESOURCES

- Alliance for Sustainable & Holistic Agriculture (ASHA). www.kisanswaraj.in/
- Baxter, N. 2009. *More Farm Planning Encouraged*. Ground Cover. Nov-Dec.
- Centre for *Phytophthora* Science and Management, Murdoch University, WA.
- Commonwealth of Australia. 2006. *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia*. Dept. of Environment. <http://www.environment.gov.au/>
- DAFWA. 2014. *Phytophthora Diseases of Cut Flowers*. DAF WA.
- Dieback Working Group. www.dwg.org.au/
- Gunningham, N and Sinclair, D. 2002. *Environmental Partnerships: Combining Sustainability and Commercial Advantage in the Agricultural Sector*. RIRDC.
- Hassal & Associates. 2001. *Genetically Modified Plants – Farm and Resource Management Issues*. RIRDC.
- Mezzalama, M., Govers, B., Sayre, K. and Verhulst, K. 2011. *Conservation Agriculture: A Solution to Soil Degradation and Soil-Borne Diseases?* Technical Innovation Brief 14 Sept 2011. www.spipm.cgiar.org.
- NGIA. 2009. *Nursery & Garden Industry Australia Environmental Sustainability Position*. NGIA.
- Sutherst, R. W. 2002. *National Electronic Modeling Network for Pest, Disease and Weed Management*. RIRDC 02/030.
- Turgeon, A. J. 2012. *Turfgrass Management*. 9th ed. Prentice Hall.
- Warburton, K., Pillai-McGarry, U. and Ramage, R. 2002. *Integrated Biosystems for Sustainable Development*. RIRDC.
- Wilson, G. *Research in Progress: Resilient Agricultural Systems 2000-2001*. Online.
- Citing the document comprising:** *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia*.
- E. O. Gara, K. Howard, B. Wilson and G. E. StJ Hardy (2005) *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia: Part 1. A Review of Current Management*. A report funded by the Commonwealth Government Department of the Environment and Heritage by the Centre for *Phytophthora* Science and Management, Murdoch University, Western Australia.
- Part 2. E. O. Gara, K. Howard, B. Wilson and G.E. StJ Hardy (2005) *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia: Part 2 . National Best Practice Guidelines*. A report funded by the Commonwealth Government Department of the Environment and Heritage by the Centre for *Phytophthora* Science and Management, Murdoch University, Western Australia.
- B. Wilson, K. Howard, E. O. Gara and G. E. StJ Hardy (2005) *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia: Part 3 - Risk Assessment for Threats to Ecosystems, Species and Communities: A Review*. A report funded by the Commonwealth Government Department of the Environment and Heritage by the Centre.
- CPSM (2005) *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia: Part 4 – Risk Assessment Models for Species, Ecological Communities and Areas*. A report funded by the Commonwealth Government Department of the Environment and Heritage by the Centre for *Phytophthora* Science and Management, Murdoch University, Western Australia.
- The Weed's Network - The Weed's News*
www.weedsnetwork.com

APPENDIX 1

Plagues and Epidemics

Plagues have been around since time immemorial, eg hail, locusts, mice, drought, rats, rust diseases.

What is an epidemic?	<p><u>An epidemic is any increase of disease in a population</u>; usually a widespread and severe outbreak of a disease.</p> <ul style="list-style-type: none"> • Most epidemics are localized and cause minor to moderate losses. • Some epidemics are kept in check by changes in the weather, chemical sprays, etc. • Occasionally however, epidemics appear suddenly and go out of control and become particularly widespread or severe on a particular plant species.
Why epidemics, epidemiology?	<p><u>Epidemiology deals with the study of causes, distribution and management of disease</u> in populations.</p> <ul style="list-style-type: none"> • <u>The major objectives of epidemiology in pest control are to:</u> <ul style="list-style-type: none"> • Prevent the invasion of a disease. • Reduce spread or virulence of disease and minimize the economic cost of a disease, ie reduce the effect of a pest below some economic or environmental damage threshold, or • Less commonly, to eradicate a disease (Shea et al 2000). • <u>Controversy over management may arise due to lack of knowledge.</u> Usually after an examination of its dynamics, all possible options are listed. <ul style="list-style-type: none"> • In some simple cases the choice of control is simple (and how to implement it). • In more complicated cases subjective or multicriteria procedures may be useful. • There is a need to better understand relationships of the ecological and evolutionary dynamics of hosts and their natural enemies and apply it to disease and pest management problems to improve use of resources.
The disease triangle – 3 elements plus Know the ingredients of a plague	<p><u>Plant disease epidemics develop as result of the timely coinciding</u> of the same <u>3 elements</u> that result in plant disease or damage (Fig. 34 below):</p> <ol style="list-style-type: none"> 1. <u>Susceptible host plants</u>, a particular kind of crop plant cultivated over a large area. 2. Appearance of a <u>virulent pathogen</u> and 3. <u>Favorable environmental conditions</u> over a <u>relatively long period of time</u>. For a disease to become significant in the field, particularly if it is to spread over a large area and develop into a severe epidemic, specific combinations of environmental factors must occur <u>either constantly or repeatedly and at frequent intervals over a large area</u>. <p><u>Additional parameters</u> The 4th element necessary for an epidemic to occur is <u>TIME</u>. The 5th and 6th elements for consideration are <u>PEOPLE and VECTORS</u>.</p>

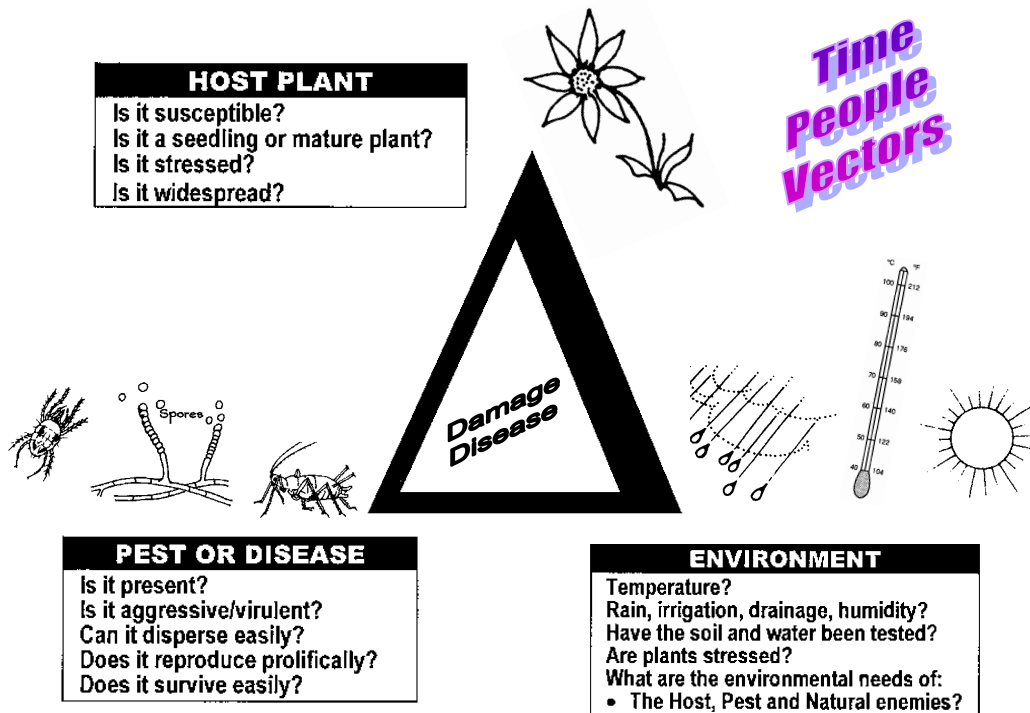
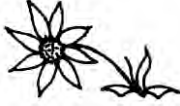


Fig. 34. The DISEASE TRIANGLE. For disease to occur all **3 elements must be present**. Any one might be removed from the equation though, eg the environment changes and is not conducive for the pathogen, or the disease is controlled through a fungicide application, etc.

Elements of an epidemic

The risk of an epidemic increases when the susceptibility of the host and the virulence of the pathogen are greater, as the environmental conditions approach the optimum for the pathogen reproduction and spread and as the duration of favorable combinations is prolonged or repeated.

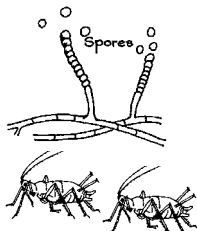
Host factors



The development of infection and of an epidemic depends on the particular plant-pathogen combination, degree of genetic uniformity, type of crop and age of plants.

- **When genetically uniform host plants are grown over large areas**, a greater likelihood exists that a new race of a pathogen will appear that can attack the host and result in an epidemic. This is why most epidemics develop rather slowly in natural populations where plants of varying genetic makeup are intermingled.
- **Genetic resistance of the host.**
 - **Susceptible host plants** provide the ideal substrate for establishment and development of new infections and so in the presence of a virulent pathogen, a favorable environment, and susceptible hosts favor the development of disease epidemics.
 - **Host plants carrying partial (horizontal) resistance** will probably become infected but the rate at which the diseases and the epidemic will develop will depend on the level of resistance and the environmental conditions.
 - **Host plants carrying race-specific (vertical) resistance** do not allow the pathogen to become established in them and so no epidemic.
- **Type of crop**, eg diseases in annual crops, eg vegetables and foliar and blossom on fruit tree epidemics usually develop more rapidly (usually in a few weeks) while diseases in the branches and stems of woody perennials such as fruit and forest trees take years to develop, eg chestnut blight, Dutch elm disease.
- **Age of the host plant** (Agrios 2005).
 - **With some host-pathogen combinations**, eg damping off and root rots, downy mildews, peach leaf curl, systemic smuts, rusts, bacterial blights and viral infections, the hosts (or their parts) are susceptible only during the growth period and become resistant during the adult period.
 - **With several diseases such as rusts and viral infections**, plant parts are quite resistant while still very young but become more susceptible later in their growth and then become more susceptible again when fully expanded.
 - **In brown rots and gray mold (Botrytis)**, post harvest infections of plant parts are resisted during growth and the early adult period but become susceptible near ripening.
 - **In Irish blight (Phytophthora infestans) and tomato early blight (Alternaria solani)**, there is a stage of susceptibility during growth of the host followed by a period of relative resistance in the early adult stage and then susceptibility again as the plant matures.
- **Ecological influences are numerous.** Native plant species may serve as reservoirs for pathogens that cause disease in crops.

Pathogen factors, pest factors



Aphids

These include:

- **Levels of virulence.**
 - **Virulent pathogens** are capable of infecting the host rapidly ensuring a faster reproduction of large amounts of inoculum.
 - **The quantity of inoculum near the hosts**, the greater the number of bacterial or fungal spores, nematode eggs, virus infected plants, etc within or near host plant the more inoculum reaches the host at an early time increasing the chances of an epidemic.
- **Primary and secondary inoculum** (Fig. 35).
 - **Primary inoculum.** The overseasoning pathogen or its spores that cause primary infection (the first infection of a plant by the overseasoning pathogen).
 - **Secondary inoculum.** Inoculum produced by infections that take place during the same growing season.
- **Type of reproduction of the pathogen – life cycle** (Fig. 36).
 - **Some pathogenic fungi, bacteria and viruses have short reproduction cycles** (polycyclic (many generations in a growing season), eg rusts, mildews and leaf spots are responsible for the most of the sudden catastrophic plant disease epidemics in the world.
 - **Some soil fungi and most nematodes have usually 1 to a few reproductive cycles per growing season** but may still cause sudden widespread epidemics in a single season. Never-the-less, they are usually local and slower in developing, eg smuts.
- **Ecology.** Most fungi produce their spores on the surface of aerial parts of the host. From there they are dispersed by wind over a range of distances and cause widespread epidemics. Some vascular fungi, bacteria and viruses reproduce inside the plant so spread is only possible with the help of vectors. Still others, eg soilborne fungi, bacteria and nematodes produce their inoculum on infected plant parts in the soil within which the inoculum disperses slowly and present little danger of sudden and widespread epidemics.
- **Modes of spread** include:
 - **Spores of many fungi**, eg rusts, mildews and leaf spots are released into the air and can be **spread by strong winds** over distances varying from a few centimeters up to several kilometers. They are responsible for the most frequent and widespread severe epidemics.
 - The next most important group is the viruses **spread by vectors** (aphids, thrips, whiteflies, leafhoppers, etc). Some are spread by beetles (Dutch elm disease).
 - **Pathogens transmitted primarily by windblown rain.** Primary fungi causing apple scab, anthracnoses and most bacteria can cause localized epidemics within a field.
 - **Seed and vegetative plant parts** contaminated internally with pathogens are often planted in the midst of susceptible plants. How easily they spread depends on the new host.
 - **Pathogens present in and spreading by soil** are generally unable to cause sudden or wide spread epidemics but often cause local slow-spreading disease of considerably severity.

Spread

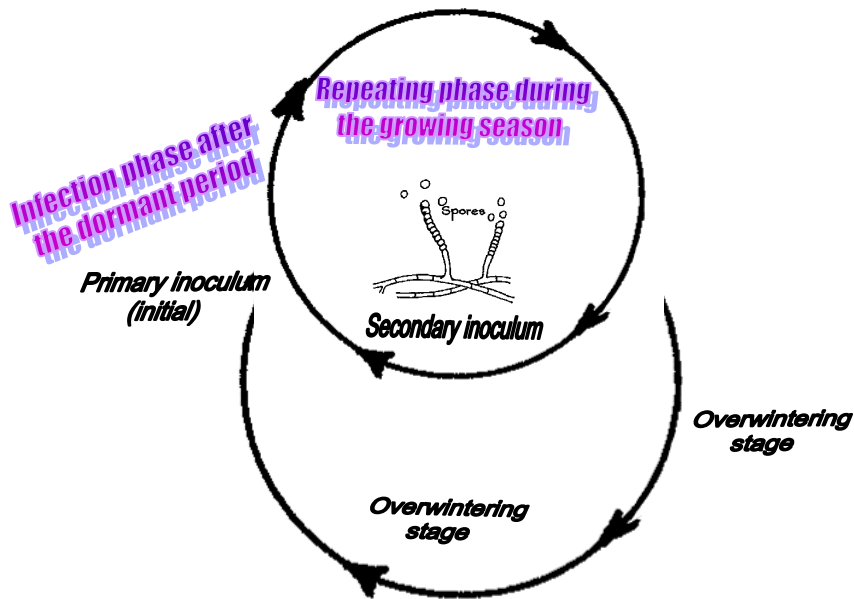


Fig. 35. **Disease cycle** – Infection phase after the dormant period of the fungus followed by the repeating phase during the growing season.

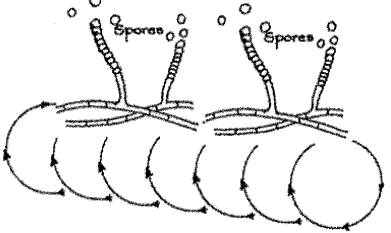
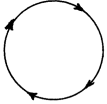

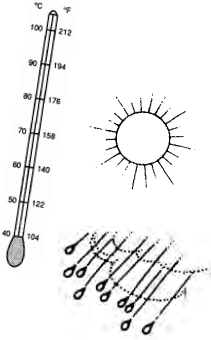
Polycyclic (multiple cycles / year) Most pathogens go through more than one (2-30) disease cycles in a growing season.	Monocyclic (single cycle / year) Pathogens that complete one or even part of one disease cycle/year	Polyetic (cycle takes at least 1 year) Pathogens that take at least 1 year to produce inoculum in the infected plant
 <ul style="list-style-type: none"> Only a small number of hardy structures survive as primary inoculum cause initial infections. Once primary infection takes place large numbers of asexual spores are produced as secondary inoculum at each infection site. These spores can produce new (secondary) infections that produce more asexual spores and so on. With each cycle the amount of inoculum is multiplied many times. Examples: Downy mildew, powdery mildew, late blight of potato, leaf spots, blight, and grain rusts, aphid borne viruses, root knot nematodes. Many of these are disseminated by air, or airborne vectors and are responsible for most of the explosive epidemics in most crops. Disease management strategies: Reducing the amount of primary inoculum has less impact, reducing the rate of the increase of the pathogen (secondary inoculum) is more beneficial. 	 <ul style="list-style-type: none"> The primary inoculum is the only inoculum available for the entire season There is no secondary inoculum and no secondary infection. The amount of inoculum does not significantly increase during the season. The amount of inoculum produced at the end of the season however, is greater than at the start of season - the amount of inoculum may increase steadily from year to year. Examples: Cereal cyst nematode, <i>Verticillium</i> wilt, black leg of potato (<i>Erwinia caratovora</i> subsp. <i>atroseptica</i>). Disease management strategies: Reduce the amount of primary inoculum or affect the efficiency of invasion by the primary inoculum. Thus the rate of disease increase is only affected by the ability of the pathogen to induce disease, environmental factors and cultural practices, etc which influence resistance of the host and virulence of the pathogen. 	 <ul style="list-style-type: none"> Multi-year cycles: Some pathogens take several years before inoculum they produce can be disseminated and imitate new infections. There are just as many diseased trees and almost as much inoculum at the beginning of the year as at the end of the previous one but both increase over the years causing slower but just as severe epidemics. Because they survive in perennial hosts they have almost as much inoculum as they had at the end of the previous year. Inoculum may increase steadily from year to year. Can cause severe outbreaks over several years. Examples: Some diseases of trees, eg Dutch elm disease, pear decline, citrus tristeza, fungal vascular wilts, mycoplasma yellows, viral infections some fungal wilts and virus and molliculite diseases of perennials hosts chestnut blight.

Fig. 36. How different types of disease cycles affect **management strategies**.

Environmental factors



The environment is a controlling influence on the development of epidemics. It may influence all stages of the host and of the pathogen and numbers of vectors of pathogens.

- **Moisture.** Abundant and prolonged or repeated high moisture whether in the form of rain, dew or high humidity is the dominant factor in the development of most epidemics caused by downy mildews. Moisture not only promotes new succulent growth in the host but more importantly, increases sporulation of fungi and multiplication of bacteria. Also high levels of moisture allow these events to take place constantly and repeatedly. Some diseases take place in dry weather but they rarely lead to epidemics.
- **Temperature.** Epidemics are sometimes favored by temperatures higher or lower than the optimum for the plant because they reduce the plant's level of natural resistance. Lower temperatures reduce the amount of inoculum that survive cold winters and reduce the number of vectors that survive winter. Low temperatures occurring during the growing season can reduce the activity of vectors. The most common effect of temperature on the pathogen is its effect during the different stages of spore germination, or egg hatching, host penetration, pathogen growth and or reproduction, invasions of the host and sporulation.
- **In reality moisture and temperature must be favorable and act together** in the initiation and development of the vast majority of plant diseases and plant disease epidemics.

Time



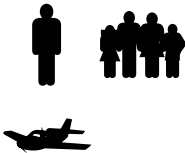
The effect of time can make disease assessments misleading

Time

The dimension of time (the 4th Factor) is added to the disease triangle to indicate that disease onset and intensity are affected by the **duration that the 3 factors are aligned.**

- **Naturally disease may not happen in the first instant the 3 factors are aligned favorable** but will occur after some duration.
- Infection usually takes **minutes to hours.**
- Symptoms and signs can take a **good deal of time to appear.**
- **Environment can become unfavorable** during certain times leading to interrupted disease development.
- **Time**, both the specific point in time at which a particular event in disease development occurs and the length of time during which the event takes place affect the amount of disease.
- **The effect of time on disease development is amazing** when you consider the importance of time of year, eg
 - The climatic conditions and stage of growth when the host and pathogen may coexist.
 - The duration and frequency of favorable temperature and rains.
 - The time of appearance of a vector.
 - The duration of the infection cycle and incubation period of a particular pathogen-host combination.

People and agronomic practices



Agronomic practices often influence disease incidence for better or for worse. The following can all favor the occurrence and severity of an epidemic.

- **Site selection and preparation.** Low lying, poorly drained and aerated fields, especially if the area is close to other infected fields.
- **People decide the types of crops grown in a particular area**, the degree of plant resistance, the numbers planted, time and density of the plantings. Resistance of the plants cultivated determine which pathogens and races will predominate,
- **Continuous monoculture.** Large areas planted to the same crop variety, high levels of nitrogen fertilizer, no-till culture, dense plantings and overhead irrigation.
 - Conventional breeding and genetic engineering results in large expanses of genetically similar plant populations. Various environmental manipulations such as irrigation, greenhouses, hydroponics.
- **Selection of propagation material.** The use of seed or nursery stock that carry pathogens increase the amount of initial inoculum within a crop.
- **Introduction of new pathogens.** The ease and frequency of world travel have led to increased movement of seeds, tubers, nursery stock and other agricultural goods and increased the possibility of introducing pathogens into areas where the hosts have not had a chance to evolve resistance to these pathogens. Epidemics may develop, eg citrus canker.
- **Disease control measures**, eg the use of certain chemicals or planting of a certain variety may lead to selection of virulent strains of the pathogen that are either resistant to the chemicals or can overcome the resistance of the variety leading to epidemics. Also poor sanitation practices.
- **Policy**, eg biosecurity can influence the occurrence of diseases.

Vectors

The spread of a plant disease by vectors represent a special case for modifying the disease triangle.

Remember, rust epidemics result from the combined effects of a susceptible host, virulent pathogen and favorable environmental conditions.

Forecasting diseases

Simulating disease epidemics



An epidemic is a dynamic process; it begins on a few plants and then depending on the environment that influences the host and the pathogen, increases in severity and spreads over a larger geographic area until finally it dies out.

- **Epidemics come to an end when all host plants** are killed by the pathogen, become resistant to the pathogen as they age or are harvested. In many cases the epidemic slows down or stops when the weather turns dry or unseasonably cold.
 - **Each plant disease epidemic**, eg downy mildew of grape, apple scab, Irish blight of potato, follows a **predictable course in each location each year**. The course of the epidemic varies with the host variety and pathogen races present, with the amount of pathogen inoculum present at the beginning of the epidemic, and with the moisture level and temperature ranges during the epidemic.
 - **Computer simulations of potential epidemics** of the most common and serious diseases are now available overseas, eg cercospora blight of celery (CERCOS), mycosphaerella blight of chrysanthemums (MYCOS) and for apple scab (EPIVEN).
 - **Simulations provide continuous information** on the spread and severity of disease over time, the likely final crop and economic losses under the certain conditions.
 - **Statistical models** can help in determining how **plant diseases may best be managed**.

Forecasting epidemics

Reduces plant disease, yield loss

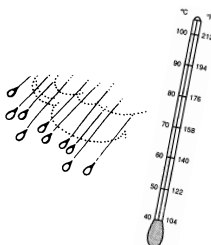
Yield loss nearly almost results in economic loss from disease.

The effect of time can make forecasting difficult

Time



Predictive stations



An investigation of the efficacy and economics of the TOMCAST disease forecasting model for timing fungicide sprays to control late blight without reducing quality or yield

Forecasting plant disease epidemics allows prediction of probable outbreaks or increases in intensity of disease and to whether, when, where and what management practices should be applied. Most fruit growers (Cooke et al 2009) need forecasts to help them determine whether to spray a crop right away or to wait for several more days - if they can wait they can reduce chemical sprays and labor without increasing the risk of disease (page 39).

- **Evaluation of epidemic thresholds.** In diseases characterized by numerous localized lesions (foliar diseases) epidemics:-
 - **1st stage of disease development** – **incidence and spread of disease**, eg economic threshold in the first phases of the epidemic for the application of fungicides to stop or slow an epidemic:
 - **1-50% of individual plants infected** (depending on the disease).
 - **1-25% of individual organs, eg leaves, fruit etc** (depending on the disease).
 - **2nd stage of disease development** – **disease severity**. Fungicides are applied according to the disease severity assessment, weather, etc, as long as there is healthy tissue on the plants that needs to be protected while the crop is not yet ready for harvest.
 - **% infected leaf area in leaves** (disease severity).
- **Evaluation of the economic damage threshold.** This is the highest disease severity level that does not decrease economic profits.
- **Assessment of primary (initial) inoculum and disease.** It is often difficult or impossible in the absence of the host to detect small populations of most pathogens.
 - **Inoculum propagules of soilborne pathogens** such as fungi and nematodes are estimated after extraction or trapping from soil.
 - **Airborne fungal spores and insect vectors** can be estimated by trapping.
 - **Usually it is easier to assess the amount of inoculum present** by measuring the number of infections produced on a host within a certain period of time. However, even in the presence of the host early infection may show no symptoms.
 - **Aerial photography using films sensitive** to infrared radiation has made both earlier detection and sharper delineation of diseased areas in crops easier (reduced reflectance of diseased foliage that are occupied by water or pathogen cells). However, by the time aerial photography detects diseased areas in field, **yield loss has already occurred**.

Monitoring weather factors that affect disease development

- **Several types of electronic sensors** have facilitated the acceptance and use of **predictive** systems to disease control on the farm. Individual environmental factors, eg temperature and humidity were and still are, often measured by individual stations.
- **In many cases 1-2 factors that affect disease development predominate** so much that knowledge of them is often sufficient for the formulation of a reasonable accurate forecast. Forecasts can be based on the amount of:
 - **Primary (initial) inoculum**, eg number of that **survived the winter**, soil tests to determine the fungi, nematodes (or insects) in the soil.
 - **Secondary inoculum**, eg the primary inoculum is usually low and generally too small to detect and measured directly. But if **temperature and moisture conditions** remain within certain ranges favorable to the fungus, the disease will develop. **Predictive systems** have been developed for tomato early blight and other diseases, eg TOMCAST.
 - **TOMCAST uses weather data to forecast the appearance of late blight of celery** in crops. Temperature and leaf wetness data are collected by a weather station positioned in the crop and fed into a computer-based model. Celery is usually sprayed weekly to control late blight, ie up to 16 sprays being applied per crop. The model determines when to spray and when not to spray for late blight. Most savings were made on winter crops. The model predicted a saving of 7-8 sprays on winter crops and 3-5 sprays on summer crops **but only in the early growth stages**. If conditions were favourable for late blight and provided no sprays had been used in the last 7 days, then a spray should be applied. If conditions were not favourable for late blight then the model shows that no sprays should be applied (Minchinton 2008).

Risk assessment of plant epidemics

Risk	<p>The risk of a plant disease developing into an epidemic is the probability that a certain intensity of incidence or severity of the disease will be reached. Numerous host, pathogen and environmental factors must be taken into account in assessing the risk of development of a particular disease, eg</p> <ul style="list-style-type: none"> • Analysis of historical data is an essential tool for identifying important invasion pathways and weak links in the chain of control measures that must be strengthened. <ul style="list-style-type: none"> • History of the disease in the field from previous years. • Resistance of planted varieties. • Presence and amount of primary inoculum. • Periods of susceptibility of the host. • Prevailing weather conditions (temperature, rainfall, relative humidity) during periods of susceptibility. • Availability and cost effectiveness control measures. • In most cases not all of information is available and since the parameters remain fairly constant from year to year, one needs to estimate as well as possible: <ul style="list-style-type: none"> • The starting inoculum of the pathogen and the first sign of disease in the field. • Small changes in moisture and temperature. • Predictions of weather changes in the near future. • CRC for National Biosecurity has developed a manual that rapidly predicts the establishment and spread of exotic plant pests and diseases, eg Asian gypsy moth, fire blight. It provides a decision-making tool to government and industry to aid biosecurity plans and incursion management responses.
Level of risk	<p>Risk assessment is usually expressed as low, moderate or high risk of reaching those disease severity values. Risk assessment provides a timely warning to the grower who responds with appropriate urgency in applying effective management measures.</p>
Managing risk	<p>Growers always weigh the risks, costs and benefits of each of their many decisions, eg</p> <ul style="list-style-type: none"> • Planting a crop in a particular field, using tested planting material. • Whether to plant expensive seed or less yielding seed but a resistant variety rather than seed of a high yielding variety that needs to be protected by chemical sprays. • Most frequently though growers need forecasts that will help them determine whether a plant infection is likely to occur so that they can determine whether to spray a crop right away or to wait for several more days. If disease forecasting allows them to wait they can reduce chemical sprays and labor without increasing the risk of disease.
New tools in epidemiology see also page 373	<p>Computer models optimize and integrate pest management tactics; to assess the risks and benefits of new agricultural biotechnologies to understand the occurrence of plant disease epidemics which can used to help develop new disease management strategies.</p> <ul style="list-style-type: none"> • Geographic Information Systems (GIS) assemble, store, manipulate and display data that are referenced by geographic coordinates. Useful in managing plant disease epidemics. • Global positioning systems (GPS) can pinpoint an individual tree, a specific area or areas of the field that are affected by a pathogen which can then be visited and examined again periodically for incremental advances of the pathogen. Similarly selected areas can be treated with a fungicide or other treatment whenever the pathogen is present without the need to treat the entire field. GPS can be used to apply pesticides, plant nutrients only in areas of the field that require it. • Geostatistical techniques can characterize quantitatively spatial patterns of disease development or the development of a pathogen in space over time. • Remote sensing involves the use of instruments for measuring electromagnetic radiation reflected from or emitted from an object. They record reflected or emitted light in the UV, visible, or infrared part of the spectrum. Data is stored, then analyzed. • Photography and electronic image analysis of large areas of field or mountains by aerial photography, ground based sensor stations and satellite-borne and airborne sensors.

Selected resources

Agrios, G. N. 2005. *Plant Pathology*. 5th edn. Elsevier Academic Press.

Australian Centre for Necrotrophic Fungal pathogens (ACNFP) – Curtin University, WA 22/9/2011. *Epidemiology and Pathogenicity*. The ACNFP program aims to understand the mechanism of pathogenicity and plant disease resistance.

Cooke, T., Persley, D. and House, S. 2009. *Diseases of Fruit Crops in Australia*. CSIRO Pub.

Minchinton, E. 2008. *Validation of a Disease Forecasting Model to Manage Late Blight (Septoria) in Celery*. State of Victoria, Dept. of Primary Industries.

Persley, D., Cook, T. and House, S. 2010. *Diseases of Vegetable Crops in Australia*. CSIRO Pub.

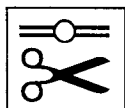
Shea, K., Thrall, P. H. and Burdon, J. J. 2003. *An Integrated Approach to Management in Epidemiology and Pest Control*. Ecology Letters 3:150-158.

APPENDIX 2

Genetic Engineering

Growers will only adopt gene technology if it gives the grower a strategic advantage
Global GM crop adoption continues to climb (Ground Cover May-June 2010)

What is Genetic Engineering (GE)?



Genetic engineering is essentially just another tool in plant breeding

Genetic engineering (GE) describes the transfer of genes of economic importance from not only other plants but also from viruses, bacteria, fungi and animals, to plants where these genes would not normally occur. **GE** allows scientists to insert or delete certain genes from a plant's chromosomes with pinpoint accuracy.

- **Traditional cross-breeding** has been successful for centuries, producing hybrids with a mix of the required characteristics. Thousands of genes are mixed up to make a new hybrid plant with a mix of required characteristics resulting in astounding physical and chemical differences between crops grown today and their wild relatives.
- **GE** speeds up this process and one or a few genes already in the population can be added to an existing plant with proven performance to make it work even better.
- **Genetically Modified Organisms (GMOs)** include viruses, bacteria, fungi, plants.
- **Genetically Modified (GM) crops** and **Genetically Manipulated Plants (GMPs)**, or **transgenic plants** are crops and plants produced by genetic engineering.

How are genes transferred?

Current estimates suggest that at least 10% of animal species and > 20% plants hybridize in nature

Protocols

Genes may be transferred in a variety of ways, eg

- **Direct introduction** into an organism of genetic material prepared outside it.
 - **One method is to cut out the genetic material** to be transferred, isolate it and then join it to something in the cell of the receiving plant, using a variety of techniques, eg '**gene shears**' which are restriction enzymes that clip or cut out a section of DNA or gene which can then be inserted into another chromosome in another organism.
- **Using a viral or bacterial vector.** Many plants have a number of viruses and bacteria which are naturally parasitic on them. Genetic material can be transferred in these viruses and bacteria, once inside the plant cell the new genetic material integrates with the genetic material of the receiving cell.
 - **Crown gall bacteria** (*Agrobacterium* spp.) have been used to transfer a number of genes from one plant to another. The gall-inducing genes causing crown gall are removed but the infective ability is retained to transfer the genes.
- **Other methods** include:
 - Fusing 2 or more cells to form a cell(s) with new combinations of genetic material.
 - Plasmids are commonly used to multiply (make many copies of) or express particular genes. Plasmids used in genetic engineering are called vectors.
 - Cell and embryo fusion.
 - Gene silencing.
 - Delivering genes by microinjection.
 - Using gene guns (biolistic systems) to inject cells with genetic information.
 - Getting rid of all the not wanted genes (classical).
- **Protocols.** **Scientists have developed a protocol for the genetic transformation of banana** cultivars, Williams and Orito as well as some plantain cultivars (*Invest Australia, Australian Functional Food*, 2004).



"Gene Shears"



Crown gall (*Agrobacterium* spp.) of stone fruit

Marker genes





Photo ©TAIR
(www.arabidopsis.org)

GE plants possess marker genes which enable researchers to identify plants that carry the new transferred genes, ie those that have escaped into other plants or to allow screening out of plants that have failed to take up desired genes.

- **Transgenic blue carnations** have a marker gene that makes them resistant to the herbicide Glean® (chlorsulfuron).
- **Transgenic corn resistant** to the European corn borer and Basta® (glufosinate-ammonium) has a marker gene makes them resistant to the antibiotic, ampicillin.
- **Marker-assisted selection (MAS).**
 - One of the first plant genome sequences was a brassica plant called **Arabidopsis thaliana** (mouse-ear cress). It is an annual plant, usually growing to **20–25 cm tall**.
 - This tiny plant became a **model for plant genomic studies** and opened the door to identifying genes and determining their functions on economically important brassicas plants like canola.

Legislation, regulation

GM foods have been approved for sale and eaten safely in Australia and around the world for over 10 years. The Office of the Gene Technology Regulator (OGTR) and Food Standards Australia New Zealand (FSANZ) assess and approve GM traits for commercial release.

<p>The Gene Technology Act 2000 (C'wth)</p> 	<p><u>The Gene Technology Act 2000 (C'wth) and its Regulations</u> in conjunction with State / Territory legislation underpins the national scheme for the regulation of live and viable GMOs in Australia.</p> <ul style="list-style-type: none"> • The aim of the Act is to protect people's health and safety and protect the environment by identifying risks posed by, or as a result of gene technology and manages those risks through regulation of certain dealings with GMOs. • The Office of the Gene Technology Regulator (OGTR) administers the national scheme for the regulation of GMOs in Australia and assesses every GM crop that is grown in Australia for trial or commercial purposes, whether in a contained laboratory or a GM crop in a field. www.ogtr.gov.au
<p>Agricultural & Veterinary Chemicals Act</p>	<p><u>APVMA operates the national system that regulates all agvet chemicals</u> including those produced in or used on GM crops. Assessments consider human and environmental safety, product efficacy (including insecticides, herbicide resistance management) and trade issues relating to residues. A Risk Assessment and Risk Management Plan (RARMP) by OGTR is carried out before release of GMOs and advising APVMA.</p>
<p>Quarantine Act</p>	<p><u>The Commonwealth Quarantine Act, 1908</u> currently regulates the importation of GMOs (see page 176). Biosecurity regulates the importation into Australia of all animal, plant and biological products that may pose a biosecurity pest or disease risk. Import permit applications must indicate the presence of GMOs or GM material and the relevant authorization under the Gene Technology Act.</p>
<p>State / Territory legislation Currently Tas and SA do not allow GM crops</p>	<p><u>Lack of universal government acceptance and/or legislation</u> between State based regulations has become par for the course in Australia which creates a challenge not only for growers whose properties straddle State borders but for most other entities that operate along the supply chain. Some States, eg Tasmania, don't allow GM crops. State websites have information on GM crops. GMOs are currently banned in some countries, eg in the European Community (EC).</p>
<p>Nagoya Protocol An international treaty</p> 	<p><u>Australia has signed the Nagoya Protocol</u>, an international treaty that will establish a legally binding framework for the use of genetic resources in a rapidly expanding global industry. The Protocol is a supplementary agreement to the UN's Convention on Biological Diversity and will help ensure researchers and companies around the world delivered benefits to Australia from their use of our genetic resources.</p> <ul style="list-style-type: none"> • The protocol helps ensure compliance with environmental law and the value of indigenous knowledge in the wider Australia-Pacific and will recognize and respect the value of traditional knowledge and genetic resources held by indigenous people making sure they also benefit from any use of this knowledge. The proposal will come into effect after 50 countries have ratified it (<i>Treaty to enforce fair sharing of natural genetic resources</i>. Ecos Magazine. Feb 2012).
<p>Food Standards Australia New Zealand Act 1991 Labelling</p> <div style="background-color: yellow; text-align: center; padding: 2px; font-weight: bold; margin-top: 5px;"> AUSTRALIAN STANDARDS </div>	<p><u>Food Standard Australia New Zealand (FSANZ)</u> is responsible for setting standards for the safety, content and labelling of food www.foodstandards.gov.au. Generally if genetic material or protein from genetic modification is present in the final food it must be identified in the label's ingredient panel, however, there are several categories under which a food or ingredient does not currently require a GM label:</p> <ul style="list-style-type: none"> • Highly refined products, eg oil from GM canola does not currently require GM labeling. • Additives and processing aids that do not contain novel DNA or protein. • Foods containing GM flavoring of less than 0.1% of the final food. • GM food intended for immediate consumption, eg restaurant and take-away foods. • Unintended presence of GM food. • For products derived from animals fed GM feed (such labeling regime is not required in any GM labeling regime around the world).
<p>The Agricultural Biotechnology Council of Australia (ABCA)</p>	<p><u>ABCA is the national coordinating organization</u> for the Australian agricultural biotechnology sector and aims to ensure that Australian farmers can appropriately access and adopt this technology for the benefit of national and global food security, the nation's farming sector and the environment. ABCA has four founding members:</p> <ul style="list-style-type: none"> • AusBiotech is Australia's industry organization, representing more than 3,000 members in the life sciences, including therapeutics, medical devices and diagnostics, food technology and agricultural, environmental and industrial sectors. • CropLife Australia represents the agricultural biotechnology industry in Australia, ie the innovators, developers, manufacturers, formulators and registrants of crop protection and agro-biotechnology products. www.croplifeaustralia.org.au • National Farmers' Federation (NFF) is the peak national body representing the agricultural and horticulture industry across Australia. • Grains Research & Development Corporation (GRDC).

Uses in agriculture and horticulture

Industrial (non-food) uses	<p><u>Industrial biotechnology adapts and modifies</u> biological organisms, processes, products and systems found in nature for the purpose of producing goods and services.</p> <ul style="list-style-type: none"> • <u>The Crop Biofactories Initiative (CBI)</u> aims to add value to agriculture and the chemical industry through the development of technologies for novel industrial compounds from genetically modified, non-food grain crops, eg <ul style="list-style-type: none"> • Biofuels. • Biodegradable plastics. • Bioremediation of pesticide-contaminated soils by identifying the presence of a particular gene in bacteria required to degrade pesticides, eg organophosphates. • <u>The International Society of Environmental Biotechnology</u> defines environmental biotechnology as "the development, use and regulation of biological systems for remediation of contaminated environments (land, air, water), and for environment-friendly processes (green manufacturing technologies and sustainable development)," eg <ul style="list-style-type: none"> • Cleaning up sheep dips and showers, irrigation tail water and used insecticide containers, using suitable resistant insects or bacteria. • In waste management by reducing waste volumes. • Bioenergy production from agricultural waste streams, adding value to farm income. • The development of novel algal based energy sources harnessing the sun's energy. • Converting salt affected agricultural land into energy producing zones.
Health care	<p><u>Unlimited future uses</u>, including:</p> <ul style="list-style-type: none"> • Pharmaceuticals, eg potatoes, tomatoes, rice, lettuce, safflower and other plants have been genetically modified to produce insulin and certain edible vaccines. • Diagnostic tools for disease prevention and treatment. • Improved bio-pharmaceuticals, eg potentially safer foods, reduced food contamination and natural toxic compounds.
Biofortification of crops	<p><u>Crop Biofortification is the breeding</u> of high-yielding, high nutrient crops. AusFoodtech (a division of AusBiotech) serves organizations and individuals with interests in functional foods and nutraceuticals.</p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p><u>Functional foods</u> are considered to be any food or food component that may provide demonstrated physiological benefits or reduce the risk of chronic diseases, above and beyond basic nutritional functions" (<i>Invest Australia, 2004</i>).</p> <p><u>Nutraceuticals</u> are regarded as a subset of functional foods. "Bioactive chemicals derived from foods but taken as supplements at much higher concentrations than diet alone could provide" (<i>Scientific American 2008</i>).</p> </div> <ul style="list-style-type: none"> • <u>A GM food crop</u> means a food crop that consists of, or includes, plants that are: <ul style="list-style-type: none"> • GM organisms, or • Derived or produced from GM organisms or • Have inherited from other plants particular traits that occurred in those other plants because of gene technology. • <u>Targeted elements and trace elements</u> include: <ul style="list-style-type: none"> • <u>Some of the vitamins and trace elements being targeted</u> include iron, zinc, carotenoids and Vitamin A. • <u>The International Rice Research Institute</u> has added a gene to wild rice to make it produce betacarotene needed by humans to make vitamin A which changes the color of the wild rice to a golden color (golden rice). Golden rice can be used in areas where Vitamin A deficiency is common and so can help prevent blindness. • <u>Commercialization work</u> undertaken by the GRDC include: <ul style="list-style-type: none"> • High-amylose wheat. • Ultra-low gluten barley. • Omega 3 canola oil. • Banana – increase levels of Vitamin A and/or iron in the fruit. • Proteins in foods may be modified to increase their nutritional qualities. • Proteins in legumes and cereals may be transformed to provide the amino acids needed by human beings for a balanced diet. • A new soybean variety has been genetically modified to produce stearidonic acid (SDA), an omega-3 fatty acid in its seeds with health benefits against coronary heart disease, rheumatoid arthritis and other disorders. • <u>Other traits</u> include: <ul style="list-style-type: none"> • New crop varieties. • Growth enhancing, phosphorous-solubilization products. • Whitening of raw sugar to save the sugar industry the cost of whitening it. • Improved taste, texture and appearance of food. • Delayed ripening of tomatoes and papayas overseas. • Getting bread to stay fresh longer, eg 5-7 days longer. • Other goods to have longer shelf life, more attractive flavor, aroma and color.
Golden rice Vit A	

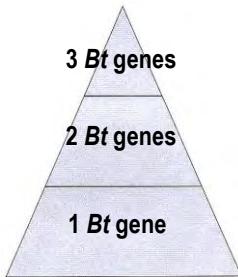
Ornamental horticulture

Unlimited future uses, including:

- Introductions of new flower colours in many ornamentals. This has been the main use of gene modification (see page 413).
- Three rose lines have been genetically modified to produce blue flowers.
- Firefly genes give orchids bioluminescence.
- **GM floral crops** have the potential to increase the productivity and quality of floral crops and significantly reduce the economic losses caused by pest damage.
- There is not the same resistance to GM ornamental crops but it is not fully exploited.

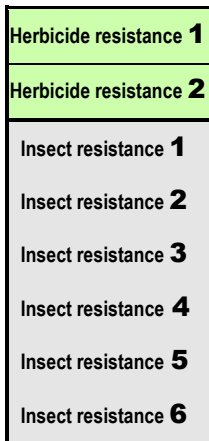
Pests, diseases and weeds of crops

Pyramid strategy



Stacked genes

SmartStax™ corn



Innovative technologies to assist with sustainable farming

Herbicide resistant crops

- In 2008 Australia began commercial cultivation of GM canola. The introduction of different types of herbicide resistance in GM canola allows growers to rotate herbicides and minimise the development of herbicide resistance in weeds.

Insect resistant crops

- **Bt cotton crops** have been genetically modified to produce pest-killing proteins from a gene of the bacterium (*Bacillus thuringiensis*) (**Bt**). Compared with typical insecticide sprays, the **Bt** toxins produced by GM crops are much safer for people and the environment.
 - **Bt crops were first grown widely in 1996**, and several pests have already become resistant to plants that produce a single **Bt** toxin. To thwart further evolution of pest resistance to **Bt** crops growers have recently shifted to the **PYRAMID** strategy: each plant produces **two or more Bt toxins** that kill the same pest. The **pyramid** strategy has been adopted extensively, with two toxin **Bt** cotton completely replacing one-toxin **Bt** cotton since 2011 in the U.S.A.
 - **Most scientists agree that two-toxin plants** will be more durable than one-toxin plants. The extent of the advantage of the **pyramid** strategy, however, rests on assumptions that are not always met, the study reports. One critical assumption of the **pyramid** strategy is "that the crops provide redundant killing, by plants producing two toxins that act in different ways to kill the same pest. So, if an individual pest has resistance to one toxin, the other toxins will kill it."

Disease resistant crops

- Faba bean varieties with **STACKED** disease resistance (fungal diseases *Ascochyta*, *Cercospora* and chocolate spot) have **higher yield potential, and better quality**. Other resistance traits, to bean leaf roll virus, will be available to growers in a few years.
- Identify and evaluate effective biocontrol agents **for soilborne pathogens**.
- *Fusarium* tropical race 4 in Cavendish bananas causes a soil borne disease for which there is no other satisfactory control in Latin America. Field trials have begun in Kenya.
- Four of the genes responsible for conferring resistance to black sigatoka in the naturally resistant banana variety *Musa Calcutta* have been isolated and will be transferred to susceptible banana varieties.
- Different GM cotton varieties are available which suit **different regions**.
- Bruise resistance and delayed ripening in tomato.
- Possibility of transferring genes for rust resistance from flax and maize to wheat.
- See also pages 154, 166.

Yield and drought tolerance

- **Research initially focused on increasing yield** but now there is a need for **drought tolerance** rather than yield potential. Drought tops world's plant breeding priorities for grains especially in poor lands and inferior climates.
- **Of particular interest are quantitative traits** such as **water use efficiency** in plants that are affected by **more than one gene and by the environment**.
- **Future GM wheat crop traits** may include improved nutrient use efficiency and phosphorus utilization; varieties modified to exhibit improved starch profiles; increased yield and drought, cold and heat tolerance; salinity tolerance.
- **Rice varieties genetically modified for flood tolerance** are being adopted at a rapid rate in flood-prone areas of India. Weather-tolerant crops are the next big thing.
- **Sugarcane** to increase sugar yield by 5-10%.
- **A gene has been found in Arabidopsis** could be transferred to rice which could make male parts redundant – they are not required for pollination and grain production. This would eliminate drought-related pollination problems.

Diagnostic tests

- For economically important disease and pests, hopefully there will be more field test kits providing accurate diagnosis.
- Soil inoculum tests are in their infancy compared with nutrient and water testing.
- DNA-based diagnostic tests.

Innovative technologies

- Investigate the use of **biofumigation** and **systemic induced resistance** for improving the efficacy of disease control strategies.
- The **MAGIC (Multiparent Advanced Generation InterCross)** project links **DNA** markers and an organism's physical traits in **wheat** (wheat quality and agronomic traits, water use efficiency, drought tolerance and disease resistance). However, putting it into practice in the field is proving harder than initially anticipated (Braidotti 2011).
- Investigating the use of biotechnology to control **feral pests**.
- Using pheromones for **occasional pests of cotton**.
- Further minimize dependence on disruptive pesticides for *Helicoverpa* in **cotton** by:
 - Improving the management of *Helicoverpa* with **semiochemicals**.
 - **Using gene silencing** to further control *Helicoverpa* in **cotton**.
 - Develop and evaluate the use of **attractants and repellants** for *Helicoverpa* spp.

GE and control methods – examples

Genetic engineering until now has mostly been used to make crops resistant to herbicides, diseases and pests.

Cultural methods



Fruit and vegetables focus on increasing crop yields and improving flavor, more nutritious vegetables, slowing the ripening process and increasing shelf life

Transgenic crops increase crop yields and nutritional quality, promote faster growth and improve adaptation to **target environments**, eg improved tolerance to frost, salinity, drought, temperature extremes and other properties.

- **Ornamental crops**, eg
 - Production of novel ornamental plants.
 - Floral initiation (*Genes controlling flowering*. Aust Hort June 200).
 - Flower color, eg blue and green carnations.
 - Flower arrangements, free flowering.
 - Improved quality and growth form of major cut flower and pot plant crops.
 - Increase vase life by reducing the amount of ethylene produced (anti- senescence).
 - Ability to be propagated.
- **Fruit and vegetables**, eg
 - Increase crop yields and improve flavor. In grapevines to boost sugar and color.
 - More nutritious vegetables, eg increased iron content of vegetables to help prevent risk of anemia. GM pineapple to resist blackheart and have longer shelf life.
 - Slowing the fruit ripening process of tomato, eg Flava-sava contains a gene to halt the ripening process, prevent damage during transport and increase shelf life.
 - Prevent food crops from taking up undesirable substances, eg heavy metals or salts.
- **Field crops**, eg focus on more nutritious grains and livestock feed, better utilization of atmospheric carbon, more efficient nutrient uptake and tolerance to drought.
 - Increase crop yields and improve nutritional qualities to enhance livestock feed.
 - Creation of more nutritious grains, eg raising the calcium content of grain to help prevent osteoporosis, or the sulphur content of grain to improve the quality of bread. In Thailand rice has been engineered to have a vitamin A derivative, a deficiency of which causes blindness in children in the developing world.
 - Better utilisation of atmospheric nitrogen by soybeans.
 - Improve the carbon: nitrogen ratio in wheat and improve various abiotic stress tolerances and micronutrient uptake of wheat and barley.
 - Modify the plant architecture of canola to reduce wind damage, more efficient nutrient uptake and seed production and photoperiods in sensitive cultivars.

Biological control



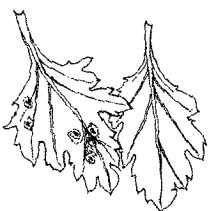
GE biological control agents or organism

The insecticidal proteins in *Bt* GM cotton are derived from a soil bacterium that has been used in agriculture for over 50 years and is approved for use in organic production systems.

Genetic engineering provides an opportunity to improve the effectiveness of traditional biological control programs, eg

- **Select for pesticide resistance in natural enemies** and analyse resistance in the predatory mite (*Typhlodromus pyri*) to synthetic pyrethroid insecticides.
- **Extend the host range** of indigenous and introduced natural enemies.
- **Improve adaptation** of natural enemies to the target environment.
- **Reduce need for insecticides** on pest resistant plants allowing predators and parasites to play a more significant role in pest control.
- **To limit mice reproduction**, there are plagues every 3 years in some of the grain belts. Females infected with a large dose of the virus become infertile.
- **Development and marketing** of improved inoculant products to growers.
- **Aid in identification** of parasitoid wasps (Hymenoptera).
- **Decreases the use of hazardous pesticides** by:
 - **Making biological control agents more effective.**
 - **Extending their host range** and their environmental tolerance.
 - **Genetically engineering natural enemies**, eg targets the immune system of the varroa mite which attacks the honey bee, tricking varroa mites into self-destructing (*GE path to varroa control not for NZ* – Lobbyist NZPA Newswide 23-Dec 2010).
 - **Genetic strategies for control of Queensland fruit fly**. The major objectives are to develop genetic markers that will allow identification of different populations of Q-fly and to develop a strain of flies for sterile release in which females have been genetically debilitated and which has potential in developing fly strains for sterile insect release.

Resistant, tolerant varieties



Disease and pest resistance. Genes that control pests and diseases have been identified in both wild and agricultural plants and are used extensively to breed crop plants which are disease and pest resistant. Examples include:

- **Ornamental crops**. Despite their value, the introduction of new GM ornamentals into the marketplace is slow and to be largely confined to **color-modified varieties**, eg carnation and rose due to regulatory costs (Chandler 2013). Flower color is one of the most important characteristics of ornamentals, and the color range is often limited by the genetics of the plant species. However, ornamental plants could be missing out on major possible traits amenable to manipulation by genetic modification techniques including
 - Pest and disease resistance.
 - Fragrance.
 - Abiotic stress resistance.
 - Manipulation of the form and architecture of plants and / or flowers.
 - Modification of flowering time.
 - Post harvest longevity.
- **Eucalypts tolerant of salinity**.
 - Genetic breeding and selection will aim for faster growth rates, improved adaptation to drought, temperature extremes and salinity, improved tree form and wood properties.

Resistant, tolerant varieties contd



Worldwide 2003
68% soybean was GM
49% cotton was GM
32% canola was GM

Today more than 90% of the 320,000 Australian cotton hectares is planted to biotech varieties, more than half of those varieties offer traits for both insect protection and improved weed control. Two of the greatest challenges faced by cotton producers worldwide.

- **Fruit and vegetables**, eg
 - Bananas resistant to **banana bunchy top** virus.
 - Lettuce resistant to viruses.
 - Peas resistant to *Ascochyta* blight and to the pea weevil (*Bruchus pisorum*).
 - Potatoes resistant to potato leafroll virus (PLRV) and potato virus Y (PVY).
 - Orange growers in Florida have come to believe that genetic engineering holds the only hope for developing a tree that is resistant to citrus greening or huanglongbing (*Candidatus liberibacter*) and the insects that carry the bacteria.
 - Confined trials of genetically modified strains of potato designed to be resistant to Irish blight (*Phytophthora infestans*). The disease is now devastating potatoes in the west Uganda. Resistance genes from wild potatoes have different levels of resistance to the disease, leading to crop immunity, approval is being sought for confined field trials.
- **Field crops**, eg
 - Canola resistant to fungal diseases, eg *Verticillium* wilt.
 - A gene for rust resistance has been isolated from flax so that transgenic wheat, maize, sunflower, soybean and peanut, resistant to **rust**, are now a possibility.
 - White clover gene for field resistance to alfalfa mosaic virus.
 - **Bt transgenic cotton (INGARD cotton)** with enhanced tolerance to waterlogging. **Bt corn** is now commercially available in a number of countries to control corn borer which is otherwise controlled by spraying (page 99).
 - GM rice plants are resistant to rice yellow mottle virus.
 - GM soybeans with herbicide-tolerance, insect and nematode resistance will be available.

Herbicide Resistant Crops from Biotechnology (HRCBs).

- **Roundup[®] Ready crops** are GM crops which are resistant to Roundup[®] (glyphosate). Crops are sprayed several times during growth with glyphosate, eg canola, cotton.
- **GM crops may be resistant to other herbicides**, eg
 - **GM lentils** (*Lens culinaris*) resistant to glufosinate-ammonium (**Basta[®]**)
 - **GM cotton** resistant to **2,4-D, Basta[®], glyphosate, and bromoxynil**.
 - **GM silo** with resistance to **glyphosate** and **simazine**.
 - **GM canola** tolerance to **glyphosate**, glufosinate-ammonium (**Basta[®]**) and **triazine tolerant** varieties (Monola76TT, Monola76TT) offer higher yields, higher oil content and secure market options.
 - **GM tomatoes** tolerant of **paraquat**.
 - **GM wheat** (Justica CL Plus, Kord CL Plus and Sabel CL Plus) each carry two genes for resistance to the **imidazolinone herbicides**.
- **TwinLink Cotton Technology** combines insect-resistance for effective management of a number of caterpillar pests (Lepidoptera) and tolerance to glufosinate-ammonium herbicides (Liberty[®]). The **stacked product** will be the industry's first dual-gene herbicide tolerance, dual gene insect resistance solution for cotton, allowing farmers to manage the pests and weeds that reduce yields and fiber quality as well as prevent or postpone the onset of weed and pest resistance in USA (2013).
- **Bollgard 11 and Roundup Ready Flex Technologies 2008**, highest yielding ever. **Roundup Ready Flex** allows spraying later in the season - season-long weed control with the flexibility of spraying over the top virtually at any time required. How will these varieties compare with regular Roundup Ready varieties?

Biosecurity



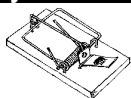
Persons proposing to import plant material are required to declare on import application forms the presence of **genetically manipulated material or artificially selected variants of plant species** with herbicide, disease or pest resistance or other relevant characteristics.

Disease-tested planting material



- Improving the quality of planting material**, eg
- **Better diagnostic tests** to ensure propagation material is free of diseases and pests.
 - **Nursery stock** is better able to withstand transplanting.

Physical methods



Rabbits, could be vaccinated with a genetically engineered virus which carries a gene making rabbits infertile, providing a more humane method of control than the present methods of shooting, trapping, poisoning or a slow death from biocontrol viruses.


Pesticides



- Genetic engineering has directly affected pesticide use**, eg
- **HRCBs** may use less toxic and less persistent herbicides, but some of these may need to be applied more often.
 - Use **less** herbicides, insecticide, and fungicides generally.
 - Prevent food crops from taking up **undesirable substances**, eg heavy metals or salts.

Management of GE crops

Cultivars have a limited life. Have a Resistance Management Plan.

<p>Resistant management strategies Guidelines are available</p> <p>Refuge crops</p>	<p><u>Where insect-resistant GM crops are grown</u>, insect resistant management strategies are employed to ensure the longevity of the products, eg</p> <ul style="list-style-type: none"> • Plants need to produce enough Bt protein to kill pests with low levels of resistance. <ul style="list-style-type: none"> • Although Bt crops have helped to reduce insecticide sprays, boost crop yields and increase profits, their benefits will be short-lived if pests adapt rapidly. • Several pests have already become resistant to plants that produce a single Bt toxin. • To thwart further evolution of pest resistance to Bt crops, farmers have shifted to the "pyramid" strategy"; each plant produces two or more toxins that kill the same pest (pages 154, 166, 412). • Refuge non-GM crops must be planted as a percentage of Bt crops in order for the insects to develop without selection to the insect resistant varieties. This must be carried out in line with post-approval monitoring, where GM crops, and their immediate environment, will be constantly evaluated for changes even after the crop has been released. • Weeds may develop resistance to the herbicides used on HRBCs. • Basic principles of IPM and Best Practice Management must be followed. Guidelines for resistance-management for RoundupReady cropping systems include growers must: <ul style="list-style-type: none"> • Not make more than 2 applications of a glyphosate-based herbicide in a field during any 2 year period, • Rotate its use with herbicides having a different mode of action, • Not plant RoundupReady crops in back-to-back years and • Avoid tank-mixing. • Check current recommendations.
<p>Buffer zones Segregation of GM and non-GM crops on-farm</p> <p>0.9% tolerance</p>	<p><u>DAFWA has produced an information paper</u> covering topics such as canola grain standards, certified seed, farmer-saved non-GM canola seed, machinery hygiene, crop management, pollen flow, GM volunteers and record keeping. Canola trading standards for non-GM canola must contain less than 0.9% accidental presence of an approved GM canola. Farmer-saved non-GM canola seed must be tested for GM status prior to sowing.</p> <ul style="list-style-type: none"> • Buffer zones between GM and non-GM canola crops must be observed. • Growers must minimize the spread of GM canola volunteers. • Organic growers need to test crops to keep GM-free status.
<p>Detection of GM contamination page 417</p> <p>0.9% tolerance Zero tolerance</p> <p>CropLife International</p>	<p><u>The European Union requires labeling of food and feed</u> containing authorized GMP above 0.9%. Other countries have different thresholds. European Union has a zero tolerance for unauthorized materials, which have not undergone a risk assessment. There are many methods for identification of genetic modification based on DNA detection. Certification standards in Australia, eg NASAA adheres to a policy of "zero tolerance" of GM plants on organically certified farms.</p> <ul style="list-style-type: none"> • Identification of unknown samples is often a two-step process. First, commonly used GM elements are detected, and second, specific GM events are determined based on the results from the first analysis. Immunological detection methods also exist for separating GM and non-GM grain lots at farm and elevator level (Holck 2012). • Reliable detection methods to test for the presence of GMPs are critical to ensure smooth international trade and by external parties to allow for compliance with international regulations and if appropriate facilitate segregation and identity preservation of products. • Detection methods are an integral part of product development, quality control and regulatory data-gathering for new products. Test methods to detect the specific proteins of DNA associated with the introduced traits are developed and validated during the development of each new GM plant product. • CropLife International and its members have made their detection methods for commercialized GM products across the globe available in an online searchable database. <ul style="list-style-type: none"> • Croplife International Detection Methods Database for commercialized GM products is available online www.detection-methods.com/database-overview. • There are more than 30 commercial traits being grown and / or consumed as GM crops in 57 countries. As many of these countries are major agricultural exporting countries, eg USA, Canada, Argentina, Brazil and Australia, much of the grain traded globally is derived from GM crops. • Testing organic crops for the presence of GM contamination. Consult your certifier on how to test for the presence of GM in your organic crop. <ul style="list-style-type: none"> • A portable DNA strip tester, which reacts to the specific protein produced by genetically modified plant DNA, can detect genetically modified organisms (GMOs) in grain and seed within five minutes. • AgriQuality (NZ) laboratories in Melbourne are a world leader in the testing of food for genetic modification (GM).
<p>Volunteer HRCB plants</p>  <p>The green bridge</p>	<p>Volunteer HRCB plants in later crops compete with subsequent crops and help to carry-over pests and insects from one crop to the next. If the variety is resistant to a range of herbicides growers may have few if any herbicide options in subsequent crops. Volunteer GM crop plants may increase spread of resistant insect pests from one crop to the next, decreasing pest control options for some growers. There is usually a:</p> <p style="text-align: center;">Technology Use Agreement</p>

Benefits, Challenges and Selected resources

BENEFITS

- Genetic engineering can introduce traits to plants that could not be generated by conventional breeding, because the genes of interest do not exist in the plant's natural gene pool.

Food and health

- GM is just one of the many tools that will assist in the production of 50% more food by 2050 when the present population of is estimated to reach 9 billion.
- It will increase crop yields, reduce risks, improve productivity and raise global production of key crops.
- Transgenic agriculture will produce higher quality food products, enzymes, yeasts and bacteria cultures to meet specific nutritional and health needs, less spoilage.
- Reduce malnutrition in the world. Crops such as rice and cassava provide cheap food to billions but current varieties lack many of the nutrients that humans need to survive. More than a million children die and 500,000 more go blind every year due to insufficient Vit A.
- Future GM crops applications involving tolerance to abiotic stress and higher nutrient contents may lead to much larger benefits. GM crops can contribute significantly to global food security and sustainable development.
- GM crops can resist pests and diseases or can be used to make vaccines, plastics, etc.
- So far herbicide-tolerant and insect-resistant Bt crops have been the primary ones employed.** These crops are beneficial to farmers and consumers. In many cases, farmers in underdeveloped countries benefit more than farmers in developed countries.

Environmental benefits

- Increasing yields that alleviate pressure to convert additional land into agricultural use
- Reduces harmful residues in food, soil and water. Improvement in **water quality** could prove to be the largest single benefit of GM crops.
- Reduces the need for cultivation to control weeds, resulting in less erosion and increased soil fertility, reducing the release of greenhouse gas emissions from agriculture.
- Herbicide-tolerant GM crops have facilitated the adoption of no-till or reduced till production** systems reducing soil erosion and improving soil moisture. The adoption of conservation and no-till cultivation practices saves nearly 1 billion tons of soil per year.
- GM crops help crops deal with **climate change**.

Reduced use of fungicides

- If approved, the late blight-resistant Irish potato will become the latest crop to undergo trials for the genetically engineered strains in Uganda, even as scientists in the country continue to differ over the proposed law to regulate production and sales of genetically modified organisms (GMOs).
- The availability of the *Botrytis cinerea* and *Sclerotinia sclerotiorum* genome sequences has brought hope for new experimental approaches to these difficult-to-control diseases.
- There *Botrytis-Sclerotinia* Post-Genome Workshop. (BSPGW) in Lyon, France in Sept 2011 provided the opportunity to establish new contacts and participate in scientific exchanges on all aspects of *Botrytis* and *Sclerotinia* biology. www.isppweb.org/nlmay11.asp

Reduced use of insecticides

- Bt crops in particular allow significant reductions in insecticide use.
- The size of the reduction varies between crops and introduced traits.
- Bt crops reduce use of more hazardous and persistent insecticides.

Reduced use of the more toxic and persistent herbicides

- Farmers who grow herbicide-resistant crops cultivate less often to control weeds and are likely to practice conservation tillage, which improves soil quality and water infiltration and reduced erosion.
- Reduces the quantity of herbicide that needs to be used.
- Reduces the number of herbicide **active ingredients** used for weed management.
- Reduces the number of herbicide **applications** made during a season.
- Increasing yield** due to improved weed management and **less crop injury**.
- If more herbicide **is** used this may be desirable if the herbicide is used **less often**, is **less toxic** and **less persistent**, than older types used on the crop.

Useful in IPM and BMP programs

- Less destructive cultivation for weed management.
- Reduces the need for pesticides.
- May allow biological control agents, eg predators and parasites of pests, to play a more significant role in pest control.
- Most **IPM** and **BMP** programs **combine a range of strategies**, eg planting resistant species, using the correct cultural methods, using strategic biological controls and pesticide applications.

Cost

- Production of **GM crops** is cheaper than conventional breeding methods, some exceptions.
- Developing new **HRCBs** is cheaper than developing new herbicides.
- There have been substantial **net economic benefits** at the farm level.
- Farmers who have adopted GM crops have either lower production costs or higher yields or sometimes both due to more cost-effective weed and insect control and fewer losses from insect damage.

Work Health and Safety

- Improves workplace and operator safety.
- Farmers appreciate the greater flexibility in pesticide spraying that GM crops provide and the increased safety for workers, from less exposure to harmful pesticides.

Making the new technology available to growers.

- The CSIRO's Plant Industry Gene Technology for Decision Makers program helps educate the public and demystify the science around GM technologies.
- AgriFood Awareness provides information about gene technology to enable informed debate.
- Australian Seed Federation promotes interests of seed industry members.

CHALLENGES

Legislation

- Patent laws giving the developers of GM crops a large degree of control over the food supply increasingly dominated by a few multinational corporations and there has been a convergence of ownership between **agvet chemical companies and GM seeds**.
- Increasing control of the seed supply by a handful of biotechnology giants is raising seed prices and reducing seed choices taking over the livelihood of small farmers and in the end a chunk of nature itself.
- Patent rights** – Codex. There are **taxonomic problems** with naming transgenic plants containing genetic material from distantly related plants.
- Liability, segregation and liability in Australian agriculture.

GeneEthics Network

- There is no doubt that GM and Organic and Bio-Dynamic production are diametrically opposed. GeneEthics Network campaigns strongly:
 - Against GE** foods.
 - For** adequate labelling of **GE** foods.
 - For** the **organic alternative**.

Consumer resistance is high Can you eat it?

- The consumer has a **Right to Know**. The 4 Pillars Policy for agvet chemicals embraces the **Precautionary approach, Right to know, No data, no market, and the Substitution principle** (page 298).
- Is the **pesticide 'treadmill'** now the **gene 'treadmill'**? **GMOs** are currently banned in some countries, eg in the European Community (**EC**).
- Perceptions that multinational companies use **herbicide-resistant crops** to maintain herbicide sales. There may be a greater use of some less hazardous herbicides.
- Clarify the **use and reliance** on fewer less hazardous herbicides on **HRCBs**.
- **Do GM crops encourage** the monoculture characteristics of intensive farming which are ecologically and socially damaging?
- **Acceptance / rejection of new technologies** based on perceptions rather than realities. While attitudes can be fluid, once strongly formed can be slow to change.
- **People look for data** to support their decision rather than seeking data information to help them reach a decision.
- **Farmers now grow enough food** to feed 12 billion people according to the UN – but transport and storage is a large problem. There is a need for education, need to work with industry to have segregation, labeling and learn from mistakes.
- **No long-term monitoring programs** to discover impact on humans. There is no scientific evidence that GM foods are directly harmful to consumers. Have enough health checks been done?
- **Transfer of undesirable traits**, eg allergenic or toxin producing properties from donor to a food plant (this could also occur with conventional breeding).
- **Controversial reports of lowered immune systems** in mice fed on **GM** potatoes.
- Possibility of **DNA transfers from GMOs to human gut flora**.
- **10 years of EU-funded Research** (2001-2010) was summarized as follows: **GMOs** potentially provide opportunities to reduce malnutrition, especially in lesser-developed countries as well as to increase yield and assist towards the adaptation of agriculture to climate change. But the research saw clearly the need for strong safeguards to control any potential risks.
- **There is public opposition to GM crops** in some regions, particularly its requirement for large areas of crop monocultures where pest species tend to be more abundant, and the perception of decreased plant diversity which affects the abundance and diversity of natural enemies.
- **Disputes** involve consumers, biotechnology companies, governmental regulators, non-governmental organizations and scientists.
- **The destruction of CSIRO'S field trials** of GM wheat in Canberra illustrated consumer resistance.

Food labelling

- **The key area of controversy related to GM food** is whether it should be labeled.
- **Some people want labelling for products** that contain GM products. Currently there is no legislative requirement to label products (milk, meat and eggs) from animals fed with GM feed. There are other exemptions from labelling.
- **EU labelling rules** will only operate above 0.9% threshold.
- **Traceability** requirements and an audit trail from seed stock to the consumer.
- Concerns about new risks have led to complex and costly biosafety, food safety and labeling regulations.

Need for vigorous assessment of the efficacy and impact of new GM crops, eg

- The role of government regulators.
- The objectivity of scientific research and publication.
- The effect of GM crops on health and the environment.
- The effect on pesticide resistance.
- The impact of GM crops for farmers.
- The role of GM crops in feeding the world population.

Biodiversity

- **Loss of biodiversity** as fewer weed species survive as a food and shelter source for animals.
- Currently it is considered that commercialized GM crops have **reduced the impacts of agriculture on biodiversity** (Carpenter 2011).
- Pollen from **Bt corn** may kill monarch butterflies in the USA America's favorite insect. However, research indicates that weather may have a greater effect.
- New genes introduced into the food supply may affect **biodiversity**.
- **Concern is growing** that domesticated fruits' wild ancestors, which are a key resource for genes linked to disease resistance, are at risk of extinction.
- **Rigorously evaluate the efficacy** and environmental impacts of new transgenic plants.
- **Pollinators such as bees** may have their lives shortened and an impaired ability to recognize flower smells.
- **Beneficial insects that prey on plant-eating pests** could be harmed by feeding on GM crops plants. Lacewings feeding on insects which had fed on **Bt maize** died. Such **Bt-resistant insects** could transfer the toxin in beneficial insects throughout the season.

The environment

- **GM crops are thoroughly evaluated** for environmental effects before entering the marketplace. Among those who conduct risk assessment procedures are the developers of GM crops, regulatory bodies, and academic scientists. Most countries use similar risk assessment procedures in considering the interactions between a GM crop and its environment. For every GM crop, these include:
 - Pre-commercialization tests for environmental safety.
 - Information about the role of the introduced gene and the effect that it brings into the recipient plant.
 - Unintentional effects such as:
 - Impact on non-target organisms in the environment.
 - Whether the modified crop might persist in the environment longer than usual or invade new habitats.
 - Likelihood and consequences of a gene being transferred unintentionally from the modified crop to other species.
- **Post-approval monitoring** by the product developer, independent researchers and government scientists required. Pocket K No. 4: *GM Crops and the Environment* (2013). www.isaaa.org

Low levels of unauthorized GM material

- **Can GM and Organic canola crops co-exist?** Landline 14/11/2004. No blanket rules. How **GM** and **Non-GM** Crops can co-exist is discussed on page 394.
- **US, Brazil and Argentina could authorize** and cultivate new types of GM crops before they are cleared in the EU for import.
- **Where a GM crop that has not been authorized in the EU is grown**, there is a chance for a small amount of this crop – referred to as an “unintended” or “adventitious” presence – to be mixed with other crops, potentially disrupting EU imports of that commodity, both GM and conventional from the country concerned. This has occurred on occasions in the past.
- **Buffer zones**. Non-GM crops contaminated with GM crops due to inadequate buffer zones etc. Required buffer zones of 400m are considered by organic growers to be a joke. How can organics and conventional crops be protected from cross contaminants by GM crops. Windblown pollen can travel considerable distances and bees also transport pollen.
- **Zero tolerance thresholds** from a global perspective, are not manageable. It appears that co-existence could be accommodated but that a risk management system that did not tolerate GM in non-GM crops was impossible.
- **Crops not grown at the same time** so no cross pollination.
- Collecting seed from GM crops or non-GM crops.
- **Best Practice Guidelines** for Management of Adventitious Presence in Canola Varieties. On May 29, USDA announced that a small number of volunteer wheat plants in an Oregon field had tested positive for genetically engineered (GE) glyphosate-resistant wheat.
- One summary lists increased herbicide usage and resultant herbicide resistance, “super weeds”, residues on and in food crops, genetic contamination of non-GM crops which hurt organic and conventional farmers.

Resistance

- Scientists argue that because the plant (*Bt* cotton) produces the insecticide continuously, there is a risk that pests will develop **resistance** to it.
- **There are moves in the USA to force** companies selling **GM** crops which make their own insecticide, to take steps **to avoid insects developing resistance**.
- **Volunteer GM** crops may increase **spread** of resistant insect pests from one crop to the next, decreasing pest control options for some growers.
- **Research indicates that only 3 *Bt*-resistant** pest populations have been documented under field conditions world-wide, one in Puerto Rico, South Africa and India.
- Resistance can reduce land values.

Superweeds

- **Potential of GM crops to create new weeds** through outcrossing (unintentional breeding of a domestic crop with a related plant) with wild relatives, or simply by persisting in the wild themselves.
- **Herbicide resistance in HRCBs** may **spread** via pollen to wild weeds which would be resistant to available herbicides and other weed eradication practices.
- **Only very limited effects** on the environment have been detected in relation to outcrossing.
- **Need to avoid introducing traits** that have a high potential to increase weediness into **high risk crops**, eg oats, sunflower, radish.
- **Triazine tolerance** in canola may spread to wild radish making control more difficult in later crops.
- **Many GM crops do not** become weeds because they are **unlikely** to survive long outside cultivation, exceptions.

Costs

- **HRCBs may cost the grower more.** Built-in obsolescence of transgenic seed means it is impossible to re-use harvested seed. There is a requirement to buy new seed every year. But, built-in pest and disease resistance should reduce the cost of pesticide applications.
- **The longest and most costly phase** of developing GM crops was the regulatory and authorization phase. www.croplife.org/
- **The higher costs associated with GM seeds** are not always offset financially by lower production costs or higher yields, eg farmers in areas with fewer weed and pest problems may not have as much improvement in terms of reducing crop losses.
- **Some new chemicals**, eg Altacor (chlorantraniliprole) are effective with residual control of larvae on cotton on conventional crops so that in some seasons (2009) the conventional cotton looks better and may be cheaper to grow 2010.

Abiotic problems – yield

- **The part that genes play in tolerance to drought**, frost, salinity and poor soils is by no means clear. It is not certain that **GE** of such multigenic traits will beat conventional plant breeding towards this end.
- **It has been suggested that although research** does not indicate that glyphosate directly causes fungal diseases that limit crop health and production, it could be the case. It is said that these GM crops do not yield more than conventional crops and nutrient deficiencies tied to root disease problems are a likely a limiting factor.
- **If there is increased herbicide use** some crops may be more susceptible to certain diseases and pests by altering their physiologies, thereby increasing the use of insecticides and fungicides, thus intensifying environmental problems.

New pests

- **As more INGARD cotton is grown** then insects which were controlled by broad spectrum sprays become more of a nuisance, eg sucking insects such as green mirids and apple dimpling bug. Spring crops and weeds support large numbers of these pests which then move onto cotton when weeds hosts dry up.
- **Factors that can account for increasing damage** by a pest in GE corn, eg insect biology, synchrony of insect and crop phenology, reduced insecticide use, increases in conservation tillage, soil type, glyphosate-resistant crops, insect genetics, insect pathogens, pre-existing insect population densities and climate change.
- **Farmer should take heed** and consider more crop rotations and tighter monitoring of glyphosate usage.
- **Regulatory requirements for novel food** – unintended effects, allergenicity of foods, produced by GM crops.
- **The scientific and commercial ethics of incorporating suicide genes**, infertility barriers or male sterility into transgenic crops to **prevent** resistance spreading via pollen to wild weeds, thus isolating transgenic crops from their wild relatives.

SELECTED RESOURCES

- Agrifood Awareness Australia. 2007. *Gene Technology in Australia: Fact Not Fiction*.
- Australian Centre for Plant Functional genomics conducts functional genomics research into abiotic stress.
- Braidotti, G. 2011. *MAGIC Needed to Decode Wheat Genetic Secrets*. Ground Cover Sept-Oct.
- Brookes, G. and Barfoot, P. 2013. *GM crops: Global Socioeconomics and Environmental Impacts 1996-2011*. PG Economics Ltd, UK.
- Carpenter, J. E. 2011. *Impacts of GM Crops on Biodiversity*. ISB News Report.
- Chandler, S. 2013. *Genetically Engineered Ornamental Plants: Regulatory Hurdles to Commercialization*. ISB News Report, Aug. 2013.
- Clive, J. 2012. *Global Status of Commercialized Biotech/GM Crops: 2012*. ISAAA (International Service for the Acquisition of Agri-biotech Applications) Brief No. 44. Ithaca, NY. www.isaaa.org
- CRC for Tropical Plant Protection.
- Com. of Australia. 2000a. *Explanatory Guide to the Commonwealth Gene Technology Bill 2000*. Australian. Dept. of Health.
- Com. of Australia. 2000b. *Gene Technology Bill 2000: Questions & Answers*. Interim Office of Gene Technology Regulator, Dept. of Health (Australian).
- Com. of Australia. 2000c. *Gene Technology Regulations 2000*. Interim office of Gene Technology Regulator, Australian Dept. of Health.
- Cormick, C. 2003. *Social Conscious of Public Concerns about Developments in Biotechnology in Australia: Comparison with other Countries and Lessons from Asia*. Biotechnology Australia. CT 18/11/2003.
- Fitzgerald, P. 2010. *GM crops Benefit but Need Stewardship*. Ground Cover July-Aug.
- Food Standards Australia New Zealand. 2005. Com. of Australia. 2000. *Explanatory Guide to the Commonwealth Gene Technology Bill 2000*. Australian Dept. of Health. www.foodstandards.gov.au
- Food Standards Australia New Zealand (FSANZ). 2005. *GM Foods: A Safety Assessment of Genetically Modified Food*. FSANZ.
- Hassal & Associates. 2001. *Genetically Modified Plant: Farm and Resource Management Issues*. RIRDC.
- Holck, A. L. 2012. *Genetically Modified Organisms Detection by Analytical and Spectroscopic Methods*. Encyclopedia of Analytical Chemistry. 15 June 2012.
- Kempken, F. and Jung, C. (eds). 2010. *Genetic Modification of Plants: Agriculture, Horticulture and Forestry*. Springer.
- National Research Council. 2010. *Impact of Genetically Engineered crops on Farm sustainability in the United States*. National Academic Press, US.
- Thompson, J. A. 2006. *GM Crops: The Impact and Potential*. CSIRO Pub.
- WA State Agricultural Biotechnology Centre (SABC), Murdoch University, WA specialises in plant biotechnology, biosecurity, genetically modified plants and the molecular basis of interactions between plants and plant pathogens.
- Biotechnology. www.industry.gov.au/biotechnology
- Brave New Food Reality. The Weekend Australian Financial Review. Feb 27-28 2010. (=>25 countries).
- Convention on Biological Diversity. *Biosafety Protocol to Protect the Environment and Human Health from GMOs*.
- Croplife Australia. www.croplifeaustralia.org.au
- GMAC/Office of Gene Technology Regulator (Annual Reports, Explanatory Guides, Fact Sheets, GMAC News, Planned Release Proposals, etc.
- GM crop problems. www.gm.org
- International Service for the Acquisition of Agri-biotech Applications* (ISAAA). www.isaaa.org
- The Australian GeneEthics Network
- The Economics of GM crops (Annual review of Resource Economics) University of Gottingen.
- The Gene File: Genetic Engineering Action Update
- The Weed's Network - The Weed's News* www.weedsnetwork.com

APPENDIX 3

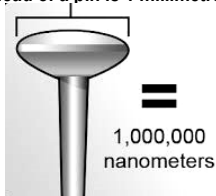
Nanotechnology

Nanotechnology is one of the fastest growing areas of research and technology.

What is nanotechnology?

One nanometre is one millionth of a millimetre

Head of a pin is 1 millimetre



Human hair is about 10,000 to 1000,000 nanometres thick.

The smallest cellular-life form, the bacteria of the genus *Mycoplasma* are around 200nm in length'

Comparative size of a nanometre is the same as that of a marble to the size of the earth

Nanotechnology generally deals with very, very small particles, structures measuring from 1-100 nanometres (nm) in at least one direction. A **nanomaterial** is anything that has been engineered to **measure between 1 and 100nm in at least one dimension**.

- **Nanotechnology** is the precision-engineering of materials at the atomic or molecular level to create **nano-sized materials** or **nanomaterials**.
- **Nanomaterials** are found naturally in milk, during lightning strikes, as by-products of forest fires, volcanoes and salt spray or incidentally as a by-product of processes such as milling, grinding or combustion. It is not the existence of nanoparticles that is new but rather the **ability to engineer products at the nanoscale**.
- **Nanomaterials can have fundamentally different physical properties** than their larger-sized counterparts, and these differences often enable nanoscale materials to be used in new and valuable ways, eg invisible sunscreens, stronger golf clubs, water and stain-resistant clothing. Nanosilver is now found in Australian shoes, socks, toothpaste, cleaning clothes, soap, shorts, towels, fridges, washing machines, mattresses, hairbrushes, etc.
- **Nanoparticles and bacteria**. Due to their small size, silver nanoparticles can penetrate the bacterial cell membrane and disrupt the cells ability to respire and reproduce slowing their growth and killing them. The bacteria eventually collapse or burst.
- **Many nanotechnologies use nanoversions of common materials** and these nanomaterials have different properties to their larger counterparts, eg a material at the nanoscale may have a different shape or surface properties and so might have greater strength, be more elastic, etc. The threshold below which the behavior of material can change in this way is between 30 and 100 nm.
- **Nanoscale materials behave in different and unexpected ways**.
- Already there are several "generations" of nanotechnology.

Methods of building

Applications of nanotechnology and the nanomaterials from which they are made need to be studied for possible impacts on public health, safety and the environment. Two main methods are used to build devices out of nanoparticles, top-down and bottom-up.

- **The top-down method** involves etching away material to "sculpt" the features required such as the manufacture of computer chips. In the **top down approach**, nano objects are constructed from larger entities without atomic-level control.
- **An example of the bottom-up methods** is the technique by which a mist of atoms is deposited onto a chosen surface. This builds up a "sandwich" of different layers to conduct electrical currents in various ways to make electronic devices. This technique is being used to create the ultra-fast computer chips of tomorrow.
- **Nano scientists often seek to imitate nature**, which has already designed strong, light and effective structures, eg the way we grow our teeth.

Legislation, regulation, trade

Standards



AUSTRALIAN STANDARDS

Since products that are produced using nanotechnologies will likely enter international trade, it is necessary to harmonize nanotechnology standards across national borders. **International standardization** will play a critical role in ensuring that the full potential of nanotechnology is realized and that nanotechnology is safely integrated into society.

- **The American National Standards Institute's Nanotechnology Standards Panel (ANSI-NSP)** serves as the cross-sector coordinating body for the purposes of facilitating the development of standards in the area of nanotechnology including, but not limited to, nomenclature and terminology, materials, properties and testing, measurement and characterization procedures.
- **ISO/TC 229 Nanotechnologies**. Standardization in the field of nanotechnologies. Specific tasks include developing standards for terminology and nomenclature, metrology and instrumentation; test methodologies; modelling and simulations; science-based health, safety, and environmental practices.
- **ISO/TS 80004-1:2010 Nanotechnologies – Vocabulary – Part 1: Core Terms**. It is intended to facilitate communications between organizations and individuals in industry and those who interact with them.
- **Nanotechnology Standards**. Nanostructure Science and Technology Series, Springer (Murashov and Howard 2011).
- **International Standards for Trade in Nano-coated Produce** have been recommended (Suppan 2012).

Legislation, regulation



Search the APVMA website for nanotechnology
www.apvma.gov.au/

Search the Dept. of Industry website for nanotechnology
www.industry.gov.au/

Search the Dept. of Agriculture website for nanotechnology
www.agriculture.gov.au/

Search Croplife Australia website for nanotechnology
www.croplifeaustralia.org.au

Any product – in any form – that makes claims to control pests must first be evaluated and registered by **APVMA** to ensure it meets human health and environmental safety standards before it can be distributed or sold. Nanotechnology raises many of the same issues as any new technology, eg concerns about toxicity and environmental effects.

APVMA participates in various committees to coordinate national regulatory systems and assess whether the current regulatory framework is appropriate to nanotechnology. The development of data requirements for nanomaterials will remain a priority for the **APVMA** as nanotechnologies continue to evolve.

Australian Office of Nanotechnology (AON) coordinates the implementation of the government's **National Nanotechnology Strategy (NNS)**.

- **NNS aims to establish** the environment that allows Australia to capture benefits of nanotechnology while addressing the issues impacting on its successful and responsible development. Key initiatives within the strategy are:
 - Health, safety and environment.
 - Public awareness and engagement.
 - International engagement.
 - Industry activities, eg important industry events and initiatives, workshops.
 - Measuring capability objectives of **National Enabling Technologies Strategy (NETS)**.
- **National Enabling Technologies Strategy (NETS)**. To remain connected with the enabling technologies community, an Advisory Council representing industry, research, non-government organizations, the social sciences and government was established in 2010. The Advisory Council meets regularly to discuss progress.

National Enabling Technologies Strategy (NETS)
Annual Reports are available online

APVMA Nanotechnology Expert Advisory Panel (NEAP) plays an important role in the provision of advice to the **APVMA** on applications as well as developments in international research and regulation.

- **The APVMA has the responsibility for ensuring agvet** chemicals that use or are enabled by nanomaterials are safe for people and safe for the environment, throughout the life cycle of the product. To date the **APVMA** has not received any requests any applications for registration of agvet chemical products that contain engineered nanomaterial.
- **Additional strategies have been put in place** to ensure that Australia remains in step with both technological and regulatory development in the field, eg
 - Monitoring the development of nanotechnologies for **agvet chemicals**.
 - Continually examining the **need for changes to our assessment procedures**.
 - **Risk management** framework or changes in legislation.
 - Providing **APVMA** staff with appropriate training.
 - Ensuring that **APVMA** policies and process are coordinated across Australia.
 - Involvement in national and international forums on the regulation of nanomaterials.
 - Publishing information on nanotechnology and providing the community and industry with information on any changes to our regulatory processes.

Work health and safety (WHS)


Various groups are working on workplace health and safety aspects of nanomaterials.


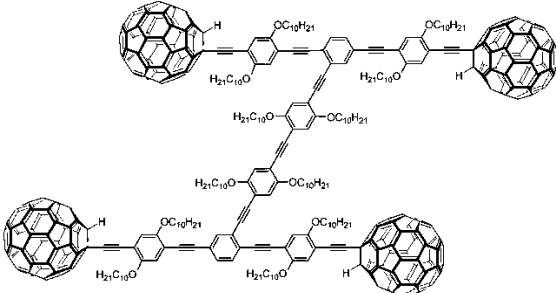
- **The NanoSafe Australia Network (RMIT University)** is a group of Australian toxicologists and risk assessors, who have formed a research network to address the issues concerning the workplace and environmental health and safety of nanomaterials.
- **WHS laws have been put in place in Australia** to restrict exposure to known hazardous nanomaterials. Two major reviews for Safe Work Australia by **RMIT University**, have been published and are available online (Jackson et al 2009, 2010).
- **The Nanotechnology Work Health and Safety Expert Working Group** aims to:
 - Promote a coordinated national approach to the managing nanotechnology **WHS** issues.
 - Identify nanotechnology **WHS** research needs.
 - Make recommendations regarding policy options and the **WHS** regulatory framework.
 - Facilitate collaboration and effective sharing of information on nanotechnology **WHS** management amongst regulators, industry, unions, researchers and relevant practitioners.
- **Safe Work Australia's Nanotechnology** aims to:
 1. Ensure nanotechnology is covered appropriately in the **WHS** Regulatory Framework.
 2. Improve understanding of the hazardous properties of engineered nanomaterials.
 3. **Assess effectiveness of WHS controls** in preventing exposure to engineered nanomaterials.
 4. Develop procedures for **detecting and measuring emissions exposure in workplaces**.
 5. Provide information and guidance for Australian nanotechnology organizations.
 6. Ensure consistency with international approaches & contributing to international work.

Uses

Nanotechnology is a revolutionary new technology and a key economic driver for the twenty-first century. It promises significant social benefits, including enhancements in medical diagnosis and treatment, more efficient energy sources, lighter, stronger and cheaper materials and electronic products and cleaner, cheaper water.


UNSW is the headquarters of the **Australian Research Centre (ARC) Centre of Excellence for Quantum Computing Technology (CQCT)** which is involved in developing revolutionary new single-atom nanotechnologies.

Manufactured nanomaterials	<p>Nanomaterials already occur in food (as colloids such as milk) and in air (aerosols for example). What is new is the ability of scientists to engineer nanoscale products and processes and thereby exploit the properties of material at the nanoscale.</p> <ul style="list-style-type: none"> In this regard, the term “manufactured nanomaterial” is used to distinguish nanomaterial which is made synthetically for specific applications from any naturally occurring nanoparticles. Nanotechnology will not generally lead to specific nanotechnology products; rather it will lead to new ways of developing or making existing products or making such products cheaper or more effective. <p>1st generation</p> <ul style="list-style-type: none"> 1st generation passive nanomaterials which recasts straightforward materials science: <ul style="list-style-type: none"> Flat-screen televisions, carbon nanotubes in TV and computer screens. Titanium oxide and zinc oxide in sunscreens and cosmetics. Silver in food packaging, clothing, disinfectants and household appliances. Surface coating, paints, outdoor furniture varnishes, cut glare, rust or fire retardants. Quantum dots and circuits for electronic devices. Coatings that improve the performance of medical drugs in the body. Stain resistant clothing. Filtration of contaminated water for drinking. Hygienic food packaging and cosmetics with skin-protection capabilities. Silver at the nanoscale has antibacterial properties and nano- silver particles are now being used in washing machines to clean clothes more effectively. Shoes, socks, toothpaste, soap, shorts, washing machines, mattresses hairbrushes. Cerium oxide as a fuel catalyst. <p>2nd generation</p> <ul style="list-style-type: none"> 2nd generation nanomaterials. Nanostructured materials for drug delivery at a controlled rate. <p>3rd generation</p> <ul style="list-style-type: none"> 3rd generation nanomaterials. Perhaps solar technology built on integrated micro and nanostructured materials that provide improved solar energy and transport. 4th, 5th, 6th generation, etc.
Diagnostics 	<p>This is a new manufacturing frontier.</p> <ul style="list-style-type: none"> Gold nanoparticles may be used for chemical sensing, particularly for testing environmental quality and searching for levels of water pollutants. However to detect a range of pollutants a diverse range of different nanoparticle sensors are required (Kaye 2007).
Use less fertilizer and pesticides	<p>The need to provide sustainable food and renewable energy (9 billion people by 2050) has led to the need to use less fertilizer and pesticide, ie improve their efficiency so that farmers can use less but get the same result, eg</p> <ul style="list-style-type: none"> Nanoscale materials can be used to transport agricultural chemicals within the plant and protect them from deterioration in the environment. These same materials can be designed to anchor to the roots of plants and deliver chemicals to the part of the plant where they are actually needed. Slow release nanomechanisms could allow measured uptake of chemicals, reducing the amount of chemical applied as well as runoff to the environment. Nanomaterials could be used as field sensors to monitor environmental stress and crop conditions and make decisions about planting, harvesting, watering, pesticide and fertilizer use with a high level of precision, minimizing inputs and waste.
Pesticides and nanotechnology	<p>The use of nanoscale materials in pesticide products and treated articles may contribute to improved human and environmental safety and could lower pest control costs, eg</p> <ul style="list-style-type: none"> More effective targeting of pests. Use of smaller quantities of a pesticide. Minimizing the frequency of spray-applied surface disinfection. Under development are crop-protection products that will use nanotechnology to deliver synthetic herbicides to weeds resulting in better weed suppression and reduced costs of production (Weed News Thurs 21 March 2013). APVMA has not received any pesticide containing nanoparticles for registration (2012).
Nanobionic plants	<p>Massachusetts Institute of Technology has managed to place carbon nanotubes in the chloroplasts of plants which is where photosynthesis takes place. So far they can:</p> <ul style="list-style-type: none"> Increase photosynthetic activity by 30% (Netburn 2014). Enable plants to detect tiny traces of pollutants in the air. Possibly perform more exotic functions, eg turn plants into communication antennas.

<p>Plant disease management <i>Field and post-harvest diseases</i></p>	<p><u>The Australian Institute for Bioengineering and Nanotechnology</u> at the University of Queensland is investigating "BioClay – crop protection against biotic stresses from field to market" as a new approach to delivering biological agents targeting field and postharvest diseases.</p> <ul style="list-style-type: none"> • Current pest and disease management tends to rely on plant genetic resistance and / or GM crops coupled with insecticide and fungicide sprays, but the cost, safety and environmental issues associated with chemical sprays often act as major impediments to controlling diseases in the field. • The technology has the potential to be an alternative to chemical spraying that is safe, low cost and environmentally friendly.
<p>Environmental applications</p>	<p><u>Some innovative materials promise to reduce environmental pollution</u>, eg</p> <ul style="list-style-type: none"> • Carbon nanotubes and metal nanoparticles are great candidate materials for cleaning polluted water and soils. • Nano-biocomposites are obtained by the association of silicates such as bioclays, with biopolymers for environmental applications with controlled end of life properties, including biodegradation (Luc and Polle 2012). • Applications include packaging, agriculture, leisure and the fast food industry.
<p>Medicine</p> 	<p><u>Nanobiotechnology, bionanotechnology and nanobiology</u> are terms that refer to the merger of nanotechnology and biology.</p> <ul style="list-style-type: none"> • Nanobiotechnology is best described as helping modern medicine progress from treating symptoms to generating cures and regenerating biological tissues. • It is likely that within 1 to 10 years drugs could be delivered using nanotechnology. • Much remains to be researched regarding their safe use.
<p>Precious metals</p>	<p><u>The feasibility of creating crops capable of producing precious metal nanoparticles</u> that are highly valued for biomedicine, optics and electronics is being researched by the University of Sydney and supported by GRDC.</p>
<p>Bionics or biomimicry</p>	<p><u>Bionics or biomimicry seeks to apply biological methods and systems found in nature</u> to the study and design of engineering systems and modern technology.</p> <ul style="list-style-type: none"> • Biom mineralization is one example. • Bionanotechnology is the use of biomolecules, viruses and lipide assemblies for various applications in nanotechnology. • Synthetic molecular motors such as the nanocar. The original nanocar does not contain a molecular motor, so it is not really a car; it was designed to answer the question of how certain molecules arranged in an H-shape chassis move about on metal surfaces; specifically, whether they roll or slide. They roll.  <p>Shirai, Y., Osgood, A. J., Zhao, Y., Kelly, K. F., Tour, J. M. 2005. <i>Directional Control in Thermally Driven Single-Molecule Nanocars</i>. Nano Letters. 5 (11): 2330–4.</p>

Issues of concern

Nanoparticles act differently from chemicals but this does not imply that they are harmful. Nanotechnology raises concerns about health and the environment effects as does any new technology.

<p>Regulation Standards</p> 	<p><u>Calls for tighter regulation of nanotechnology</u> have occurred alongside a growing debate related to the human health and safety risks associated with nanotechnology.</p> <ul style="list-style-type: none"> • Friends of the Earth (International nanotechnology lobby group), have been lobbying the government to tighten legislation and labelling of nano-silver and other nanomaterials. • International regulation. There is the beginning of internationally agreed definitions and terminology for nanotechnology, but there does not appear to be internationally agreed standardized protocols for toxicity testing of nanoparticles. • The Institute for Food and Agricultural Standards notes that “developing countries should have a say in international nanotechnology standards development, even if they lack capacity to enforce the standards”.
--	---

Health issues	<p><u>The USA's Office of Pesticide Programs has warned that nanomaterials</u> behave differently to standard materials:</p> <ul style="list-style-type: none"> • <u>Health, safety and environment issues</u> for consideration by employers, workers, manufacturers, suppliers and regulators include: <ul style="list-style-type: none"> • <u>The size and shape of nanoparticles</u> influences their toxicity on human biology. • <u>The properties</u> of nanomaterial may affect how materials are handled in the workplace. • <u>Possible ease of penetration</u> into the body causing harm, requiring testing and regulation. Being extremely small, nanomaterials can easily be absorbed by living organisms. • <u>There are many potential human health and environmental concerns</u> that must be addressed; including <u>dermal absorption and inhalation of nanoherbicides</u> from <u>spray drift and spray vapour</u>. Weed News Thurs 21 March 2013. • <u>The tiny size of nanoparticles confers different properties</u> to its counterpart with larger particles, allows them to penetrate further into the body and in the case of nano-silver, produce more of the silver ions that kill the bacteria. • <u>Concern about the use of pesticides</u> allegedly containing nanoscale materials, such as nano-silver, to control microorganisms. • <u>Nature Nanotechnology</u> (magazine) published a suggestion that some forms of carbon nanotubes could be as harmful as asbestos if inhaled in sufficient quantities. Anthony Seaton of the Institute of Occupational Medicine in Edinburgh, Scotland said that some carbon nanotubes have the potential to cause mesothelioma. • <u>A study found that when rats breathed in nanoparticles</u>, the particles settle in the brain and lungs which led to increases in biomarkers for inflammation and stress response. Nanoparticles induce skin aging through oxidative stress in hairless mice. • <u>The Centre for Responsible Nanotechnology (CRN)</u> is a global non-profit research and advocacy organization with a focus on molecular manufacturing and its possible effects, both positive and negative. • <u>Government, academic and private sector scientists</u> in multiple countries are performing research into the human health effects of diverse nanoscale materials, resulting in a substantial and rapidly growing body of scientific evidence.
Food	<p><u>Nano Foods – Is our food safe to eat?</u> Can we eat them?</p>
Environmental issues	<p><u>Concerns about environmental risks</u> associated with nanoparticles and their products.</p> <ul style="list-style-type: none"> • <u>Non-biodegradable nanoparticles bio-accumulate</u> and some could pose unknown problems. Nano-silver is emerging as a possible environmental pollutant. • <u>Silver nanoparticles which are bacteriostatic</u> may destroy beneficial bacteria which are important in breaking down organic matter in waste treatment plants or farms.
Resistance	<p><u>Scientists are divided about the potential for nanotechnology used to kill bacteria</u> in socks and other everyday items, <u>to breed the next batch of antibiotic resistant superbugs</u>.</p> <ul style="list-style-type: none"> • <u>Nano-silver</u> is being rolled out to provide peace of mind to consumers worried about bacteria breeding on items in their homes, ranging from undies to socks, etc. <ul style="list-style-type: none"> • <u>Nano-silver is not new</u> and in 1859 when called “colloidal silver” was used to stop bacterial on surfaces such as swimming pools. For centuries silver was used to kill bacteria and prevent their spread in open wounds or burns. • <u>Opinions are divided</u> regarding the possibility that overuse will lead to bacteria <u>developing resistance</u> through widespread regular exposure to small amounts of silver with the emergence of <u>multidrug-resistant superbugs</u> (Friends of the Earth). • <u>Nano-silver's widespread use in homes</u> is thought by some to have the potential to lower the immune defenses of Australians who are no longer exposed to common household germs. • <u>Basically the more you use and the more widespread its use</u>, the bigger the risk? • <u>Some consider that erroneous resistance claims</u> have been damaging to the progress of nanotechnology.
Speculative issues	<p><u>Specific risks associated with the speculative vision of molecular nanotechnology</u>.</p> <ul style="list-style-type: none"> • Concerns about monopolies and concentrated control and ownership of new nanotechnologies were raised in Australia in 2004. The study concludes that we are moving towards a “nanotech industry built solely on selling nanotubes, nanowire and the like” which will “end up with a few suppliers selling low margin products in huge volumes”.
Societal issues	<p><u>Concern for the effects that the availability of nanotechnological devices</u> will have on politics and human interaction.</p> <ul style="list-style-type: none"> • The needs to raise community awareness about nanotechnology and issues relating to public health, safety and the environment. www.nanotechnology.gov.au/ • Effect on society and what action if any is appropriate to mitigate these risks.


<p>Other issues</p>	<p>Other health, safety and environment issues for consideration, include:</p> <ul style="list-style-type: none"> • Unintentional impacts on public health, safety and the environment. • Labelling of food and products. • Tests for the presence of nanomaterials. • Some nanomaterials, eg carbon nanotubes could be harmful when used in certain ways. • Short and long term hazards. • A risk of nanoparticles or nanotubes being released during disposal, destruction and recycling. Manufacturers of products should publish procedures. • The current risk assessment protocols are based on conventional methods that may not be suitable for nanomaterial. • The effect industrial-scale manufacturing and the use of nanomaterials would have on human health and the environment.
<p>The 4 Pillars Policy</p> <p>DISCUSSION PAPER A national scheme for assessment, registration and control of use of agricultural and veterinary chemicals (March 2011). www.ntn.org.au</p>	<p>The National Toxics Network (NTN) considers there is a strong case for a moratorium on the commercial use of nanomaterials until specific risk assessment procedures can be validated, the safety of nanomaterials can be assured and an effective regulatory regime is in place. The 4 Pillars Policy should underpin the regulatory framework for nanomaterials (a Toxics-Free Future in which all chemicals are produced and used in ways that eliminate significant adverse effects on human health and the environment):</p> <p style="text-align: center;"> Right to Know No data / No market Precautionary Principle Substitution Principle </p> <p>The National Industrial Chemicals Notification and Assessment Scheme (NICNAS) says the risk that nanoparticles may pose to human and environment health is not yet fully understood. The precautionary principle suggests keeping environmental release of nanoparticles minimal until their fate and toxicity is better understood.</p>
<p>Organic standards</p>	<p>Nanotechnology products and processes are prohibited in all aspects of organic production systems and products. This includes:</p> <ul style="list-style-type: none"> • Prohibition of formulations of substances approved for farming inputs which include manufactured nanoparticle additives and ingredients or intentionally formulated nanoparticle size emulsions. • Prohibition of all manufactured nanoparticle additives and ingredients in processed products, for example cosmetics, clothing or foods. A particle shall be considered to be a nanoparticle where: <ul style="list-style-type: none"> • The mean particle size is 300nm or less in one dimension or more; and • The minimum particle size is 200nm or less in one dimension or more. • However, this prohibition does not apply to the presence in certified organic products of naturally occurring nanoparticles, eg from nanoparticles in volcanic soils, or incidentally produced (non-manufactured) nanoparticles, eg occurring in flour as a by-product of the traditional milling process.

Selected resources

- Jackson, N., Lopata, A., Elms T. and Wright, P. 2009. *Engineered Nanomaterials: Evidence of the Effectiveness of Workplace Controls to Prevent Exposure*. Safe Work Australia.
- Jackson, N., Tepe, S. and Wright, P. 2010. *Engineered Nanomaterials: Investigating Substitution and Modification Options to Reduce Potential Hazards*. Safe Work Australia.
- Kaye, T. 2007. *Materials Science: Nano Future Beckons*. CSIRO Solve Issue 10, Feb.
- Luc, A. and Pollet, E. (eds). 2012. *Environmental Silicate Nano-biocomposites*. Biocomposites Series: Green Energy and Technology. Springer.
- Murashov, V. and Howard, J. (eds). 2011. *Nanotechnology Standards*. Nanostructure Science and Technology Series. Springer ISO/TC 229. Nanotechnologies.
- Netburn, D. 2014. *Bionic Veg Branch Out with Super Powers*. SMH 31/3/2014.
- Shirai, Y., Osgood, A. J., Zhao, Y., Kelly, K. F., Tour, J. M. 2005. *Directional Control in Thermally Driven Single-Molecule Nanocars*. Nano Letters. **5** (11): 2330–4.
- Stewart, F. 2011. *Questions over Bug Offensive*. Canberra Times Oct 16.
- Suppan, S. 2012. *International Standards for Trade in Nano-coated Produce*. Institute for Agriculture and Trade Policy
- Thompson, J. A. 2006. *GM Crops: The Impact and Potential*. CSIRO Pub.
- US Environmental Protection Agency. *Regulating Pesticides that Use Nanotechnology*. www.epa.gov/
- APVMA nanotechnology (search for Nanotechnology on the APVMA website www.apvma.gov.au/)
- Australian Office of Nanotechnology. 2008. Series of Fact Sheets www.industry.gov.au
- Croplife Australia www.croplifeaustralia.org.au
- Dr. Peter Hatto, Chairman ISO TC 229 and CEN TC 352 nanotechnologies technical committees, Director of Research, Ionbond Limited, Co Durham, UK.
- IMEC in Leuven, Belgium, is a world-leading independent research centre in nanoelectronics and nanotechnology. 2009. *Facing the World of Society, Science, Technology, Industry and Education in the 21st Century*. www.nanotech-now.com/news.cgi?story_id=32449_9
- International Conference on Nanoscience and Nanotechnology (ICONN) held in a different country annually.
- ISO/TC 229 Nanotechnologies.**
- ISO/TS 80004-1:2010. Nanotechnologies – Vocabulary – Part 1: Core Terms.**

APPENDIX 4

Risk Assessment and Management

<p>The standard</p>	<p>Risk management—Principles and guidelines. AS/NZS ISO 31000:2009 describes the process for managing risk, the framework in which it is developed and principles for managing risk. It provides guidance on good management practice.</p>
<p>AS/NZS ISO STANDARD</p>	<p>AS/NZS ISO 31000:2009 <i>is not a certification standard.</i></p>
<p>Steps for managing risk</p> 	<p>Risk analysis is the process of defining and analysing the dangers to individuals, businesses and government agencies posed by potential natural and human-caused adverse events. Risk analysis involves the following processes:</p> <ol style="list-style-type: none"> 1. Communicate and consult with internal and external stakeholders. Record the action you have taken or plan to take. 2. Establish the context and criteria against which risk will be evaluated. A wide array of risk analysis processes may be used. A risk analysis report can be either: <ul style="list-style-type: none"> • Quantitative (numerically determine the probabilities of various adverse events and the likely extent of the losses if a particular event takes place), eg economic impact. • Qualitative (used more often). 3. Risk / hazard identification. Identify where, when, why and how events could prevent, degrade, delay or enhance the achievement of the objectives. 4. Assess the nature and degree of risk associated with the hazard, ie compare estimated levels of risk against the pre-established criteria and consider the balance between potential benefits and adverse outcomes. This enables decisions to be made, treatments required and about priorities. 5. Manage the risk. Risk management is the process of taking appropriate action to reduce, manage and control the risk. The risk must be adequately communicated. 6. Monitor, review and continually improve all steps of the risk management process for their effectiveness. A set of instructions is repeated a specified number of times or until a specific result is achieved. Keep records for continual improvement.
<p>Principles for managing risk</p>	<p>Risk management must be an integrated part of the organizational processes, it is:</p> <ul style="list-style-type: none"> • Part of the decision-making process. • Explains uncertainty in that it is: <ul style="list-style-type: none"> • Systematic, structured and timely and, • Based on the best available information at the time. • Tailored to the situation, eg <ul style="list-style-type: none"> • Takes human and cultural factors into account. • Transparent and inclusive procedure, eg <ul style="list-style-type: none"> • It is dynamic, repetitive and responsive to change (the repetition of a sequence of operations yields results successively closer to a desired result). • Facilitates continual improvement and enhancement of the organization.
<p>What can risk management be used for? Prevention strategy</p>	<p>A means of systematically ranking hazards, prioritizing issues and identifying controls that prevent their manifestation, eg</p> <ul style="list-style-type: none"> • Primarily for prioritization and informing decisions that do not have an impact on trade. Species are assessed, scored and ranked into impact categories of high, medium and low based on invasiveness, distribution, impact, etc. • To gather additional information on a particular species of concern when there is an identified need to do so, eg trade. • It is a more detailed assessment of the risks and uncertainties surrounding a particular species, group of species or pathways of concern. • Assist effective rapid responses. • Underpin decision-making. • It is a vital part of any prevention strategy.
<p>Managing environmental related risk</p> <p>Work with Governments to ensure regulations meet society's changing expectations</p> <p>Environmental Risk Assessment Guidance Manual for Agricultural and Veterinary Chemicals</p>	<p>SA/SNZ HB 203:2012 Managing environment-related risk (handbook) is intended to help organizations manage environment-related risk based on the process set out in AS/NZS 31000:2009.</p> <ul style="list-style-type: none"> • AR Avoid the Risk. Decide not to proceed with the activity or adopt an alternative process or choose a more suitable location. • MR Mitigate the Risk: Introduce new technology or changes practices. • RL Reduce the Likelihood: Training or planning or supervision, or monitoring or preventative maintenance, or review work practices to reduce the probability of an incident occurring. • RC Reduce the Consequences: Minimize physical exposure to risk sources by relocating an activity or improving contingency and emergency response preparedness or buffer zones or spill controls. • RR Retain the Risk: Administrative responses, eg the development of standard operating procedures (SOPs) or basic training or plans to deal with outcomes if risk realized. <p>Various publications assist environmental risk assessment of pesticides, eg Environmental Risk Assessment Guidance Manual for Agricultural and Veterinary Chemicals.</p>

<p>Biosecurity</p> <p>Biosecurity has shifted from zero risk to managed risk (pages 186)</p>	<p>The Centre of Excellence for Biosecurity Risk Analysis builds on the work of ACERA (Australian Centre of Excellence for Risk Analysis) at the University of Melbourne and aims to deliver practical, rigorous solutions and advice related to the assessment, perception and communication of biosecurity risk.</p> <ul style="list-style-type: none"> • A CRC for National Plant Biosecurity manual is available which provides information on rapidly predicting the establishment and spread of exotic plant pests, eg Asian gypsy moth, Khapra beetles and fire blight, to provide a decision-making tool to government and industry to aid biosecurity plans and incursion management responses.
<p>Genetically modified crops</p>	<p>The Office of the Gene Technology Regulator (OGTR) assesses, mitigates and manages risks of releasing GM crops through its comprehensive risk management strategy.</p>
<p>Plant epidemics</p>	<p>The risk of the development of a plant disease into an epidemic is the probability that a certain intensity of incidence or severity of the disease will be reached. Numerous host, pathogen and environmental factors must be taken into account in assessing the risk of development of a particular disease (pages 403-408).</p> <ul style="list-style-type: none"> • In most cases not all of information is available and since the parameters remain fairly constant from year to year, one needs to concentrate on estimating as well as possible: <ul style="list-style-type: none"> • The starting inoculum of the pathogen, and the first sign of disease in the field. • Following close changes in moisture and temperature. • Predicting weather changes in the near future. • Risk assessment is usually expressed as low, moderate or high risk of reaching those disease severity values. Risk assessment provides a timely warning to the grower who responds with appropriate urgency in applying effective management measures. • Simulations models provide continuous information on the spread and severity and statistical models can help in determining how plant diseases may best be managed (page 407).
<p>Agvet chemical products – 2 examples</p> <p>Consider risk assessment and management</p> <p>Muir, T. 2006. <i>Getting the Mix Right: Washdown Bays and Chemical Mixing Areas</i>. Aust. Turfgrass Management April-May.</p>	<p>Protecting the health and safety of all those who work with chemicals in agriculture and horticulture production is a fundamental goal of the APVMA assessment and registration of agvet chemicals.</p> <ul style="list-style-type: none"> • The APVMA considers the possible extent of worker risk from the chemical product and how that risk and its consequences can be mitigated. <ul style="list-style-type: none"> • APVMA measures a worker's risk by first considering toxicological hazards that a chemical has and then by considering the potential exposure to that chemical that a worker might routinely encounter during the course of his or her job. • The critical element of determining the WHS implications is the level of exposure that workers are likely to encounter for that product. This may depend on the task being performed, eg spraying an orchard, or inside a glasshouse, eg <ul style="list-style-type: none"> • Type, duration and frequency of chemical application tasks. • The quantity of chemical handled. • The concentration of the chemical during handling. • The formulation of the product. • Type of mixing / loading operations. • Type of application and mixing / loading equipment. • Type of protective clothing used. • Type of engineering controls used (special protective equipment, eg closed loading systems or closed cabs). • The time of re-entry into treated areas and nature of tasks undertaken while there. • APVMA draws on human health specialists for expert technical advice on WHS issues. • Depending on the risk, the APVMA determines which activities can be permitted, often requiring that the use of specific protective clothing and other special protective devices and places specific instructions on the product label for how the product may be used. • The APVMA only allows chemicals to be used for which there is a safe threshold of exposure, ie for exposure below that threshold there is no known impact of risk. <p>Low level of exposure.</p> <ul style="list-style-type: none"> • Currently low level exposure receives less attention than does acute poisoning. Standard Operating Procedures (SOPs) should be developed and training provided on a regular basis. Safe handling practices may need to be reevaluated in order to increase compliance (Muir 2006).
<p>Emergency procedures</p>	<p>Standard emergency procedures need to be practiced regularly. The problem is that emergencies happen intermittently, a bit like bush fire fighting.</p>
<p>Growers always weighing up the risks</p>	<p>Growers always weigh the risks, costs and benefits of each of their many decisions, eg</p> <ul style="list-style-type: none"> • Whether to plant expensive seed or less yielding seed but a resistant variety rather than seed of a high yielding variety that needs to be protected by chemical sprays. • Growers may need assistance to help them make decisions, eg forecasts that will help them determine whether a plant infection is likely to occur so that they can determine whether to treat a crop right away or to wait for several more days. • Plant a crop in a particular field. • Managing risk creates value.

APPENDIX 5

Pesticide Resistance

Herbicide resistance

Australia is second only to the USA in terms of number of weed biotypes that have developed resistance to herbicides. Annual ryegrass resistance in Australia is the world's worst case of herbicide resistance.

Herbicide resistance in Australia is now widespread in annual ryegrass (*Lolium rigidum*) and wild radish (*Raphanus raphanistrum*).

There are more than 100 documented cases of established weed populations as glyphosate-resistant

Australian Herbicide Resistance Initiative (AHRI) 2010

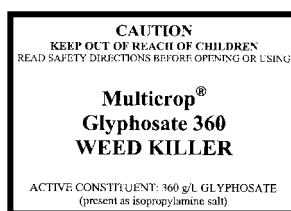
- recommends:
- Rotate herbicide mode of action groups.
 - Use double knockdown
 - Rotate crops.



- GRDC. 2013. *Herbicide Resistance*. GRDC Supplement. May-June.
- Heap, I. 2006. *The International Survey of Herbicide Resistant Weeds*. Online.
- Penfold, K. 2011. *Growers Face New Weeds Learning Curve*. Ground Cover May-June.
- Penfold, K. 2011. *The Link between Resistant Ryegrass and Food Demand*. GRDC May-June.
- Rossel, T. V. 2011. *Grain and Cotton Weed Alliance*. GRDC Nov-Dec.

Glyphosate is as important to world food production as penicillin was to human health (Heap 2006). Glyphosate has been relied on for fallow weed control for 20 years and has allowed a move towards more sustainable cropping systems. So far there is no replacement for glyphosate in the market.

- **Drivers** of glyphosate resistance are:
 - Intensive use of glyphosate to control weeds with no other effective herbicide treatment.
 - Increasing adoption of minimum tillage, no tillage.
 - Glyphosate-tolerant crops.
 - Relying on one form of weed control, ie in this case, glyphosate.
- **Australian National Glyphosate Sustainability Working Group** aims to extend the lifetime of glyphosate and paraquat herbicides (Penfold 2011), eg
 - **Delay** the incursion of herbicide resistant weeds on farms currently free of them.
 - **Help growers with resistant weeds manage them** effectively and economically.
 - **Rotate control methods**, rotate pesticide groups and rotate herbicides (as recommended).
 - **Rotate** between different pre-emergent herbicides as recommended by CropLife Australia. www.croplifeaustralia.org.au
 - **Some companies recommend** double knockdown herbicide applications (glyphosate followed by paraquat or Spray.Seed® (paraquat and diquat) about 7-10 days later), any individual not controlled with glyphosate will be killed by paraquat. This delays resistance by reducing the number of potentially glyphosate resistant individual surviving weeds. Note that Spray.Seed has a **DANGEROUS POISON** signal heading.

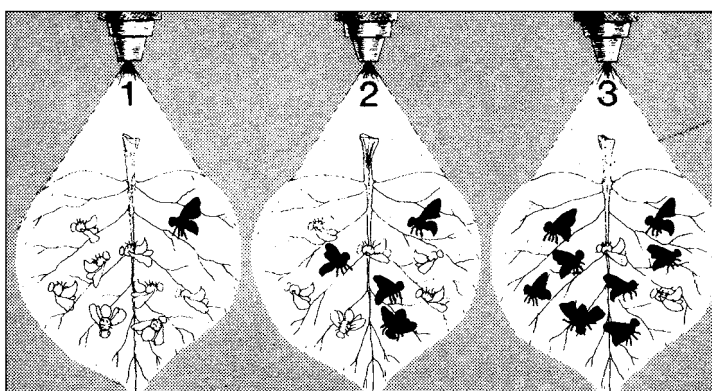


- **Follow** weed resistance warning on the label (page 290), never cut herbicide rates.
- **Save** new herbicides until you really need them.
- **Herbicide resistance** may occur for other reasons, eg
 - **In many situations** resistance to Group B herbicides (sulfonylurea) has resulted from prolonged exposure to Group A herbicides.
 - **Resistance can also be brought** onto farms through crop or pasture seed purchased from a farm with resistance or from hay bought for stock feed.
 - **Seed can be carried long distances** on or in machinery, on livestock or in fodder or grain. If saving seed for next season choose paddocks so that you avoid spreading resistant weeds.
 - **Nursery plants** are commonly exchanged between production sites; the resistant populations migrate much faster than is possible in other horticultural systems.
- **IWM Management practices are essential.** www.weedscience.org. Monitor and manage resistance. Use as many different tools as practical, eg
 - **For annual cropping situations.** Start with a clean field and control weeds early.
 - **Clean** equipment between sites.
 - **Increase seeding rates.** use competitive varieties and effective herbicides. Use good agronomic principles that enhance crop competitiveness.
 - **Ensure** crop seed is really weed-seed free.
 - **When resistant weeds have been identified** prevent the resistant plants from setting viable seed or proliferating vegetatively.
 - **Manage weed seeds** to reduce the weed seedbank for next year; weed seeds, especially some grass species have only a short seedbank life. Use chaff carts, burning windrows, moldboard ploughs (for burying weeds seeds), Weedseeker® technology or the proposed new Weed Seed Destroyers.
 - **The Weed Seed Wizard** will assess farm activity impact on weed populations allowing farmers to pick the optimum strategy for managing different weeds.
- **Detect resistance:**
 - Before you plant, monitor weeds and control.
 - At planting, eg mulch, pre-emergent and then,
 - Post planting.
- **Herbicide Resistance Action Committees (HRACs)** provides advice on how to manage herbicide resistance.

Insecticide resistance

More than 500 species of insects and mites have developed tolerance to pesticides, including those regarded as being environmentally benign.

- **Insecticide Resistance Management Strategies (IRMSs)** have been developed for certain crops including cotton. www.croplifeaustralia.org.au
 - **Cotton Ingard®** plants (**1-gene Bt** (*Bacillus thuringiensis*)) produces a protein has proved an effective tool for the sustainable management of *Helicoverpa* in Australia. Adherence to a **Resistance Management Plan (RMP)** is necessary.
 - **Bollgard 11** plants (**2 gene Bt**) produce 2 separate **Bt** proteins, providing better control of bollworm, reducing insect sprays and increasing yields. The 2 proteins will make it much more difficult for resistance to develop as each protein works in a different manner. Strict adherence to a **RMP** is necessary. Monsanto Bollgard 11 Technical Manual.
 - **Bollgard III** plants (**3-gene Bt**) is in the pipeline to provide added protection from a broad spectrum of the *Helicoverpa* complex and *Spodoptera*.
- **IPM management practices are essential.**
 - Hectare restrictions.
 - Refuge crops.
 - Spray limitations.
 - Pupae busting.
 - Trap crops.
 - Control of volunteers.



Selection of resistant pests. **1.** Crop almost free of target pests (**BLACK**). **2.** Target pests seem to be more abundant - spray seems to have lost some of its effect even when the spray is used at the recommended rate. **3.** Almost all of the target pests survive treatment - there is a resistance problem (Shanahan, G. J. and Hughes, P. B. 1981. *Looking at Insecticide Resistance*. Seed and Nursery Trader. Mar).

Redlegged earth mite resistance

- **How growers react to increasing resistance may be an issue of concern.**
 - **In WA 12 cases of red-legged earth mite (RLEM) resistance** have been identified since 2006. If resistance was perceived to spread from other farms rather than from excessive use of miticides on their own farm, growers could be even less inclined to reduce insecticide use.
 - **Concerns about resistance** developing may not deter some growers from continuing use of low cost / low risk practices.
 - **The policy implications also differ.** Research is needed on:
 - Factors leading to adoption of **IPM** as well as the
 - Causes and extent of the spread of resistance.
- **Insecticide Resistance Action Committees (IRACs)** provides advice on how to manage insecticide resistance.

Fungicide resistance

Many fungi have developed resistance to fungicides.

- **Fungicide Resistance Management Strategies (FRMSs)** have been developed for some fungal diseases on some fruit and vegetable crops. www.croplifeaustralia.org.au
- **The total risk of resistance** is influenced by management factors such as fungicide usage, environmental conditions and inherent factors of the pathogen.
- **Fungi with short life cycles which produce large number of airborne spores**, eg rusts, grey mould (*Botrytis*), powdery and downy mildews rapidly develop resistance, fungi with long life cycles or less prodigious spore production, eg soilborne fungi, take longer (page 405).
- **IDM management practices are essential**, eg early destruction of crop residues, crop rotation, good cultural practice (air movement, wide separation of successive plantings) and resistant cultivars can be used in conjunction with fungicides. Two or sometimes 3 fungicides from different groups are used in combination, mostly a protectant, eg mancozeb or copper combined with an at-risk product.
- **Fungicide Resistance Action Committees (FRACs)** provide advice on how to manage fungicide resistance.

APPENDIX 6

Pesticide Residues (MRLs, WHPs, Trade)

Maximum residue limits (MRLs)

Food & feed residues



PESTICIDE RESIDUES

- The traces of pesticide and its breakdown products remaining in, or on the target after treatment, or
- In soil, water or plants.

REDUCING MRLs

There is increasing pressure to reduce residues further due to more stringent requirements by overseas markets for clean produce.

Overseas countries often have LOWER or ZERO MRLs in food.

MARKETING

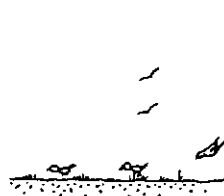
National basket surveys are used to check on chemical residues in fruit and vegetables.

Advertising must not be misleading.

Remember all food in Australia is good (Rick Roush)

The International and Australian Standard for residues, is called the **Maximum Residue Limit (MRL)** and is the highest concentration of a residue of a particular chemical that is **legally permitted or accepted in a food or animal feed**.

- **Food Standards Australia New Zealand (FSANZ)** develops standards that regulate the use of ingredients, processing aids, colorings, additives, vitamins and minerals.
- **The APVMA in conjunction with FSANZ** ensures that **MRLs** are set at levels that are acceptable for both long and short term human exposure.
- **MRLs help to monitor** that the pesticide has been used as directed on the approved label. If an **MRL** is exceeded, it usually indicates a misuse of the chemical but does not normally indicate a public health or safety concern.
- **The APVMA imposes 100-fold maximum residue limits (MRLs)** to ensure a safe margin above observed effects on human health, so we should be confident that registered pesticides are safe **when applied in accordance with label directions for use**.
 - **MRLs** may be revised, pesticides may be reviewed, withdrawn or restricted, eg fenthion, dimethoate (page 364).
 - **No evidence** that food containing less than the **MRL** is harmful.
 - Australian Government research shows that over **99% of Australian foods tested have no detectable residues or are below the maximum residue limit**. CropLife Australia has produced fact sheets on **pesticide residues**. www.croplifeaustralia.org.au/
- **Residues monitoring** is an important part of the overall strategy to minimize unwanted residues and environmental contaminants in **food** and to demonstrate compliance with domestic and overseas standards.
 - **New developments in testing methods** mean more traces of pesticides in food are discovered and more regulations go into effect. The Australian and State / Territory Governments, commodity boards, food and retail companies and authorities in overseas countries, monitor produce for residues. Australia Food is tested by State, Federal and independent authorities and by industry. Total diet studies indicate very low levels in food.
 - **The National Residue Survey (NRS)** monitors residues of agvet chemicals and environmental contaminants in **Australian food commodities**. **NRS's** annual reports are published by the Australian Department of Agriculture. www.agriculture.gov.au (under construction, previously www.daff.gov.au/). Trace back was not always possible. **NRS** supports Australia's food industry and primary producers by facilitating access to key export markets and confirming Australia's status as a producer of clean food. **NRS** programs encourage good agricultural practices, help to identify potential problems and indicate where follow-up action is needed.
 - **The 24th Australian Total Diet Study (ATDS 2014)** by **FSANZ** is Australia's most comprehensive assessment of consumers' **dietary exposure** (intake) to a range of food chemicals including food additives, nutrients, pesticide residues, contaminants and other substances. The survey is conducted approximately every two years and is available online. www.foodstandards.gov.au/
 - **Some States have targeted testing programs related to matters of local concern** within their States.
 - **Fresh Produce Watch** (a project of the Australian United Fresh Fruit and Vegetable Association Ltd (AUF) informs the media, community and the fruit and vegetable industry about the positive actions taken by the fresh produce industry to improve food safety and to implement ecologically sustainable farming practices.
 - **Sydney Basin market gardens**. Concerns about contamination by chemical residues of fruit and vegetables grown which supplies 80% of the Sydney's perishable needs. A very high proportion of the market gardeners have a Culturally and Linguistically Diverse Background (CLDB) and are at risk through in appropriate use of chemicals.
 - Pesticide residues are also discussed on page 308.



Treated seed




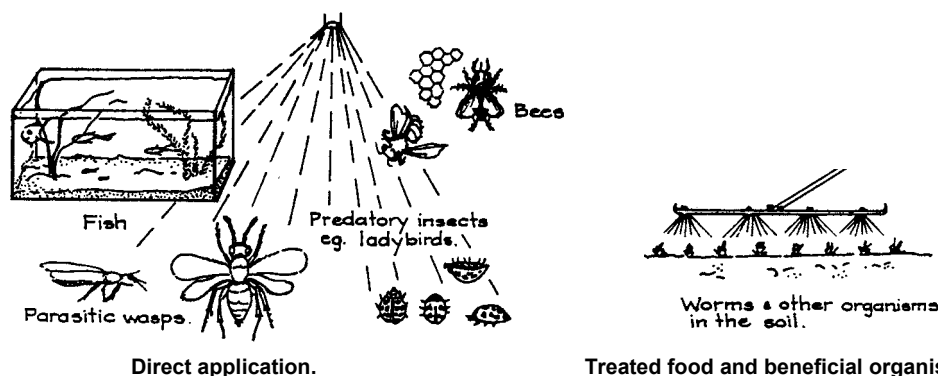
Treated lawns & playing fields.



Treated fruit.

© - 2014

<p>Withholding periods (WHPs)</p>	<p>The withholding period (WHP) is the period that must elapse between the last application of a chemical and harvesting of plants, grazing or cutting for stock food, consumption by a human and animal after postharvest use.</p> <ul style="list-style-type: none"> • The WHP provides users with the information they require to ensure that residues in their treated produce do not exceed the legal MRL, eg data must demonstrate that the MRL will not be exceeded when the appropriate WHP is observed. • Records must be kept.
<p>Residue violations</p>	<p>Farmer markets and local growers can send their produce direct to local markets without any testing.</p> <ul style="list-style-type: none"> • Residues above the legal limit in export produce are a trade risk. • The ability to accurately measure residues of chemicals in primary produce in a fast and cost-effective manner would be a significant advantage.
<p>Trade, vendor declarations</p>	<p>Residues remain a threat for export markets.</p> <ul style="list-style-type: none"> • Procedures must ensure that any chemical used is acceptable to trading partners and is supported by scientific data and that the required MRLs have been met. • Vendor declarations may be requested stating that a produce has been grown or handled under an accredited quality assurance (QA) program or that it has not been treated with any fumigant, pesticide or insecticides. If it has been treated, products used and dose rates must be provided.
<p>Residues in the environment Persistence</p>  <div style="border: 1px solid black; padding: 5px;"> <p>Herbicide residues affecting crop performance may be the result of herbicides applied < 1-2 seasons ago.</p> </div> <p>Israel, B. 2013. <i>Fungicide Use Surging, Largely Unnoticed</i>. Environmental Health News 22 Feb. Uni. of Kentucky.</p> <p>Wightwick, A., Walters, R., Allinson, G., Reichman, S. and Menzies, N. 2010. <i>Environmental Risks of Fungicides Used in Horticultural Production Systems</i>. Chap 14. <i>Fungicides</i>. Intech 2010. CRC CARE and Vic DPI. www.crccare.com</p> <p>Smith, J. 2008. <i>Fungicides revisited: A critical look at copper- and sulphur-based fungicides in organic agriculture</i>. FARMSTART.</p>	<p>The effects of some pesticides in the environment, eg residues in water, air, soil, plants and plant products have been well documented (page 308).</p> <ul style="list-style-type: none"> • Horticulture Environmental Audit completed in 2001. Specific topics included disposing of chemicals, soil degradation and contamination, irrigation scheduling, managing farm vegetation, using buffer zones, dust management, pest monitoring and chemical / non-chemical weed control options. • Herbicide residues from previous crops, especially if they fail early. Read the label and check for warnings about persistence or plant-back periods before other crops are sown. Aerial herbicide applications may contaminate waterways. In CT crop production systems in which traditional cultivation is reduced and mechanical weed control is replaced or supplemented by the use of herbicides, persistence of some in soil (the length of time a herbicide remains active) will determine when the area can be replanted. • Insecticide residues and their effect on fish and bees, etc are well documented. • Fungicide residues. Fungicide use is increasing in horticulture production systems but has received relatively little attention compared to insecticides and herbicides as contamination of waterways near these emerges. Experts say that there is inadequate environmental monitoring and information on their safety (Israel 2013). • Australia currently has no organized, long-term way of monitoring levels of commercial fungicides in soil and waterways. This is despite the fact that in Australasia over 7,500 tonnes of copper fungicides are applied to grapes, fruit and vegetable crops every year, representing 13 per cent of the global total, and that copper can remain in the soil for 1,000 years or longer. Copper is more likely to have detrimental effects on soil organisms responsible for nutrient cycling and continued soil health than on the plants themselves (Wightwick et al 2012). Soil has naturally occurring copper and soils test should be done to determine the level of this metal before adding more to the environment (Smith 2008). Copper can be toxic to most organisms, highly toxic to fish and has been linked to liver disease in vineyard sprayers after years of exposure. The European Union has been working on banning copper-based fungicides since 2002; however, suitable alternatives have been difficult to develop. • Sulphur is less persistent in soil than copper. However, sulphur also can be toxic to plants at varying levels, according to species, especially at high temperatures or when mixed with oil products. Sulphur is applied at rates far exceeding those of copper and synthetic fungicides; this could lead to its toxic effects simply based on quantity. • A recent study comparing organic and conventional crop protection strategies reveals that copper and sulphur-based fungicides are as harmful as conventional fungicides.



Soil, compost

Kohlhaase, B. 2013. *Herbicides Pollute commercial compost*. The Weed's News Digest 20/3/2013. Planet Natural 07 Dec 2012.

It has been possible to measure the fate of pesticides in the soil for many years.

- **Soils with coarse sandy textures** are generally more permeable and have greater potential for groundwater contamination than less permeable soils. Organic matter is the single most important factor affecting absorption (binding of pesticides to soil particles) of pesticides in soils.
- **Contaminants in commercial compost overseas** has included a wide array of herbicides, heavy metals and other chemicals as well as bacterial pathogens, prescription drugs and sewage sediments and sludge (Kohlhaase 2013).

Water

Residues in ground water



Ground and surface water quality is an increasing problem

Regulations apply for herbicides being applied near waterways (CRC Weed Management Guidelines. 2005. *Herbicides: Guidelines for use in and around water*).

- **Pesticide Impact Rating Index (PIRI)** is a **free risk-based assessment software package** developed by **CSIRO Land and Water** that provides the **relative risk of a pesticide** to move off-site and pollute waterways, be toxic to organisms, and assist planning and decision-making associated with pesticide operations (2011). **PIRI** provides an off-site impact of different pesticides and land uses and can be compared using a simple risk indicator. www.csiro.au/clw
 - Sustainable Gardening Australia (SGA) in conjunction with the Uni of Melbourne Burnley's college has developed a rating system that groups horticultural chemicals into 3 levels that indicate degree of environmental harm so SGA nurseries promote low environment damage products
- **Residues in ground water.** The following is a list of **BMPs** to prevent groundwater contamination by pesticides. The use of herbicides near waterways should be minimized so the use of alternative techniques should be considered that are alternatives to, or complementary, with herbicides.

<ul style="list-style-type: none"> • Select pesticides less likely to leach • Check the WHP • Do not exceed recommended application • Calibrate equipment to apply the desired rate • Use preventative IPM strategies • Mix and load carefully to prevent spills • Do not apply immediately prior to irrigation or heavy rainfall • Do not over irrigate • Follow label directions 	<ul style="list-style-type: none"> • Late herbicide applications to crops increase the risk of residues in harvested crops potentially leading to breaches of MRLs • The responsibility to avoid herbicide residues in delivered products sits squarely with growers and their advisors • Key points: Correct usage, product labels must be followed, adhere to WHPs and no off-label use without a permit • Consult with buyers to be sure
---	---

- **Pesticide storage areas, wash bays and environmental responsibility.** There is plenty of information on how pesticides move into groundwater. Wash bays are where pollution of surface water is likely to occur unless appropriate systems are in place (pages 300, 311).
 - **Checklists are available protecting groundwater from contamination** which include:
 - Storage facilities with concrete floor and bunding.
 - Rinsates collected. Prevent surface water contamination.
 - Water hose have a check valve to prevent back siphoning.
 - Select products which are least toxic, least persistent and least likely to leach.
 - Observe buffer zones when spraying trees overhanging streams and dams.
 - Use IPM to reduce the amount of pesticides required.
 - There is no excuse for spills.
 - **Tail water from irrigation water of cotton farms** is stored often in dams the size of 10 football fields resulting in a buildup of toxic residues. Native animals, including birds, amphibians and reptiles are drawn to these water sources where they can be affected by the residues. Simply by incorporating native plants, wood chips and other filtering mediums such as basalt and gravel beds, water quality can be improved.

Food chain

The food chain is a succession of living organisms in which each one feeds, at least in part, on the preceding one.

- **Because pesticides are sprayed or spread across entire paddocks or crops,** over 90% of sprayed insecticides and herbicides reach a destination other than their target species.
- **Some animal species will be affected directly,** others may be affected when they eat treated food or feed, eg pasture, swim in contaminated water, etc. Birds of prey may feed on affected animals. Some pesticides, eg organochlorines bio-accumulate over time, with the concentrations of organochlorine compounds increasing in animals higher up in the food chain (the reason why they are not used today).

APPENDIX 7

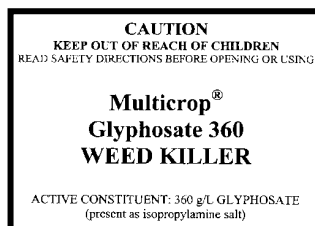
3 Generations of Pesticides

Whatever pesticide you are using, you must still know the following

How hazardous the product is

SIGNAL HEADING	WHAT IT MEANS
No signal heading	The chemical is "unscheduled" and it is relatively safe to the person using the chemical. However, never treat any chemical lightly as it may still affect our health, either in the short term or the long term.
CAUTION	The chemical is low to moderately hazardous to the person using the chemical. Often it can irritate the skin or eyes.
POISON	The chemical is very hazardous to the person using the chemical. It can cause poisoning if it enters a person's body.
DANGEROUS POISON	The chemical is extremely dangerous to the person using the chemical. Just a small amount of the chemical can cause poisoning and even death if it enters a person's body. For these poisons there are usually restrictions on the purchase and use that are imposed by State or Territory governments such as training and accreditation requirements. Check with your State / Territory coordinator.
Not available to home gardeners	

The signal heading also includes instructions to **KEEP THE PRODUCT OUT OF REACH OF CHILDREN**, and to **READ THE SAFETY DIRECTIONS BEFORE OPENING OR USING** the product.



Inert ingredients

Inert ingredients are added to pesticide formulations for a number of reasons, eg helping a product stick to the surface of leaves and soil, spread over surfaces, or dissolve in water.

- They can be **more toxic** than the active pesticidal ingredient to humans, nontarget plants, animals and microorganisms, eg surfactants in some glyphosate formulations can increase its aquatic toxicity.
- **Generally there is no requirement to identify the inert ingredients on pesticide labels** or publically available registration information as pesticide proprietors claim the identity of 'inerts' as confidential business information. This makes it difficult for the general public or researchers to know what is in the formulations being used.

Effective and safe application Some spraying tips



1. **Planning**, eg legislation, policy, etc
 - Keep records.
 - Do you have the required products, personal protective equipment (PPE), etc?
 - What pre-application procedures are required?
 - Notify your neighbours.
2. **Select a product.**
 - Identify crop growth stages for application before selecting a pesticide.
 - Identify pest, disease or weed accurately. What stage is to be targeted?
 - Check pesticide selection criteria, persistence, hazard, etc. Is it suitable for the situation?
3. **Read and understand the label** and the **Safety Data Sheet.**
 - Check plants, pests, etc on which registered.
 - Check use restrictions.
 - Manage resistance, buffer zones, and droplet size.
4. **Know your application equipment.**
 - Suitability for the job and set up appropriately, eg for fungicides, herbicides or insecticides, drift reduction nozzles, droplet size, low drift settings.
 - Calibration, rate, calculation checked.
 - Measuring / mixing, eg closed systems, mix compatibility, spray volume, water quality.
5. **Application - Timing is everything** (Thomson et al, 2004), eg
 - Monitor weather at the beginning, during and end of the operation.
 - Can you comply with **WHPs** for the required **MRLs, REIs** and **plant back times**?
 - **Right stage** of host, right stage of pest, disease or weed.
 - Where is the target? On the leaves, flowers, buds, in the soil, germinating weed seeds?
6. **Post-application procedures carried out**, eg irrigation.
7. **Cleaning up**, eg disposal of containers, excess spray, **PPE**, shower, etc.
8. **Audit.** Was the application effective? Were there any safety incidents or accidents?

Thomson, S.P., Heinz, K. and Krauter, P. C. 2004. *Timing is Everything*. Ornamental Outlook. Sept.

Application equipment	<p><u>Application equipment is getting more sophisticated</u>; has it been set up properly? Precision agriculture / horticulture has not been taken up as much as expected.</p> <ul style="list-style-type: none"> • Having the right spray equipment for a particular job is crucial to maintaining a successful pest control program. • Check spray equipment before use. Maintain spray equipment in good order, check for leaks, blocked nozzles or faulty hoses before using. Does it work properly? • Ensure sprayer is properly calibrated. • Use modern practices and technologies, eg closed mixing and transfer systems, anti-siphoning and drift reduction nozzles. When handling and applying pesticides, minimize exposure and reduce risks of off-target drift.
Know how the herbicide works <p>GRDC Spray record book. 2012. <i>How will you spray this year? Steps for effective weed control.</i></p> <p>Leonard, E. 2009. <i>Sensors on show at PA Symposium.</i> Ground Cover. Nov-Dec.</p> <p>Leonard, E. 2011. <i>Rules change but responsibilities the same.</i> Ground Cover July-Aug.</p>	<p><u>Correctly identify weed species and weed seedlings.</u> Some weeds are only controlled effectively with herbicides at early stages of their development.</p> <ul style="list-style-type: none"> • Effective use of herbicides requires a thorough knowledge of: <ul style="list-style-type: none"> • The target weed (weed identification, biology, susceptible growth stages). • The herbicide (herbicide activity and application methodology). • Whether it is premergent, postmergent; its persistence. • Moisture stress is one of the most common causes of poor weed control. • Allow for higher weed density when spraying. • Types of emerged weeds: <ul style="list-style-type: none"> • Young annual weeds are generally more susceptible to herbicide and less likely to be moisture stressed than older weeds, eg in summer the window for application for knockdown herbicides after a significant rainfall event may be 4-10 days on lighter textures soil and 7-14 days on heavier clay types. Weeds can be sprayed when still actively growing (early morning and night are ideal). • Control of perennial weeds such as, couch grass and certain perennial broadleaf weeds may be more effective if applied later in the season to allow for adequate translocation of herbicides into the roots and / or tubers associated with above ground growth. Too early application may give rise to rapid regrowth following initial knockdown. • Allow weed regrowth. Following grazing of weeds, fresh regrowth will be necessary for acceptable control with herbicides. Regrowth of about 15-20cm may be desirable on summer grasses while a lesser amount may be required for control for winter grasses and broadleaf weeds. • Delay glyphosate resistance. Do not to allow the 3 drivers of resistance, ie intensive use of glyphosate, no tillage and no other effective herbicidal treatment to come together. • Heavy dust should be avoided.
Know how the insecticide works	<p><u>Most insecticides</u> only kill the young (larvae or immature) and adult stages of insects and mites and have no direct effect on eggs and pupae or they may be in the soil, etc.</p> <ul style="list-style-type: none"> • As a result, 2-3 repeat applications may be necessary. This is especially important when there are many overlapping generations. A common problem is that spray intervals may be too long which often leads to inadequate control. When some insecticides, eg soaps and / or horticultural oils are applied at frequent intervals this may result in phytotoxicity. • Aerosols and fine sprays may be more effective in controlling flying adults whereas high-volume sprays are preferred for controlling sedentary insects or immobile stages and pests inhabiting the growing medium.
Know how the fungicide works <p>Gordon, B. 2011. <i>Guidelines for Fungicide spraying</i> Ground Cover Sep-Oct (Top 10 Tips).</p>	<p><u>Top tips for fungicide applications</u> include:</p> <ul style="list-style-type: none"> • Ensure equipment is properly decontaminated, especially if previously used for herbicide. • Check the equipment is set up to apply fungicides. • Most systemic fungicides protect new growth so the sprayer needs to be adjusted for precise application on lower plant parts. • Spray in appropriate weather conditions. • Apply preventative fungicide treatments only when diseases are a constant problem, otherwise apply only when conditions are conducive for disease and a threshold has been reached. • For many vegetable and ornamental diseases, targeted fungicide application is an important component of a disease management program. • Use defense activators, these non-pesticide agents are applied before infection to activate the plant's inherent resistance mechanisms (pages 156, 157, 165). They may be of synthetic origin (formulated chemical) or biological (non-pathogenic microorganisms or their products). Defense activators can be used in conjunction with traditional methods of disease management.

1st Generation pesticides

Insecticides

SILENT SPRING
Rachel Carson

DDT
dieldrin
lindane,
endosulfan
etc

acephate
azinphos-methyl
diazinon
dichlorvos
dimethoate
fenitrothion
fenthion
omethoate
maldison
methidathion
mevinphos
phorate
etc

aldicarb
endiocarb
carbaryl
methiocarb
pirimicarb
thiobencarb
thiodicarb
etc

Organochlorine pesticides (OCs) have been used in Australia in the past as insecticides, termiticides, fungicides and herbicides.

- **OCs** were the first widely used group of synthetic insecticides, coming into widespread use after World War II, eg DDT, lindane, dihedron, and endosulfan.
- They are generally **very stable compounds and can persist for long periods** of time after their original use.
- **OCs** generally degrade slowly and are fat-soluble, meaning that they can accumulate in humans, animals and plants.
- They can bio-accumulate over time, with the concentrations of organochlorine compounds increasing in animals higher up in the food chain.
- They can volatilise in warm regions and spread over long distances, and have been detected and measured near the Arctic Circle and in alpine areas where they have not been used.
- These stable organochlorines have been phased out of agricultural use in most countries due to concerns about environmental persistence, bioaccumulation and trans-boundary movement.
- **The History of 'Organochlorine' Pesticides in Australia** is on the APVMA website.

Organophosphates pesticides (OPs) are still widely used in all forms of pest control.

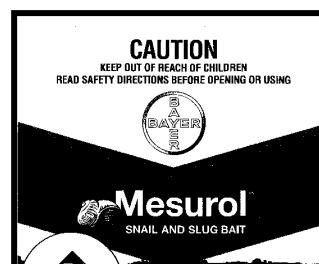
- Mostly they degrade rapidly by hydrolysis on exposure to sunlight, air, and soil, although small amounts can be detected in food and drinking water. Their ability to degrade made them an attractive alternative to the persistent organochlorines, such as DDT and dieldrin. Note though, that **many pesticides need some controlled persistence** for them to be effective.
- **Although organophosphates degrade faster than the organochlorines**, they have **greater acute toxicity**, posing risks to people who may be exposed to large amounts.
- **Cholinesterase** is one of many important enzymes needed for the proper functioning of the nervous systems of humans, other vertebrates, and insects.
 - **Organophosphates and carbamates (below) are anticholinesterase compounds** that work against undesirable insects by interfering with, or 'inhibiting' cholinesterase. While the effects of cholinesterase inhibiting products are intended for insect pests, these chemicals can also be poisonous, or toxic, to humans in some situations.
 - **Organophosphates and carbamates** can cause death in the short term, but chronic exposure could also have serious health risks.
 - **Organophosphate and carbamate poisoning** most commonly results from **exposure to insecticides**. **Organophosphates** are one of the most common causes of poisoning worldwide, and are frequently intentionally used in suicides in agricultural areas.
 - **It is recommended that people who will be working** with organophosphates or carbamates pesticides be tested for their blood baseline levels of **cholinesterase**. This provides a benchmark in case the person is exposed to high levels of pesticide, so that medical personnel can determine whether the person has been exposed to a toxic level.

ACTIVE CONSTITUENT: 1500g/L MALDISON (an anti-cholinesterase compound)



Carbamate pesticides are derived from carbamic acid and kill insects in a similar fashion as organophosphate insecticides by virtue of their ability to inactivate the enzyme acetylcholinesterase. Mesurol (methiocarb) is a snail and slug bait.

ACTIVE CONSTITUENT: 500g/L CARBARYL (an anti-cholinesterase compound)



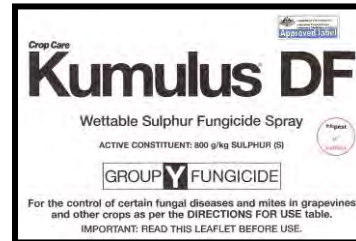
Fungicides

There are many “old fungicides”, eg products containing arsenic, mercury, etc. which are not in use today.

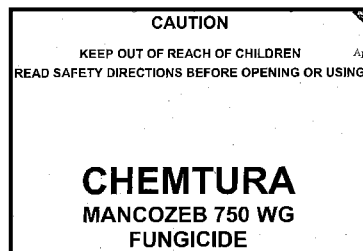
- Some though are still registered and widely used, eg copper, sulphur and the dithiocarbamates (thiram, mancozeb, ziram, zineb, etc).
- Copper was originally discovered to control down mildew of grapevines, while sulphur was discovered to control powdery mildew of grapevines! Copper is a persistent fungicide and may damage some plants.
- An excellent short history of fungicides is available (Vince Morton, V. and Staub, T. 2011. *A Short History of Fungicides*. APS Press online).

**Copper oxychloride
Copper ammonium complex**

**Dusting sulphur
Lime sulphur
Wettable sulphur**



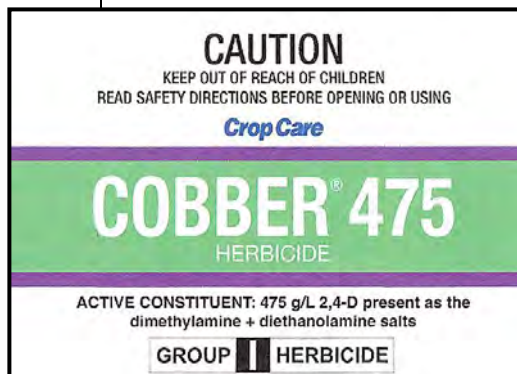
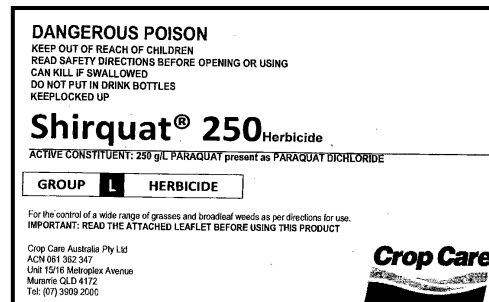
Flowable TMTD
Thiram



Herbicides

Herbicides containing arsenic are no longer registered and in use. However, there are many “old herbicides”, which are still registered and in use today, eg 2,4-D, 2,4-DB, MCPA, dicamba, Dacthal (DCPA), atrazine, simazine, paraquat, diquat, diuron, bromoxynil, Goal (oxyfluofen), Stinger (clopyralid), Casoron (dichlobenil), Devrinol (napropamide) and many more. They are often formulated and sold under new trade names.

**MCPA
Dicamba
2,4-D**



**Diuron
Simazine
Dichlobenil
etc**

2nd Generation – Synthetic pesticides

New agricultural active constituents are listed in the Commonwealth of Australia Gazette on the **APVMA** website.

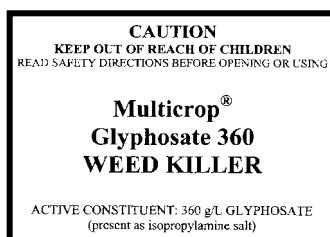
Herbicides

Can we keep developing new herbicides?

Weed News Thurs 21 March 2013.

Herbicides will remain the dominant product type.

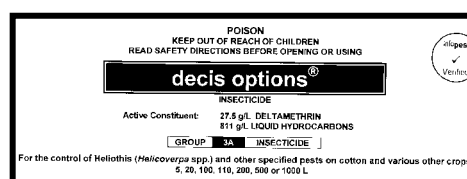
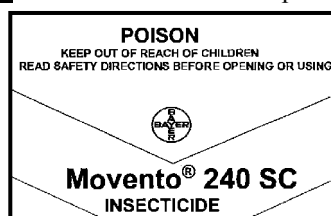
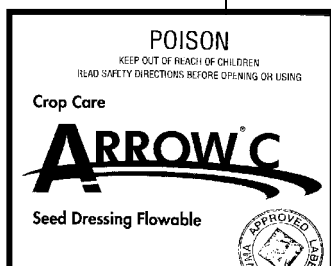
- **Weeds are increasingly developing resistance** to commonly used synthetic herbicides.
- **Roundup Attack® with IQ inside™**, an unique targeting technology and a new patented penetrator that gets into weeds more efficiently, kills faster and more effectively. Also more tank options, greater flexibility and can continue closer to rain than most conventional Roundup® formulations. www.roundupattack.com.au/
- **'Double-knock' applications**. Many herbicide companies are recommending more toxic alternatives with 'double knock' applications to keep synthetic herbicides in use a little longer. Formulations of paraquat and diquat which are fast acting contact, rainfast within minutes, with no residual or plant back problems are used with glyphosate in resistance management strategies. Seek advice before attempting double knockdown applications. Note that paraquat and diquat formulations have **DANGEROUS POISON** signal headings (page 432).
- **More integrated approaches to herbicides**.
 - Glyphosate (post-emergent) is often mixed with a pre-emergent herbicide.
 - Terrain (flumioxazin) provides rapid knockdown and controls grass and broad leaved weeds when mixed with glyphosate and paraquat /diquat herbicides in a range of crops.
 - The post emergent, Monument Liquid (trifloxysulfuron sodium) is compatible with Barricade (prodiamine) which provides pre-emergent control of weeds in turf.
- **There are many 2nd generation herbicides**, eg Surflan (oryzalin), Ronstar (oxadiazon).
- **Nanotechnology**. Under development are crop-protection products that will use nanotechnology to deliver synthetic herbicides to weeds. There are many potential human health and environmental concerns that must be addressed, eg dermal absorption and inhalation of nano-herbicides from spray drift and spray vapor.



Insecticides

Insecticide volume in the large agricultural market is expected to decline due to wider use of *Bt* and transgenic seeds that are more resistant to pests.

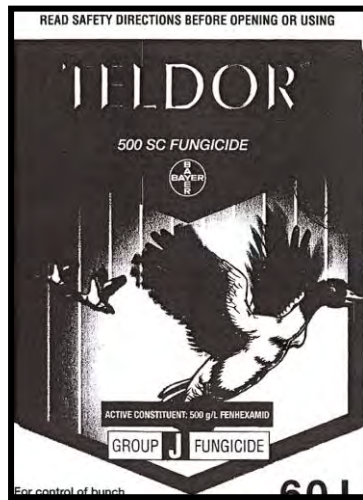
- **The Agrow Annual Awards**. The winner of the **Most Innovative Chemistry** section was Movento® (spirotetramat). Its unique **2-way systemic activity** distributes the active constituent **upwards and downwards in the plant** to find and kill pests wherever they live and feed. Movento offers broad spectrum control of many sucking insects and is an important addition to pest management programs in grapes, citrus, vegetables, tree fruits and nuts, pome fruit and hops in more than 70 countries. www.agrowawards.com/winner
- **Pesticide companies generally are withdrawing older chemical products** from the market and replacing them with innovative products with enhanced biological efficiency. Overseas, seed treatment with **Poncho®/VOTiVO™** (clothianidin and *Bacillus firmus*) protects certain crops from certain insect pests and certain soil nematode pests.
- **Belt (flubendiamide) and Decis (deltamethrin)** are other more modern options for farmers worldwide.



Fungicides

Fungicide use is likely to increase on some crops. Many are available, eg

- **Scorpio® Ornamental Fungicide** (tebuconazole + trifloxystrobin) is a **contact and systemic broad spectrum fungicide**, eg azalea petal blight, powdery mildews on a range of ornamental plants. Rainfastness within 1 hour of application.
- **Moncut or Monstar** (flutolanil) is systemic with both **protective and curative properties** for black scurf *Rhizoctonia* in potatoes.
- **Vision®** (fluquinconazole) - black spot in apples and pears powdery mildew in apples.
- **Teldor®** (fenhexamid) - *Botrytis* (grey mould) in grapes and strawberries.
- **Prosper®** (spiroxamine) for control of powdery mildew in grapes.
- **Headway Maxx** (azoxystrobin + propiconazole) offers broad spectrum control of fungal diseases in turf.
- **Vibrance™** is a **proprietary seed treatment fungicide** based on the new active ingredient sedaxane. It is the first Syngenta molecule developed specifically for the seed treatment market. Vibrance offers unique RootingPower™ that results in stronger, healthier roots for higher crop performance right from the start.



Scorpio
Ornamental Fungicide
Tebuconazole +
Trifloxystrobin

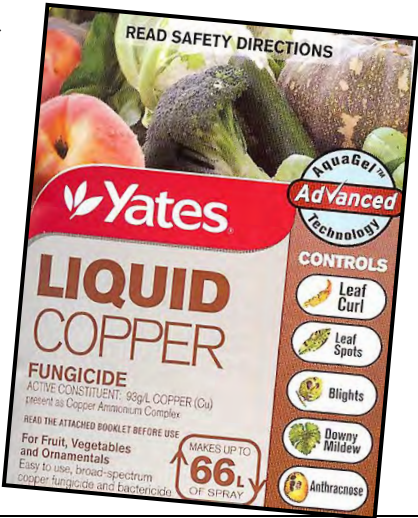
Headway Maxx
Turf fungicide
Azoxystrobin
Propiconazole

Vibrance
Fungicide Seed Treatment
Difenoconazole
Metalaxyl-M
Sedaxane

New formulations, packaging, etc dispensing

Examples include:

- **New stickers / extenders**, eg Pro-Film 904.
- **New formulations of existing conventional fungicides**, eg liquid copper.
- **New formulations / mixtures** of existing active constituents.
- **New packaging**, ready-to-use products. Products that require minimal handling, easier to pour, will remain the dominant product type.
- **Development of seed treatments** (fungicide and insecticide seed treatments).
- **Dual Salt Technology**, a unique combination of potassium and mono-ammonium salts, combined with a surfactant package. There are currently more than 500 formulations of glyphosate-based products registered in Australia. Choice of glyphosate product can now be made on criteria such as:
 - Concentration – 360, 450, 510, 540, 700 or 840.
 - Physical form – dry or liquid.
 - Surfactant included – one or two containers.
 - Surfactant type – “from Friendly”.
 - Packaging – drum or carton. Each of these variations has their own advantages.
- **Tree implants** (fungal plugs) of a biofungicide to treat Parkinsonia weed.
- **Special purpose wetting agents** designed to conserve water and maintain turf health under Australian conditions, eg Aquaforce, Restore, Broadwet, and Terracare (SST).



3rd Generation – Biological chemical products

Biopesticides

Biorationals
Semiachemicals
Soft pesticides
Mycoherbicides
Semiachemicals
Bioactives (fertilizers
and microbes)

“A **biological chemical product** is an agricultural chemical product where the active constituent comprises or is derived from a living organisms (plant, animal, microorganisms, etc), with or without modification. This includes many products that are commonly referred to as ‘botanicals’, ‘organics’ or ‘herbals’ (where the active constituent comprises an extract derived from an organism rather than the whole organism, it may be accompanied by unidentified components).”

There are currently 4 major groups of biological products:

Group 1. Biological chemicals, eg pheromones, hormones, growth regulators, enzymes and vitamins.

Group 2. Plant and other extracts, eg plant extracts, oils.

Group 3. Microbial agents, eg bacteria, fungi, viruses, protozoa.

Group 4. Other living organisms, eg microscopic insects, plants and animals plus some organisms that have been genetically modified.

Reduced risk

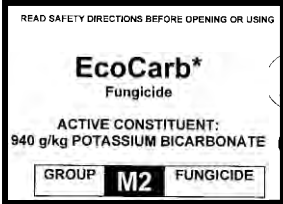
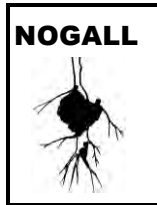
In the last 15 years there has been an increase in the registration of pesticides that are described as “reduced risk”.

- **Many biological chemical products in Australia are regulated by APVMA** to ensure that their use will not pose unreasonable risks of harm to human health and the environment. More evaluation and improved assessment of biopesticides for efficacy is warranted in Australia.
- **They are generally less toxic to humans**, are short-lived in the environment and mostly less harmful to natural enemies, than conventional pesticides. Minimal impact on plants.
- **They are mostly target specific** and have little or no impact on non-target organisms and predators which means that growers can use them in **IPM** systems much more successfully.
- **They can be costly or ineffective if incorrectly applied**, they are biodegradable. Formulations have been developed to protect biocontrol agents from degradation by exposure to sunlight
- **Many are short residual** and so have to be applied more often. They may degrade rapidly.
- **Some biological chemical products provide control** only when disease or pest pressure is low.
- **Biological chemical products are expected to register the fastest growth** of any product type.
- Some are not commercially available and there is **often a lack of efficacy data**.

Fungicides, bactericides

Targeted fungicide applications are an important component of ornamental and vegetable disease management programs.

Fungicides are increasing being used on commercial crops to control rusts and other diseases, eg cereals.



- **Potassium phosphanate**. Is used to control some *Phytophthora* species– check label for species that can be treated **and** method of application.
- **Milk** and whey provide some control of grapevine powdery mildew within 24 hours of treatment by causing the hyphae of the powdery mildew to collapse.
- **Potassium bicarbonate** is effective against powdery mildew and black spot of roses; it needs the addition of surfactants to give fungicidal properties at low application rates that prevent burning.
 - **Ecocarb (potassium bicarbonate)** for powdery mildew on grapevines, vegetables, strawberries, roses and rust in geraniums and roses.
 - **Ecocarb** is classified as a contact fungicide and has no systemic activity. The product works by way of changing the pH on the leaf creating a more alkaline environment. This mode of action disrupts cellular processes of germinating fungi, inhibiting their growth and preventing their spread. EcoCarb also damages cell walls of fungi, resulting in dehydration and death of fungal organisms, providing effective disease control.
 - **Ecocarb** is compatible with **IPM** programs. There are no withholding periods, or re-entry restrictions. However, it is important to observe worker protective clothing guidelines when applying any sprays.
 - **Eco-rose** (potassium bicarbonate) for powdery mildew and black spot of rose and rust in geraniums.
 - **Eco-protector** (potassium salts of fatty acids) fungicidal potassium soap for the control of *Botrytis* in grape vines.
- **Microbials (bacteria, fungi, viruses) effective against soilborne diseases.**
 - *Agrobacterium* (Nogall).
 - *Trichoderma harzianum* T-22, Rootshield, Biotrek, Companion, Rhapsody, etc.

- **Vegetable oils**, sugar, Qwel (new one made from *Macleaya* sp.).
- **Plant Activators** which turn on a plant’s own defense system to fight or prevent disease. **SARS** compounds activate a plant’s own defenses against disease, eg BION.
- **Polymers** produced from plants or nanoparticles could induce resistance that is passed to the next generation on seed. Polymers extracted from cereal bran reduced fungal infections in barley. Trials looking at the biopolymers effect on *Ascochyta* and powdery mildew in field peas are progressing (Davidson 2011). Polymers do not prevent spore germination, but induce a resistance in barley which could be transferred to the next set of new leaves.
- **Antitranspirants** made from non-toxic polymers and are as effective against some powdery mildews as systemic triazole fungicides. Their action is non-specific so unlikely to result in a buildup of resistance; they are biodegradable and inexpensive. Antitranspirants are used for relief of wilt and water stress, improved water use and protection against fungal diseases without phytotoxicity problems (manufacturers are not pursuing this market **because of liability** (Quarke 2000).
- **Sorbic acid and its salts**, such as sodium sorbate, potassium sorbate, and calcium sorbate, are often used as preservatives in food and drinks to prevent the growth of mold, yeast, and fungi. The use of nonselective fungicides (sodium carbonate, chlorine, sorbic acid) and heat treatments can significantly lower disease pressure on harvested commodities.
- See also Biofungicides page 112.

Davidson, J. 2011. *Novel Fungicides on Trial*. Ground Cover Jul-Aug.

Quarke, W. 2000. *Anti-transpirants as least Toxic Fungicides*. IPM Practitioner Vol XX11, 1. Jan.

Herbicides

- **Plant growth regulators**, eg MatchPlay Intercept (ethephon) is a powerful means of preventing the population explosion that results from the annual flush of wintergrass (*Poa annua*) seed. When used in a program with MatchPlay ShortStop and Primo, a robust wintergrass control strategy starts to take shape. Products such as ShortStop and Primo suppress winter grass in favor of desirable species. MatchPlay Intercept prevents the formation of seedheads and so reduces the seedbank.
- **Organic Weed Killer Arcadia** (powdered seaweed) is 100% water soluble and so can be applied through drip irrigation systems – how does it work?
- **Organic Herbicide: General Spot Weeder** (pine oil mixed with rain water) is an effective knock down residual herbicide, non selective, kills most weeds and grasses. Requires direct contact to destroy foliage, does not spread systemically through plant.
- **Sarritor Natural Weed Control** (naturally occurring fungus) reduces broadleaved weeds in lawns, eg dandelion and other rosette-type weeds. Efficacy is enhanced by only applying in appropriate weather conditions and extensive watering after application.
- **GreenMatch EX** (oil of lemongrass) is a non-selective, post-emergent broad spectrum weed killer. **GreenMatch** (d-limonene) and **Matran EC** (clove leaf oil). The need for frequent application and cost may deter use.
- **Many “home made” weedkillers**, eg vinegar (acetic acid).
- See also Bioherbicides (pages 91, 92).

**Insecticides,
molluscicides**
Bioinsecticides pages

3rd generation insecticides are suitable for application to hot spots of insect or mite activity in biocontrol programs.

Some registered botanical insecticides are toxic to fish, beneficial insects and mites and mammals

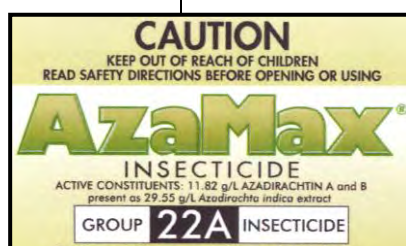
Spider-venom peptides are being investigated as a potential source of bioinsecticides. Years before it will be available

With an estimated 100,000 species, spiders are one of the most successful insect predators.

Cloyd, R. A. 2004. *Allelochemicals – Natural Instincts*. American Nurseryman. July 15 2004.

Petroski, R. J., Teliez, M. R. and Beble, R. 2005. *Semiochemicals in Pest and Weed Control*. American Chemical Society.

- **Horticultural oils** today are lighter and more highly refined and may be made from petroleum products or plants (vegetable oils). Often called ultra-fine or summer oils as they can be applied to actively growing plants and plants in full leaf throughout the growing season. Oils block breathing holes of soft bodied insects, eg Eco Oil Organic Miticide Insecticide, Synertril Horti Oil.
- **Insecticidal soap** generally leaves minimal residues, is less toxic to humans and beneficials and is short-lived in the environment. Soaps have minimal effects on hard bodied insects, eg beetles. Not harmful to bees and ladybeetles, no harmful residues, insects cannot become resistant.
- **Natural pyrethrums** are contact poisons which quickly penetrate the nervous system of the insect (pest and beneficial). They may cause sneezing, asthma breathing, etc most severe effects in infants, extremely toxic to fish.
- **Lure and kill formulations.**
 - **Male annihilation technique (MAT)** involves the trapping of **male fruit flies** using a high density of trapping stations consisting of a **lure** combined with an insecticide, to reduce the male population to such a low level that mating does not occur.
 - **Spinosad** (Eco-Naturalure, Entrust) contains a yeast protein bait that lures **both male and female fruit fly** to feed on it and ingest the spinosad which kills them before they can mate and lay eggs. From a soil actinomycete bacterium *Saccharopolyspora spinosa*). Clean up rotting fruit because it is an excellent source of protein.
 - **Magnet™ Med** is not presently registered in Australia. It consists of a cardboard sandwich containing a **female attractant**. The outside of the device is coated with an insecticide, deltamethrin. The device is hung in the tree canopy, and **Medflies** that are attracted receive a lethal dose when they sit on the trap. In WA, trials indicate that **Magnet™ Med** can reduce Medfly populations, but will not give 100 per cent protection.
 - **Magnet Insect Attractant Technology** is a blend of volatile attractants formulated with insecticides effective against **Helicoverpa moths**. Magnet attracts moths to treated strips in the crop. Can be used for monitoring or a knockdown product.
- **Microbials (bacteria, viruses), eg Dipel (Bacillus thuringiensis)**. See also page 99.
 - **Spinetoram** (Success) is derived from beneficial soil bacteria and kills some caterpillars, thrips, pear and cherry slug and other insects.
- **Natural or botanical insecticides** in most cases are less toxic to humans than synthetically-derived insecticides (Cloyd 2004), some are not registered for use on food crops; others are toxic to fish, beneficial insects and mites, as well as mammals. They have rapid action, low mammalian toxicity, selective primarily due to their short residual activity and minimal impact on plants. They degrade rapidly.
 - **Neem (Azadirachtin)**. AzaMax contains botanical oils and a concentrated botanical extracts from the neem tree (*Azadirachta indica*). Affected insects stop feeding, stop moulting (stop growing) and lose interest in mating and egg laying.
 - **Others**, eg Derris Dust (rotenone), citrus oil extracts, ryania, etc.
- **Pheromones and semiochemicals** are chemicals emitted by plants, animals and other organisms, and synthetic analogues of such substances, which evoke behavioural or physiological response in individuals or the same or other species (pages 101, 104).
- **Eradicoat** (composed of a polymer, vegetable oil extracts and water) can be used to treat hot spots of spider mite, thrips and aphids. Fast acting and non-persistent, it dries quickly leaving no residual activity. Eradicoat blocks the breathing holes of insects and mites quickly killing them.
- **Enzyme inhibitors** such as **piperonyl inhibitors (PBOs)** are natural substances derived from sesame oil. It incorporates a time delay mechanisms. Using novel micro-encapsulated formulations they are able to deliver an enzyme inhibitor and the pesticide in a single dose. Firstly the insect's resistance mechanisms are deactivated and then 4-5 hours later the insect is exposed to the pesticide.
- **Essential oils**. The use of Nutri-Gro Plus (a mixture of eucalyptus and melaleuca oil) for African black beetle and armyworm control has **reduced reliance** on synthetic pesticides.
- **Insect growth regulators** prevent insects from molting to the next development stage. Admiral (pyriproxyfen) controls silverleaf whitefly on certain crops.
- See also Bioinsecticides page 99.



APPENDIX 8

Training

Education is the ultimate in renewable energy (Dr S. Parker, 2013)

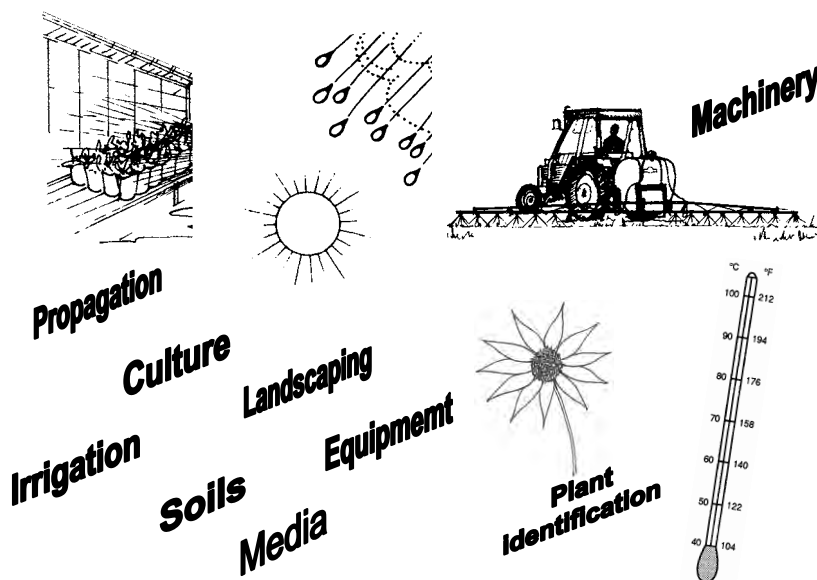
Pest control is changing at an ever increasing rate, in addition the changing climate, new emerging pests, diseases and weed problems, new crops are being developed, some being grown in new regions, new varieties, etc but no area more so than in control methods. There is a need to continually update skills to stay abreast of developments not only in their own fields of technical expertise but also in industry strategies and priorities.

Formal training Quality assurance

Effective training should aim to improve practice which is important for worker health and safety and environmental health. Training should lead to practical, on the ground improvements.

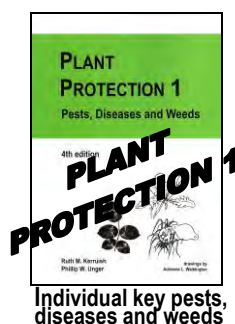
For a thorough understanding of Plant Protection it is preferable to examine topics, as far as practical, in the following order:

BACKGROUND - Growing the crop, eg prior knowledge of horticulture and agriculture, including plant identification, propagation, culture, soils, machinery and other equipment, irrigation, environment, biodiversity, sustainability.



PESTS, DISEASES AND WEEDS COURSES are offered as part of formal agriculture and horticulture certificate, diploma and degree courses. Unless a problem is diagnosed accurately, control measures are likely to be ineffective.

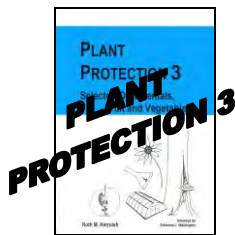
- **Pests.** Lots of websites give you insect orders, eg CSIRO entomology, State museums. *Entomology Curriculum Australia (ECA)* is a series of undergraduate entomology subjects accessible to any person interested in the study of entomology. The distance-based online subjects provide relevant, real world entomology education. The curriculum is offered by several universities. www.entomology.edu.au/
- **Diseases.** Workshops are available for special groups or types of diseases, eg soil fungal diseases such as *Phytophthora*, foliar diseases of cereals crops. There is a nationally accredited training workshop for grains advisers on the management of cereal foliar diseases. The courses usually include their practical management and provide an opportunity to update their skills base.
- **Weeds.** Courses of general weed identification and management are common, eg Integrated Weed Management (CRC for Weeds). Workshops may be offered on individual weeds, crop weeds and Weeds of National Significance (WONS).





CONTROL METHODS and THEIR MANAGEMENT include:

- **Control Methods**
 - Cultural
 - Sanitation
 - Biological control
 - Resistant and tolerant varieties
 - Biosecurity, Plant Health Australia, Quarantine
 - Disease-tested planting material.
 - Physical methods
 - **Pesticides.** There are *nationally accredited courses for farm chemical users* (page 273-280).
- **Management and Quality Assurance (QA)**
 - Managing the crop
 - Integrated Pest Management (*IPM*)
 - Environmental Management
 - Organic standards
 - Holistic Management (*WSM*)



CROPS

- A knowledge of the diseases, pests and weeds that attack your crop ensures that Quality Assurance systems (QA), integrated pest management (IPM), organic standards and best management practice (BMP) programs can be competently prepared.
- Many management programs are already available, eg
 - Management / QA systems for specific industries, crops, eg roses, citrus, grapevines.
 - Management / QA systems for specific pest, diseases or weeds, eg
 - Nursery Industry Accreditation Scheme Australia (NIASA).
 - Industry Biosecurity Plans and Manuals (pages 186, 187).



DIAGNOSTICS

Acquiring a degree of expertise in identifying pest, diseases, weeds and beneficials in your crop, property or region is essential. Only by this means will you be aware of any new exotic arrivals. Be familiar with available diagnostic services, new test kits, new information on pest life cycles, etc (see page 1).

In-house training

Muir, T. 2006. *Getting the Mix Right: Washdown bays and chemical mixing areas.* Aust. Turfgrass Management April-May.

Have **Standard Operating Procedures (SOPs) in the workplace** and provide **training on a regular basis in the workplace** (Terry Muir, 2006). Safe work practices may need to be re-evaluated in order to **increase compliance**. **SOPs** need to be **practiced regularly**.

Work experience

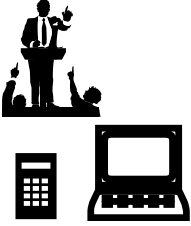
Work experience under a trained experienced operator is much underrated and often overlooked.


Management responsibilities

Management must ensure that **Standard Operating Procedures (SOPs)** are carried out. It is not enough to train workers, manager and supervisors also be appropriately trained. Poor management is not uncommon in such traditional industries as farming and horticulture where life style and conservation often motivate

Mandatory training and updating

- Training may be mandatory**, eg
- **Accreditation is necessary for commercial operators** in some States and Territories.
 - Re-accreditation every few years is required. This is necessary to maintain skills and knowledge, etc.

<p>Providers</p>	<p>Providers should have a higher level of training than of those they are teaching. Providers include:</p> <ul style="list-style-type: none"> • TAFE, Universities, Government Departments, CSIRO. • Registered Training Organizations (RTOs), eg accredited agronomists familiar with regional crop choices and farm practices, consultants. • Industry associations. • Fertilizer and chemical companies. • Biocontrol companies, eg Beneficial Bugs, Biological Services, IPM technologies. • Precision agriculture and Farmscape industry-approved training providers. • Customized training for groups of 10 or more. • Biosecurity. • Series of textbooks, eg Plant Protection 1, 2, 3 and 4 available in print form and online. www.apps.net.au/
<p>Formats</p> 	<p>Formats include:</p> <ul style="list-style-type: none"> • On campus learning allows you to learn in a class room environment. The majority of students still want some form of face-to-face update as they feel it was the best method of learning. • Online courses help broaden access to agricultural and horticulture training. Great for flexibility, are interactive, self-paced. To date, no significant difference in quality between computer mediated, online education and that delivered by more traditional means has been identified. However, practical work is recommended for some topics. Massive Open Online Courses (MOOCs) are online courses aimed at unlimited participation and open access via the web. • Distance learning gives you an opportunity to learn when it suits you. Course materials may be mailed out in print format and/or sent to you on DVD or email. • Workplace training. Practical training and assessment delivered in the workplace by industry specialists. • Block delivery is a form of scheduled learning structure to support learners, employers and industry to reinforce individual development. • Flexible delivery is designed to support all modes of learning for individuals and employers, evening classes. • Scenario-based learning, eg Lucid Identification tools (CBIT - Centre for Biological Information Technology). • PestFax Map is an interactive risk management tool to address pest and disease threats in the WA grain belt. • Workshops, short courses, half-day courses. • Webinars.
<p>Language, maths and IT</p> <p>Don't assume that if a person is Australian borne, that they have good reading and math skills</p> <p>Australian National Training Authority (ANTA) www.anta.gov.au</p>	<p>People with poor language, literacy and numeracy skills require support. In horticulture and agriculture growers needs to be able to follow instruction for using and maintaining equipment safely. They need to be able read labels of fertilizers, seed packets, pesticide labels, biological control agents, calculate rates, etc.</p> <ul style="list-style-type: none"> • The Relevant Label Particulars (RPLs) which relate to APVMA's assessment of whether labels have adequate instructions for safe and effective handling and use of a product are continuing to improve (page 283). <p>Language</p> <ul style="list-style-type: none"> • Growers who have poor English language skills or have English as a second language may lack the language skills to use farm chemicals safely and correctly. • Some have good oral English skills but poor reading and writing skills. • The provision of plain English and translated information is a critical issue that must be addressed. It is of limited benefit to train people if they lack access to understandable information on an ongoing basis. Training itself generally requires a translator with the production techniques and the use of language by a particular ethnic group. • Growers from Culturally and Linguistically Diverse backgrounds (CLDB) form an integral component of the Australian horticultural industry. There is a wide diversity of language groups. Although information is available in some languages there is no doubt a need to extend the range. <p>Maths</p> <ul style="list-style-type: none"> • Most workers in all aspects of agriculture and horticulture need basic maths skills in order to calibrate equipment, calculate dose rates, and calculate quantities of fertilizers and pesticides, etc. • Fortunately with the aid of IT, calculations of rates are getting simpler. <p>Information technology</p> <ul style="list-style-type: none"> • IT is available in most workplaces for calculating rates, record keeping etc, but not everyone has the equipment and necessary knowledge. • Most legislation, chemical registration status and other relevant information is readily accessible online, so accessing this information online during accredited training courses is essential. • More and more courses will be available online, or parts will be.

<p>Assessment of competency How do you measure effectiveness of training?</p>	<p><u>Assessment procedures are often criticized</u> as being inadequate and that instead of outcomes we need Acts, Regulations and Standards to be more prescriptive.</p> <ul style="list-style-type: none"> • How can presenters administer assessments for participants who have language, literacy or numeracy difficulties? Different States may have different procedures for implementing this. • How do you measure effectiveness of training? • Increasing reliance on tests for students, teachers and schools can lead to corruption. Both sides of politics ignore the evidence and continue to put blind faith in the test-based accountability policies that have failed to deliver in the US (Cobbold T. 2013. <i>Obsession Sorely Tests Integrity of Education Systems</i> (CT April 10/2/13). • System of learning and accessing knowledge rather than defined training and examination and checking.
<p>Quality assurance (QA), Trade Constant improvement</p> 	<p><u>In order for training to constantly improve, there is a need for</u> the systematic measurement, comparison with standard, monitoring of processes and an associated feedback loop that confers error prevention. Training must be audited to ensure that appropriate standards are maintained. All QA training programs as a minimum require:</p> <ul style="list-style-type: none"> • Records to be kept. • Monitoring. • Auditing. • Various tests. <p><u>Export and domestic trade</u> is underpinned by Australia's status as a producer of clean food.</p>
<p>Targeted courses</p>	<p><u>Targeted courses which address</u> specific needs in terms of crops grown and production systems may be required, particularly if new technology is being introduced.</p> <ul style="list-style-type: none"> • Precision agriculture, horticulture and forestry. • Drift reduction technologies, eg nozzles, buffer zones, wind speeds, temperature, volatility of chemical. • Standard operators procedures for those assisting spray operations, eg women, children and others (wearing no protection) who "assist" spray operators (wearing personal protective equipment). • Fungicide applications in cereals. • Online record keeping. • Reducing reliance on pesticides. • See also pesticide training pages 274.

GLOSSARY & ACRONYMS

- 3D printing** A process of making three dimensional solid objects from a digital model using **additive processes**, by laying down successive layers of material. Traditional techniques (**subtractive processes**) mostly rely on the removal of material by methods such as cutting, etc
- AAPGA** Australian Apple and Pear Growers Association
- ABARES** Australian Bureau of Agricultural and Resource Economics and Sciences
- ABCA** Agricultural Biotechnology Council of Australia
- ABIN** Australian Biosecurity Intelligence Network
- Abiotic** Non-living
- ABRS** Australian Biological Resources Study
- Absorption** The uptake of a substance into plants, animals (including humans) and microorganisms
- AC** Active constituent
- ACA** Australian Consumers Association
- ACAHS** Australian Centre for Agricultural Health and Safety
- ACCC** Australian Competition and Consumer Commission
- Acceptable Daily Intake (ADI)** Is a measure of the amount of a specific substance in food or drinking water that can be ingested on a daily basis over a lifetime without an appreciable health risk
- Accreditation** Formally authorized
- Accumulation** Organisms accumulate certain chemicals in their tissues
- ACIAR** Australian Centre for International Agricultural Research
- Acid** Having a pH of less than 7
- ACNCS** Australian Citrus Nursery Certification Scheme
- ACNFP** Australian Centre for Necrotrophic Fungal Pathogens
- ACO** Approved Certifying Organization
- ACO** Australian Certified Organic
- ACPGF** Australian Centre for Plant Functional Genomics
- ACRA** Australian Conference of Robotics and Automation
- ACRA** Australian Cultivar Registration Authority
- ACT** Australian Capital Territory
- Activated charcoal** Finely ground charcoal which adsorbs liquids and gases
- Active constituent** This is the name of the component of a pesticide that kills the weeds, insects or other pests
- Activity** The degree of toxicity a pesticide has against the disease, pest or weed; compare with toxicity
- ADG Code** Australian Code for the Transport of Dangerous Goods by Road and Rail
- ADI** Acceptable Daily Intake
- Adsorption** Chemicals bound to a surface by physical or chemical attraction. Clay and organic soils tend to adsorb some pesticides which are only slowly available
- Adventitious** A plant part developing in an abnormal position, as a root that grows from a stem or leaf
- Adventive Biological Control** Regulation of a pest population by a natural enemy that has arrived from elsewhere without deliberate introduction
- Aerobic** A microorganism that lives, or a process that occurs, in the presence of molecular oxygen
- AFAS** Australian Fumigation Accreditation Scheme
- AFPA** Australian Forest Products Association
- AFRI** Australian Fungicide Resistance Initiative
- AFSA** Australian Fertilizer Services Association
- AGCAS** Australian Garden Centre Accreditation Scheme
- AGDISP** Platforms for modelling spray deposition for a range of application types
- AgDRIFT** An atmospheric model that predicts spray deposition patterns
- AgMorag** Agricultural Manual of Requirements and Guidelines which provides information on data requirements and guidelines for applications to register or approve agricultural chemical products, labels, active constituents and issue permits
- Agronomy** The science and technology of producing and using plants for food, fuel, fiber and land reclamation
- Agsafe** Implements an agvet chemical industry co-regulatory compliance program
- Agvet chemicals** Agricultural and veterinary chemicals
- AHP** Analytical Hierarchy Process
- AHQCS** Australian Horticultural Quality Certification Scheme
- AHRI** Australian Herbicide Resistance Initiative
- AI** Allowed Input
- AIMS** AQIS Import Management System
- AIRI** Australian Insecticide Resistance Initiative
- ALA** Atlas of Living Australia
- ALG** African lovegrass
- ALIRU** Australian Legume Inoculant Research Unit
- Alkaline** Having a pH of more than 7
- Allele** Any of several alternative forms of a gene
- Allelopathy** The inhibition of growth in one species of plants by chemicals produced by another species
- Alternate host** One of two kinds of plants on which a parasitic fungus, ie rust, must develop to complete its life cycle
- Amendment** The act of changing for the better; an improvement
- Anaerobic** A microorganism that lives, or a process that occurs, in the absence of molecular oxygen
- Analysis** The detailed examination of the elements or structure of something
- Analytical Hierarchy Process** A process that helps choose one of the options of a list of choices. Each choice has a few parameters attached to it and we can set the weights of each parameter and have **AHP** pick the best choice from the list of choices
- ANBG** Australian National Botanic Gardens
- ANFIC** Australian Nurserymen's Fruit Improvement Co
- Annual** A plant that completes its life cycle in one year
- ANTA** Australian National Training Authority
- Antagonism** Reduction of activity when 2 or more different agvet chemicals are mixed together; opposite of synergism
- Antagonist** A natural enemy of a pest or disease
- Antagonistic** Biological structure or chemical agent that interferes with the physiological action of another
- Antibiosis** An association between two or more organisms that is detrimental to at least one of them
- Antibiotic** A chemical compound, eg penicillin, produced by one microorganism which inhibits or kills other microorganisms, eg bacteria
- Antibody** A protein, produced in a warm blooded animal in reaction to an injected foreign antigen and capable of reacting specifically with that antigen
- Anticholinesterase** A substance that inhibits the activity of cholinesterase
- Antidote** An agent used to prevent or counteract action of a poison in the body
- Antigen** A substance, usually a protein, that, when injected into a warm blooded animal, causes the formation of an antibody, which is antagonistic to the foreign substance
- Antiserum** The blood serum of a warm blooded animal that contains antibodies; provides immunity to a specific disease
- Anti-transpirant** A substance which is applied to a plant specifically to slow transpiration
- ANZECC** Australian and New Zealand Environment and Conservation Council
- ANZFA** Australian and New Zealand Food Authority
- AON** Australian Office of NanoTechnology
- AP** Approved Product
- APFIP** Australian Pome Fruit Improvement Program
- APLC** Australian Plague Locust Commission
- APPD** Australian Plant Pest Database
- Applicator** A person, or piece of equipment, which applies pesticides
- APPS** Australasian Plant Pathology Society
- APVMA** Australian Pesticides & Veterinary Medicines Authority
- AQAF** Australian Quality Assured Flowers
- AQF** Australian Qualification Framework
- AQIS** Australian Quarantine and Inspection Service
- Arabidopsis** A small flowering plant in the family Brassicaceae (cabbages etc) that is widely used as a model organism in plant biology; the first plant to have its entire genome sequenced
- ARMCANZ** Agriculture and Resource Management Council of Australia and New Zealand
- AS** Australian Standard
- Asexual reproduction** Non-sexual reproduction, vegetative reproduction by rhizomes, bulbs and cuttings
- ASOBP** Australian Standard for Organic and Bio-dynamic Produce
- Assurance** A positive declaration intended to give confidence; confidence or certainty in one's own abilities
- AT** Action threshold
- ATDS** Australian Total Diet Study
- ATSC** Australian Tree Seed Centre
- Attribute (noun)** A quality or feature regarded as a characteristic or inherent part of someone or something
- Audit** An evidence gathering process used to evaluate how well audit criteria are being met. Audits must be objective, impartial and independent and the audit process must be both systematic and documented. There are several different types of audits; check which one you need
- AUF** Australian United Fresh (AUF) Fruit and Vegetable Association
- Augment** To make something already developed or well under way, greater, as in size, extent, or quantity
- AusBiotech** Australia's Biotech Organization
- Auschem** A nationally accredited chemical user's training course for commercial operators
- AUS-QUAL** An approved certifying organization

<p>Australian Qualification Framework A national system of qualifications encompassing all post-compulsory education</p> <p>AusVeg Represents the interests of growers to government and assists growers with research and development that meets the needs of the vegetable industry</p> <p>AusVit Australian Viticulture Vineyard Management System</p> <p>AusVit™ Chemical Database A database providing detailed information on registered agrochemicals to assist grape growers and vineyard managers to achieve their target levels of vineyard efficiency</p> <p>Auxin A plant hormone effective in regulating cell elongation</p> <p>Avicare National Association for Crop Protection and Animal Health</p> <p>Avirulent Inability to infect a certain plant variety, not strongly pathogenic</p> <p>AWD Australian Waste Database</p> <p>AWM Area Wide Management</p>	<p>Biofumigation Suppression of soilborne pests and pathogens by plants that contain inhibitory chemicals. The plants can be harvested as rotation crops or ploughed back into soil as green manure</p> <p>Biofungicide A form of fungicide based on microorganisms or natural products</p> <p>Bioherbicide A form of herbicide based on microorganisms or natural products</p> <p>Bioinsecticide A form of insecticide based on microorganisms or natural products</p> <p>Biointensive IPM Incorporates ecological and economic factors into agricultural system design and decision making. It addresses public concerns about environmental quality and food safety; can include reduced chemical input costs, reduced on- and off-farm environmental impacts, and more effective and sustainable pest management</p> <p>Biolistic A gene gun or a biolistic particle delivery system, originally designed for plant transformation, is a device for injecting cells with genetic information</p> <p>Biological chemical product An agricultural chemical product where the active constituent comprises or is derived from a living organism (plant, animal, microorganism, etc), with or without modification. This includes many products that are commonly referred to as 'botanicals', 'organics' or 'herbals' (where the active constituent comprises an extract derived from an organism rather than a whole organism, it may be accompanied by unidentified components)</p> <p>Biological control The deliberate use of a pest, disease or weed's natural enemies to control that particular pest, disease or weed (classical biological control)</p> <p>Biological farming Looking at the whole agronomic, environmental, nutritional and biological components of what constitutes a healthy soil</p> <p>Biomagnification The process whereby some organisms accumulate chemical residues in higher concentrations than in the organisms they consume</p> <p>Biomass The biological material from living or recently living organisms such as waste material, wood, etc</p> <p>Biomineralization The formation or accumulation of minerals by organisms especially into biological tissues</p> <p>Bionanotechnology, nanobiotechnology and nanobiology Terms that refer to the intersection of nanotechnology and biology</p> <p>BioNew Offers solution-oriented services for biological agriculture, including a standard of nutrition, natural plant disease resistance, yield, and pesticide-free crops which are beyond the scope of agro-chemical and organic methods</p> <p>Bionics, Biomimicry The application of biological systems found in nature to the study and design of engineering systems and modern technology</p> <p>Biopesticides (biological pesticides) Pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals</p> <p>Biopriming seed A seed treatment system that integrates the biological and physiological aspects of disease control, involves coating the seed with a bacterial biocontrol agent and incubating the seed under warm, moist conditions. It is an ecological approach using selected fungal antagonists against the soil and seed-borne pathogens</p> <p>Biorationals Pesticides which have minimal effect on beneficial insects</p> <p>BioSecure HACCP The on-farm biosecurity program for production nurseries in Australia. The program validates many of the best management practice strategies employed under the Nursery Industry Accreditation Scheme Australia (NIASA)</p>	<p>Biosecurity Protection of the economy, human health and the environment from the negative impacts associated with entry, establishment or spread of exotic pests, diseases and weeds</p> <p>BioSirt A Biosecurity Surveillance, Incident, Response and Tracing software application</p> <p>Biostimulant Diverse formulations of compounds, substances and other products that are applied to plants or soils to regulate and enhance the crop's physiological processes to improve crop vigor, yields, quality and post-harvest shelf life / conservation</p> <p>Biosurfactant A substance, such as a detergent, that can reduce the surface tension of a liquid and thus allow it to foam or penetrate solids; a wetting agent</p> <p>Biotechnology The use of genetically modified organisms and / or modern techniques and processes, with biological systems, for industrial production, eg plant breeding</p> <p>Biotype A group of organisms having an identical genetic constitution</p> <p>BMP Best Management Practice</p> <p>BOLT Biosecurity Online Training</p> <p>Brand A name, term, design, symbol, or any other feature that identifies one seller's goods or services as distinct from those of other sellers</p> <p>Brassicac Plants belonging to the cabbage family, eg cabbages, broccoli</p> <p>BRC British Retail Consortium</p> <p>Breeding Controlled reproduction to improve certain characteristics in plants</p> <p>Broadleaf plants Plants with broad, rounded or flattened leaves with netted veins</p> <p>Broad spectrum A product that is effective against a wide range of pests, diseases or weeds, non-selective</p> <p>Brush control Control of woody plants</p> <p>BSES Bureau of Sugar Experimental Station</p> <p>Bt <i>Bacillus thuringiensis</i></p> <p>Buffers Adjuvants used to retard chemical degradation of some pesticides by lowering the pH of alkaline water</p> <p>Buffer zone A zonal area that lies between two or more other areas</p> <p>Bunding A raised mound around the edge of an area to contain chemical spills and fire-fighting water within that area</p>
<p>Bacteria Microscopic living organisms, usually one-celled, that can cause infection of plants or animals, or be beneficial, eg biocontrol agents, wine making and decomposing plant residues</p> <p>Bacteriophage A virus that infects and replicates within bacteria</p> <p>Bacteriostatic An agent which inhibits rather than destroys bacteria</p> <p>Band application Application of a farm chemical or other material in or beside a crop row rather than over the entire field</p> <p>Banker plants Plants which can sustain a reproducing population of natural enemies within a crop to provide long-term pest suppression</p> <p>Bark The tissues of a woody stem or root from the cambium outwards</p> <p>Barrier A physical structure which blocks or impedes something</p> <p>BDRI Bio-dynamic Research Institute</p> <p>Benchmarking A methodology that is used to search for best practices</p> <p>Beneficial insect An insect that is useful or helpful to humans, eg pollinators, parasites and predators of plant pests</p> <p>Best Management Practice Methods that have consistently shown results superior to those achieved with other means</p> <p>Biennial A plant that completes its life cycle in 2 years. It grows vegetatively for 1 year then flowers, seeds and dies the 2nd year</p> <p>Bioaccumulation The accumulation of substances, such as pesticides, or other organic chemicals in an organism</p> <p>Bioactive (of a substance) Having a biological effect</p> <p>Bioassay The use of a test organism to measure the relative infectivity of a pathogen or toxicity of a substance</p> <p>Biochar A name for charcoal when it is used for particular purposes, especially as a soil amendment</p> <p>Bioicide A substance capable of poisoning and killing living organisms</p> <p>Bioclay Clay that is highly successful in destroying a range of bacterial agents</p> <p>Biodegradable Any substance or object that is capable of being decomposed by bacteria or other living organisms.</p> <p>Biodiversity Wide range of flora and fauna</p> <p>Bio-dynamic agriculture A method of organic farming originally developed by Rudolf Steiner that employs what proponents describe as "a holistic understanding of agricultural processes"</p> <p>Biofertilizer A substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant</p>	<p>Bt <i>Bacillus thuringiensis</i></p> <p>Ca Calcium</p> <p>CA Conservation agriculture</p> <p>CA Controlled atmosphere</p> <p>CAB Conformity Assessment Bodies</p> <p>CaCV Capsicum Chlorosis Virus</p> <p>Calendar spraying Spraying according to calendar date rather than on needs-based monitoring of the environment</p> <p>Callus A mass of undifferentiated thin-walled cells, developed as a result of wounding or culture on nutrient media</p> <p>Cambium (vascular) A thin layer of cells between the xylem and phloem that divides to form these tissues</p> <p>Canopy Chlorophyll Content Index (CCI) Can predict nitrogen status of crops</p> <p>Capillary action / wicking The physical process by which fluid material is drawn upwards from a fluid surface through narrow tube-like structures, either natural (in stems) or manufactured, eg glass</p> <p>Carbamates A group of agvet chemicals containing carbon, hydrogen, nitrogen formulated as insecticides, fungicides or herbicides</p> <p>Carbon The name of carbon comes from the Latin <i>carbo</i>, meaning charcoal. In many foreign languages the words for carbon, coal and charcoal are synonyms</p> <p>Carcinogen A substance or agent which produces cancerous tumors.</p> <p>CAUTION (signal heading on a label) A chemical that is low to moderately hazardous to the person using the chemical. It may irritate the skin or eyes</p>	

<p>CBD Convention on Biological Diversity</p> <p>CBI Crop Biofactories Initiative</p> <p>CBIT Centre for Biological Information Technology</p> <p>Certification A formal procedure by which an accredited or authorized person or agency assesses and verifies (and attests in writing by issuing a certificate) the attributes, characteristics, quality, qualification, or status of individuals or organizations, goods or services, procedures or processes, or events or situations, in accordance with established requirements or standards</p> <p>Certified organic food Food produced to a set of standards and principles concerning issues such as chemical pesticides, food additives, animal welfare and sustainability</p> <p>ChemCert A nationally accredited chemical user's training course for commercial operators</p> <p>ChemClear Agsafe's national program which collects and safely disposes of obsolete agricultural chemicals</p> <p>ChemCollect Agsafe's nationally coordinated scheme for the collection and safe disposal of unwanted and deregistered agvet chemicals from farms during the period 1999 to December 2002, eg persistent organochlorine pesticides (OCPs)</p> <p>Chemical fallowing Controlling weeds during a fallow with herbicides</p> <p>Chemigation Application of fertilizers or pesticides to soil or plants by inclusion in irrigation water</p> <p>Chemisterilant A chemical compound capable of inhibiting insect reproduction</p> <p>Chitin A fibrous substance consisting of polysaccharides, which are the major constituent in the exoskeleton of insects, etc and cell walls of fungi</p> <p>Chitosan Derived from chitin (above)</p> <p>Cholinesterase An enzyme that hydrolyzes choline esters and that is found especially in blood plasma</p> <p>Cholinesterase inhibitor A chemical that inhibits the acetylcholinesterase enzyme from breaking down</p> <p>Chromosome A thread-like structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes</p> <p>CIMMYT International Maize and Wheat Improvement Center, is a non-profit research and training organization</p> <p>CLDB Culturally and Linguistically Diverse Background</p> <p>Climate change A significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years</p> <p>Climate smart agriculture Agriculture that sustainably increases productivity, resilience (adaptation), reduces / removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals (FAO)</p> <p>CLIMEX A computer model that describes the response of a species or other taxonomic unit to climate</p> <p>Clone The group of genetically identical individuals produced asexually from one individual</p> <p>C:N Carbon : Nitrogen ratio</p> <p>CNP Certified Nursery Professional</p> <p>CO₂ Carbon dioxide</p> <p>COAG Council of Australian Governments</p> <p>Code of Practice A set of professional standards or written guidelines agreed on by members of a particular profession or written guidelines issued by an official body or a professional association to its members to help them comply with its ethical standards</p>	<p>Companion planting The planting of different crops in proximity for pest control, pollination, providing habitat for beneficials, maximizing use of space, and to otherwise increase crop productivity</p> <p>Compatible Chemicals which can be mixed without reducing the effectiveness of any individual chemical</p> <p>Compendium A concise, yet comprehensive compilation of a body of knowledge</p> <p>Conservation agriculture Agricultural technologies to improve production while protecting and enhancing land resources on which production depends</p> <p>Conservation tillage Crop production systems in which regular cultivation is reduced, and weed control is replaced or supplemented by the use of herbicides</p> <p>Contact pesticide A pesticide that kills primarily by contacting the insect or plant tissue (little or no translocation)</p> <p>Contamination The presence of an unwanted substance in or on the plant, soil, water, or structure</p> <p>Controlled traffic farming (CTF) A management tool which is used to reduce the damage to soils caused by heavy or repeated agricultural machinery passes on the land</p> <p>Convection currents Currents of air or water set in motion through variation in density caused by differences in temperature</p> <p>Corrosive poison A poison containing a strong acid or base which will severely burn skin, mouth, stomach, other tissue</p> <p>Cover crop A crop planted primarily to manage soil fertility, soil quality, water, weeds, pests, diseases, biodiversity and wildlife in an agroecosystem</p> <p>C-PAS Centre for Pesticide Application and Safety (University of Qld)</p> <p>CPSM Centre for Phytophthora Science and Management</p> <p>CR Controlled release</p> <p>CR Crop rotation</p> <p>CRG Cooperative Research Centre</p> <p>CRG CARE CRC for Contamination Assessment and Remediation of the Environment</p> <p>CRG NPC CRC for National Plant Biosecurity</p> <p>CRF Controlled Release Fertilizer</p> <p>CropLife Australia The peak organization representing the agricultural chemical and biotechnology sector in Australia</p> <p>Crop topping Where a weed wiper is used to apply paraquat or glyphosate mostly to pulse crops but also on cereals on out of control patches of ryegrass</p> <p>Cross breeding To produce (an organism) by the mating of individuals of different breeds, varieties, or species; hybridize</p> <p>Cross protection The phenomenon in which plant tissue infected with a mild strain of an organism, usually a virus, is protected from infection by other more severe strains of the same organism (sometimes called mild strain protection)</p> <p>Cross resistance The tolerance to a usually toxic substance as a result of exposure to a similarly acting substance</p> <p>Crown gall A plant disease caused by various bacteria of the genus <i>Agrobacterium</i> (gall-producing state)</p> <p>CSIRO Commonwealth Scientific and Research Organization</p> <p>CT Conservation tillage</p> <p>CTC Centralized Testing Centre</p> <p>Culture To grow microorganisms or plant tissue artificially on nutrient media</p> <p>Curative A measure which can inhibit or kill a disease-causing organism after it is established in the plant</p> <p>Customer Vendor Declarations Records of all crop treatments, eg fertilizers, chemicals, etc, applied on the grower's property within a certain distance of the crop, and other information.</p>	<p>Cwllth Commonwealth</p> <hr/> <p>DA Department of Agriculture (Cwllth.)</p> <p>DAFF Department of Agriculture, Fisheries & Forestry (Cwllth.)</p> <p>DANGEROUS POISON (signal heading on a label) A chemical that is extremely dangerous to the person using the chemical. Just a small amount of the chemical can cause poisoning and even death if it enters a person's body. For these poisons there are usually restrictions on the purchase and use that are imposed by State or Territory governments such as training and accreditation requirements. Check with your State or Territory coordinator</p> <p>Day degree The growth of a plant is dependent on the total amount of heat to which it is subjected during its lifetime accumulated as degree days. Common practice is to use 10°C as a base - if the mean daily temperature for a particular day is 16°C, then 6 degree days are accumulated for that day on the centigrade scale. The total number of growing degree days required for maturity varies with the crop. The temperature below which the plant is damaged or unable to grow also varies with the crop, eg 4°C for peas, 13° C for citrus fruits. If the total number of degree days required for maturity of a given crop is known, planting, harvesting and pest management can be better planned.</p> <p>Decontaminate To remove or degrade a chemical residue from a surface or substance</p> <p>DED Dutch Elm Disease</p> <p>Defoliant A chemical which initiates premature leaf drop</p> <p>Delimiting surveys Establishing boundaries of an area considered to be infested by or free from a pest. These surveys are usually carried out to determine the boundaries of an infestation rather than to define an area that is free from a pest</p> <p>Delta T The relationship between temperature and relative humidity that gives a score for deciding when best to apply sprays on crops. Growers use it to help them decide the most suitable spraying conditions when applying pesticides, particularly during the warmer summer months. Conventional wisdom is that Delta T of 2-10 is the ideal for spraying</p> <p>Demeter Quality Produce is grown using biological-dynamic agricultural methods founded on a holistic perception of nature</p> <p>Denitrification The loss or removal of nitrogen or nitrogen compounds; reduction of nitrates or nitrites commonly by bacteria (as in soil) that usually results in the escape of nitrogen into the air</p> <p>Deoxyribonucleic acid (DNA) The hereditary or genetic material contained inside each individual cell of all plants and animals including humans. Each cell of an individual plant or animal, is an identical copy of that individual's DNA</p> <p>Desiccant A chemical that promotes drying or loss of moisture from leaves or other plant parts</p> <p>Detoxify To render a toxic active constituent harmless</p> <p>DI Deficit irrigation</p> <p>Diapause A period of suspended development and growth accompanied by decreased metabolism in insects and some other animals. It is correlated with seasonal changes</p> <p>Diatomaceous earth A whitish powder used as an absorbent in the manufacture of pesticides</p> <p>Diazotroph An organism that is able to grow without external sources of fixed nitrogen, eg <i>Rhizobia</i> and <i>Frankia</i> (in symbiosis) and <i>Azospirillum</i></p>
---	---	--

Dicotyledon One of the 2 divisions of flowering plants, characterized by 2 cotyledons in the seed, eg beans	Effectiveness The degree to which a planned effect is achieved	Evasion An act or instance of escaping, avoiding, or shirking something
Dieback Progressive death of shoots, branches and roots, generally starting at the tip	Efficacy The effectiveness of the product	Exclusion zone A zone established by a sanctioning body to prohibit specific activities in a specific geographic area
Diploid A cell with 2 complete sets of chromosomes	Electrolysis A process in which an electric current is passed through a liquid causing a chemical reaction	EXDOC Electronic Export Documentation
Directed spray A spray applied to a restricted area such as a row, or at the base of plants	Electron microscope High powered microscope that uses beams of electrons focused by magnetic lenses instead of rays of light, the magnified image being formed on a fluorescent screen or recorded on a photographic plate	Exotic pests Pests and diseases that are not yet present in Australia, or which have yet to become established, examples include citrus canker, Siam weed
Disease Any malfunctioning of host cells and tissues that results from continuous irritation by a pathogen or environmental factor that leads to the development of symptoms	Elicitors Compounds when introduced into a living organism signal the activation or synthesis of another compound	Expert systems Computer programs designed to simulate the problem-solving behavior of human experts within very narrow domains or scientific disciplines (entomology, plant pathology, etc.)
Disease cycle The stages of development of the disease organism and the effect of the disease on the host	ELISA A serological test in which one antibody carries with it an enzyme that releases a colored compound	Expiry date The date after which a pesticide or other product should not be used
Disease free Implies that seed or vegetative propagation material is free from all diseases or pests. However, this is usually not practical	EMI Electromagnetic induction	
Disease-tested Planting material that has undergone therapy or been grown in special areas to free it from specified diseases and then tested to see if the treatment has been successful	EMS Environmental Management System	FAC Forced-air cooling
Disinfectant Any chemical agent that is used mainly to destroy or inhibit the growth of destructive organisms	EN Entomopathogenic nematodes	Fact sheet A presentation, usually on a single printed page, providing information about a product or service in a format which emphasizes key points concisely. The layout is simple and often standardized, eg using a table, bullet points and / or headings, and is / can be used for publicity purposes
Dispersing agent An adjuvant that facilitates mixing and suspension of a pesticide formulation in water	Endemic pests Pests and diseases which are established in Australia, eg sugar cane smut, bridal creep, and cane toads. A pest or disease is considered to be established if it has survived and continued to spread within Australia's plant species (or animal populations) for a sufficiently long enough period of time after entry into Australia for it be considered unlikely to be eradicated	Facultative parasite An organism that may resort to parasitic activity, but does not absolutely rely on any host for completion of its life cycle
DNA Deoxyribonucleic acid	Endogenic Relating to or arising from an internal process; same as endogenous	Fallow To leave land in an uncropped state for a designated period of time prior to sowing another crop
Dormancy A period in which a plant, pest, disease or weed does not grow, awaiting necessary environmental conditions such as correct temperature, moisture, etc	Endoparasite A parasite which enters a host and feeds from within	FAO Food and Agriculture Organization
Dormant spray A pesticide application made in late winter or in early spring prior to the resumption of plant growth	Endophyte Usually a bacterium or fungus that lives within a plant for at least part of its life without causing apparent disease	Farm Chemical User's Course A nationally accredited chemical user's training course for commercial operators
Dose / dosage Given quantity of agvet chemical applied to a given site or target	Endorhiza A term describing the radicle of the embryo of monocotyledonous plants, which is developed inside a sheath from which it issues in germination	Farmers Market A predominantly fresh food market that operates regularly within a community, at a focal public location that provides a suitable environment for farmers and food producers to sell farm-origin and associated value-added processed traditional food products directly to customers
Double-cropping Producing 2 crops on the same land within the same year, one after the other	Entomopathogenic An organism (generally a bacterium, virus, protozoan or fungus) causing disease in insects	FCUC Farm Chemical User's Course
Downwind If a person is spraying downwind the spray is moving with the wind and away from the person	Environmental assurance Demonstrates the use of management practices that achieve the level of environmental protection expected of itself and its domestic and overseas customers, the community and other interested parties	Fe Iron
DPI Department of Primary Industry	Enviroveg The vegetable industry's environmental program	Feral Wild, untamed, uncultivated
DPSC Drugs and Poisons Schedule Committee	Enzyme Protein produced by living cells that can catalyze a specific organic reaction	Fermentation Oxidation of certain organic substances in the absence of molecular oxygen
Dressing (seed) Covering seeds with a fine coating of fungicide or insecticide	EPA Environmental Protection Authority	FFEZ Fruit Fly Exclusion Zone
Drift Airborne movement of a pesticide (spray, dust, vapor) beyond the intended contact target area	EPG Emergency Procedure Guide	Filtration The process of separating suspended solid matter from a liquid, by causing the latter to pass through the pores of some substance, called a filter
DRIS Decision Regulation Impact Statement	EPHC Environment Protection Heritage Council	Fit-for-purpose products Goods that will be fit for their intended purpose
Drone Unmanned aerial vehicle (UAV), an aircraft without a human pilot aboard	Epicuticle Thin waxy outer covering of insects, protects insects from water loss	Flammable Readily ignited, 'inflammable'
DRT Drift Reduction Technologies	Epidemic A widespread and severe outbreak of disease	Florabank An information network to improve availability and quality of native seed used for revegetation and conservation
drumMUSTER Agsafe's national program that collects empty, triple-rinsed agricultural chemical containers for recycling, providing an important tool to ensure containers are not stored on-farm, sent to landfill, buried or burnt	Epidemiology The incidence, distribution, and possible control of plant diseases and other factors relating to plant health	FMS Farm Management System
DSS Decision Support System	Epidermis 1. The superficial layer of cells occurring on all plant parts. 2. Single layer of living cells in insects which secrete substances forming the cuticle	Food chain Sequence of species in a community, each member of which serves as a food source for the species next higher up the chain
	EPP Emergency Plant Pest	Forecasting Prediction of pest incidence using features of weather, host and pest
EBIC European Biostimulants Industry Consortium	Eppo European and Mediterranean Plant Protection Organization	Fortuitous biological control Regulation of a pest population by a natural enemy that has arrived from elsewhere without deliberate introduction
EC Emulsifiable concentrate	EPRD Emergency Plant Pest Response Deed	Free-living A microorganism that lives freely, unattached, or a pathogen living in the soil, outside its host
EC European Community	Eradicate The complete destruction of something	Freshcare The national on-farm assurance program for the fresh produce industry; an industry-owned on-farm assurance program and not-for-profit organization
ECA Entomology Curriculum Australia	ESD Ecologically Sustainable Development	FSANZ Food Standards Australia and New Zealand
EcoHort The national environmental management system for production nurseries, growing media manufacturers and greenlife markets	ET Economic threshold	FRW Fuller's rose weevil
Ecological engineering see Habitat manipulation, Revegetation by Design	EU European Union	Fumes Smoke, vapor or gas
Economic threshold The highest disease severity level that does not decrease economic profits	Eurogap See GlobalGap	Fumigation A method of pest control that completely fills an area with gaseous pesticides to kill the pests within
ECRP Existing Chemical Review Program	Evaporation When water changes into vapor	
Ectoparasite A parasite feeding on a host from the exterior	Evapo-transpiration The process in which plants lose water from leaves and other parts by the (imperceptible) escape of molecules from the plant surface	

<p>Functional food Food or food component that may provide demonstrated physiological benefits or reduce the risk of chronic diseases, above and beyond basic nutritional functions</p> <p>Fungi Have cell walls that contain chitin, unlike the cell walls of plants which contain cellulose. They have a mycelium of hyphae, produce spores and cause diseases of plants (powdery mildews, rusts) and animals. Can be beneficial, eg as biocontrol agents, food, yeasts.</p> <p>Fungistatic An agent which inhibits rather than destroys a fungus</p>	<p>Ground-penetrating radar (GPR) A geophysical method that uses radar pulses to image the subsurface</p> <p>Groundwater Water located beneath the soil surface from which bore water is obtained or surface springs are formed</p> <p>Growcom The peak representative body for Qld horticulture</p> <p>Growth regulator A chemical which alters the growth processes of a plant or animal</p> <p>GTR Gene Technology Regulator</p> <p>GWRDC Grape & Wine Research and Development Corporation</p>	<p>Horticulture Australia Ltd (HAL) A not-for-profit, industry-owned company. It works in partnership with Australia's horticulture industries to invest in research, development and marketing programs that provide benefits to industry and the wider community</p> <p>Horticulture for Tomorrow Environmental Assurance for growers and industry</p> <p>Hortstats A program which analyses and monitors factors which can affect crop production including climate, improved crop varieties, changes in management and changes in the market price of a crop</p> <p>Host A plant on or in which a pest or disease lives</p> <p>Host range Kinds of host plants that may be attacked by a pest or disease</p> <p>HRCB Herbicide Resistant Crops from Biotechnology</p> <p>HRDC Horticultural Research and Development Corporation</p> <p>Humidity Amount of water vapor in air</p> <p>HV High volume (spray)</p> <p>HWSD Harrington Weed Seed Destructor</p> <p>HWT Hot water treatment</p> <p>Hybrid The offspring of two individuals differing in one or more heritable characteristics</p> <p>Hybridization The crossing of two individuals differing in one or more heritable characteristics</p> <p>Hydrolysis Breakdown of a chemical in the presence of water</p> <p>Hydrophobic Leaves and other substances that repel water</p> <p>Hygiene See Sanitation</p> <p>Hyperparasite A parasite parasitic on another parasite</p> <p>Hypersensitivity Excessive sensitivity of plant tissues to certain pathogens; affected cells are killed quickly, blocking the advance of obligate parasites</p>
<p>GE Genetically engineered</p> <p>GEC Genetically Engineered Crop</p> <p>Gene A segment of a chromosome which determines one or more hereditary characteristics, transferable from parents</p> <p>Gene gun A gene gun or a biolistic particle delivery system, originally designed for plant transformation, is a device for injecting cells with genetic information</p> <p>Gene shears Cuts messenger RNA molecules, causing them to lose their ability to convey genetic information</p> <p>Gene silencing The interruption or suppression of the activity of a targeted gene that prevents it from coordinating the production of specific proteins</p> <p>Genetically manipulated material Includes plants using biotechnology and artificial selection techniques (conventionally bred and unintentionally selected)</p> <p>Genetic engineering Transfer of genes of economic importance from other plants and animals, viruses, bacteria and fungi to plants where these genes do not normally occur</p> <p>Genome The entirety of an organism's hereditary information. It is encoded either in DNA or, for many types of viruses, in RNA</p> <p>Genotype The genetic constitution of an organism</p> <p>Geofabrics Permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. Typically made from polypropylene or polyester, and usually woven, needle punched, or heat bonded</p> <p>GHG Greenhouse gas</p> <p>GIS Geographic Information System</p> <p>GlobalGap Non-governmental organization that sets voluntary standards for the certification of agricultural products around the globe</p> <p>GM Genetically modified</p> <p>GMAC Gene Manipulation Advisory Committee</p> <p>GMI Grow-Me-Instead</p> <p>GMO Genetically modified organism</p> <p>GMP Genetically manipulated plant</p> <p>GMP Good Manufacturing Practice</p> <p>GPS Global Positioning System</p> <p>GRDC Grain Research & Development Corporation</p> <p>Green bridge A temporary vegetative link between the harvesting of one crop and the germination of the following crop allowing the survival of insect vectors, diseases, etc</p> <p>Green manure crops A crop which is not harvested, but ploughed under when green to improve the soil</p> <p>GreenSeeker® fitted machinery Assesses whether the target being observed contains live green vegetation or not</p> <p>Green waste Biodegradable waste that can be composed of garden or park waste, such as grass or flower cuttings and hedge trimmings, as well as domestic and commercial food waste. The differentiation green identifies it as high in nitrogen, as opposed to brown waste, which is primarily carbonaceous</p>	<p>Habitat manipulation Manipulation of agricultural areas and the surrounding environment with the aim of conserving or augmenting populations of natural enemies, eg the planting of a refuge for natural enemies; may be called Ecological engineering, Revegetation by Design</p> <p>HACCP Hazard Analysis and Critical Control Points</p> <p>HAL Horticulture Australia Ltd</p> <p>Half-life Time taken for a substance in the environment to be reduced to 50% of its original value</p> <p>Halophyte A plant adapted to living in a saline environment</p> <p>Haploid A cell with a single complete set of chromosomes</p> <p>Hard water Alkaline water with a pH of more than 7</p> <p>Hazard A situation that poses a level of threat to life, health, property, or environment</p> <p>Heartwood As new sapwood is produced by the cambium, the sapwood towards the center of the trunk ceases to function and becomes impregnated with gums and other compounds, these usually give it a darker color. This wood is then called heartwood, it helps to strengthen the tree</p> <p>Herbaceous plant A plant that does not develop woody tissue</p> <p>Herbigation The metering of herbicide into irrigation water for weed control</p> <p>HerbiGuide Provides information on weeds, pests and diseases in crops, pastures, horticulture and the environment to help with crop protection decisions</p> <p>Hermaphrodite An individual bearing both functional male and female reproductive organs</p> <p>Heteroploid A cell, tissue, or organism that contains more or fewer chromosomes per nucleus than the normal for that organism</p> <p>Hierarchy Any system of persons or things ranked one above another</p> <p>Holistic Characterized by the belief that the parts of something are intimately interconnected and explicable only by reference to the whole. Emphasizing the importance of the whole and the interdependence of its parts</p> <p>Hormone A chemical substance produced in the body that controls and regulates the activity of certain cells or organs</p> <p>Hormone herbicide A herbicide that acts like a plant growth regulator. Volatile hormone herbicides (phenoxy herbicides) have the potential to cause off-target spray damage. There are regulations which restrict the use of hormone herbicides. There is a 'duty of care' for landholders and spray contractors not to cause off-target spray damage. Leaf twisting caused by hormone herbicides means that off-target damage is very obvious, eg MCPA, 2,4-D</p> <p>HortGuard Links to information on important pests, diseases and weeds</p>	<p>ICA Interstate Certification Assurance</p> <p>ICBN International Code of Botanical Nomenclature</p> <p>ICM Integrated Crop Management</p> <p>ICON Import conditions database</p> <p>IDM Integrated Disease Management</p> <p>IFOAM International Federation of Organic Agricultural Movements</p> <p>IFS Integrated Farming Systems</p> <p>Immature Juvenile stages of insects and other organisms</p> <p>Immunity The ability of a plant to remain completely free from attack by specified diseases and pests</p> <p>Imperfect fungus A fungus that is not known to produce sexual spores</p> <p>Impervious Not allowing something, eg a pesticide, to pass through</p> <p>Import Risk Analysis (IRA) The process to develop a new biosecurity policy where no policy exists</p> <p>IMS Irrigation Management Strategies</p> <p>Incident An event that could have had serious consequences</p> <p>Incompatible Two or more materials which cannot be mixed or used together</p> <p>Incorporation The mixing of pesticides with the top layer of soil by cultivation</p> <p>Incubation period The time between inoculation and penetration and appearance of the disease symptoms</p> <p>Indicator plant A plant that reacts to certain viruses or environmental factors with production of specific symptoms and is used for detection and identification of these factors</p> <p>Industry Biosecurity Manual Provides practical information that producers can use to implement on-farm biosecurity to reduce the likelihood of exotic pests and diseases</p>

<p>Industry Biosecurity Plan Outlines key threats to a specific industry, identification and categorization of exotic pests, risk mitigation plans and contingency plans</p> <p>Inert Chemically unreactive, eg material in a pesticide which does not have pesticidal or microbial activity</p> <p>Infection The establishment of a parasite within a host plant</p> <p>INFER Investment Framework for Environmental Resources</p> <p>Infested Containing great numbers of insects, mites, nematodes, etc on plants, soil, container or tool or in an area</p> <p>Infra red radiation Electromagnetic radiation (light) that has a longer wavelength (shorter frequency) than optical (visible) light</p> <p>Inoculant (legume seeds) Inoculation is the process of introducing commercially prepared rhizobia bacteria into the soil. Agricultural inoculants are beneficial microorganisms (bacteria or fungi) encapsulated in carrier material and applied to the environment for remediation and enhancement of agricultural productivity</p> <p>Inoculate To bring a pathogen into contact with a host plant or host organs</p> <p>Inoculum The disease organism or its parts that can cause infection</p> <p>Input Something put into a system or expended in its operation to achieve an output or a result</p> <p>Insect growth regulator A chemical compound that interferes with the normal growth pattern of insects, eg juveniles do not become adults</p> <p>Insects A class of invertebrates within the arthropod phylum that have a chitinous exoskeleton, a three-part body (head, thorax and abdomen), three pairs of jointed legs, compound eyes and one pair of antennae</p> <p>INSV Impatiens necrotic spot virus</p> <p>Integrated Crop Management (ICM) There is no agreed definition, usually they include specific objectives such as pest management, fertiliser use, nitrogen reduction and limiting use of pesticides</p> <p>Integrated Disease Management See Integrated Pest Management</p> <p>Integrated Farming / Production A term commonly used to explain a more integrated approach to farming as compared to existing monoculture approaches. It refers to agricultural systems that integrate livestock and crop production and may sometimes be known as Integrated Biosystems</p> <p>Integrated Pest Management A decision-making process using multiple pest management tactics to prevent economically damaging out-breaks while reducing risks to human health and the environment</p> <p>Integrated Weed Management A flexible system incorporating multiple weed management tactics aiming to reduce weed numbers. See also Integrated Pest Management above</p> <p>Inundative To receive or take in a large amount of things at the same time</p> <p>Invasive species Animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species</p> <p>IPM Integrated Pest Management</p> <p>IPPC International Plant Protection Convention</p> <p>IRA Import Risk Analysis</p> <p>IRMS Insecticide Resistance Management Strategy</p> <p>ISO International Standardization Organization</p>	<p>ISPM The International Standard for Phytosanitary Measures</p> <p>Iterative Repetitious, repeated</p> <p>IWM Integrated Weed Management</p> <p>IWRS Industry Waste Reduction Scheme</p> <hr/> <p>JAS-ANZ Joint Accreditation System of Australia and New Zealand</p> <p>JAS MAFF The Japanese Agricultural Standard (JAS) for organic law implemented by the Japanese Ministry of Agriculture, Forestry, & Fisheries (MAFF)</p> <hr/> <p>K Potassium</p> <p>Kairomones Types of pheromones produced by organisms to attract a mate; can also attract parasites and predators</p> <p>Knockdown spray 1. An insecticide spray used against flying insects that acts quickly causing sprayed insects to fall. 2. A contact herbicide that is rapid in action</p> <p>KPI Key Performance Indicator</p> <hr/> <p>Larvicide A pesticide active against insect larvae, eg caterpillars</p> <p>Latent period Time from infection until production of new inoculum (reproduction)</p> <p>LBAM Lightbrown apple moth</p> <p>LCS Life Cycle Stewardship</p> <p>LD Lethal dose</p> <p>Legislature An organized body of persons having the authority to make laws</p> <p>Leisa Low External Inputs Sustainable Agriculture</p> <p>License 1. The verb license means to give permission. 2. The noun license refers to that permission as well as to the document recording that permission</p> <p>Life cycle The stage or successive stages in the growth and development of an organism that occur between the appearance and reappearance of the same stage of the organism</p> <p>Lure A chemical that attracts a pest to a bait or to a lethal deposit of pesticide</p> <p>Lure & kill formulations Insect pests attracted by a semiochemical lure are subjected to a killing agent, which eliminates affected individuals from the population after a short period</p> <p>Lysimeter A device for measuring the water balance in the soil, allowing the measuring of deep drainage, evapotranspiration, and storage.</p> <p>Lysis The breaking down of a cell, often by viruses, enzymes, or osmosis</p> <hr/> <p>Macroclimate The general climate of a large geographic area</p> <p>Macroscopic Visible to the naked eye without the aid of a magnifying lens or microscope</p> <p>MAD Multi-factor Agricultural Diversity</p> <p>MAGIC Multiparent Advanced Generation InterCross</p> <p>Management system The framework of processes and procedures used to ensure that an organization can fulfill all tasks required to achieve its objectives, eg an environmental management system enables organizations to improve their environmental performance through a process of continuous improvement - "Plan, Do, Check, Act"</p> <p>MAP Modified Atmosphere Packaging</p> <p>Marker genes Genes that can be used to identify the tiny number of cells which have successfully acquired a new gene. The marker gene is transferred alongside the gene of interest (the target or beneficial gene). The most commonly used marker genes at present are antibiotic or herbicide resistance genes</p>	<p>MAS Marker Assisted Selection</p> <p>Maximum residue limit (MRL) The international and Australian Standard for residues and is the highest concentration of a residue of a particular chemical that is legally permitted or accepted in a food or animal feed</p> <p>Medfly Mediterranean fruit fly</p> <p>Median That category situated in the middle of a linear scale. It is different from the average</p> <p>MERI Monitoring, Evaluation, Reporting and Improvement</p> <p>Meristem Undifferentiated plant tissue at the growing tip of a plant</p> <p>Metabolite A compound derived from changes in the active constituent of a chemical through various reactions. The metabolite may be simpler or more complex and may or may not be more toxic than the original chemical</p> <p>Mg Magnesium</p> <p>MIA Murrumbidgee Irrigation Area</p> <p>MiCoR Manual of Importing Country Requirements</p> <p>Microbial pesticide Bacteria, viruses, fungi and other microorganisms used to control pests</p> <p>Microclimate The atmospheric conditions affecting an individual or a small group of organisms, eg on a leaf</p> <p>Microorganism An organism too small to be seen without a microscope</p> <p>Microscopic Too minute to be visible to the naked eye, without the use of a hand lens or microscope</p> <p>Minimum till (mini-till) At least one cultivation before sowing</p> <p>Minor Use Products Chemicals used in crops deemed not to be major crops; or with emergency permits. More than half the 25 grain crops subject to GRDC research levies are classified as minor crops; chemical companies consider it uneconomic because of the size of the market and registration costs</p> <p>Miscible Mixes easily with water</p> <p>Miscible liquids Two or more liquids which can be mixed and will remain mixed, eg water and ethyl alcohol; water and oil are not miscible</p> <p>Mist spraying Concentrated spray atomized into a high velocity air stream, the air acting as diluent and carrier</p> <p>Mite Minute arachnid which has four pairs of legs when adult, related to the ticks; many kinds live in the soil and a number are parasitic on plants or animals</p> <p>Mn Manganese</p> <p>Mode of action The way in which an active constituent exerts an effect on the target plant, animal or microorganism</p> <p>Molecular tests Includes tests and methods to identify a disease or the predisposition for a disease by analyzing the DNA or RNA of an organism</p> <p>Monitoring 1. A regular system of checking on whether pesticides are escaping into the environment. 2. Used to determine pest numbers and damage in order to evaluate the need for, or effectiveness of, treatment 3. Health surveillance</p> <p>Monocotyledon One of the 2 divisions of flowering plants characterized by 1 cotyledon in the seed, eg grasses</p> <p>Monoculture A crop of a single species or variety</p> <p>Monocyclic A single cycle</p> <p>Monoploid A cell with 1 complete set of chromosomes</p> <p>Morphology Form or structure of a plant</p> <p>MOU Memorandum of Understanding</p> <p>MRL Maximum Residue Limit</p> <p>MSDS Material Safety Data Sheet</p> <p>MUP Minor Use Product</p>
---	---	---

<p>Mutagen A substance or agent able to cause genetic changes in living cells</p> <p>Mutant An individual with a new, heritable characteristic as a result of a mutation</p> <p>Mutation An abrupt appearance of a new characteristic in an individual as a result of an accidental change in a gene or chromosome</p> <p>Mycorrhizic A fungus especially formulated to control weeds</p> <p>Mycorrhizal A fungicide especially formulated to inhibit weed growth</p> <p>Mycorrhiza A symbiotic association of a fungus with the roots of a plant</p> <p>Mycotoxins Toxic substances produced by fungi in infected seeds, feeds or foods, capable of causing illnesses of varying severity, or death, to animals and humans who eat them</p> <hr/> <p>N Nitrogen</p> <p>Nanomaterial Anything that has been engineered to measure between 1 and 100nm in at least one dimension</p> <p>Nanometer One billionth (10⁻⁹) of a meter</p> <p>Nanoscale Having dimensions measured in nanometers</p> <p>Nanotechnology The branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules</p> <p>NAP National Action Plan (sustainable use of pesticides)</p> <p>NAQS Northern Australian Quarantine Strategy</p> <p>NASAA National Association of Sustainable Agriculture Australia</p> <p>Natural enemies Organisms that kill, decrease the reproductive potential of, or otherwise reduce the numbers of another organism</p> <p>NChEM National Framework for Chemical Environmental Management</p> <p>NCO NAASA Certified Organic</p> <p>NDP National Diagnostic Protocols</p> <p>NDVI Normalized Difference Vegetation Index</p> <p>Necrosis Death of plant or animal tissues causing discolored, sunken or dead areas</p> <p>Necrotrophic A parasite that kills its host, then feeds on the dead matter</p> <p>Negligence A failure to exercise the care that a reasonably prudent person would exercise in like circumstances</p> <p>Nematodes Having a long, round, usually unsegmented body; roundworms or eelworms. Most are microscopic, but some are much larger. They are mostly parasites, in plants and animals, but some are free-living in soil or water, some are biocontrol agents</p> <p>NESA Nursery Environmental Self-Audit</p> <p>NESB Non-English Speaking Background</p> <p>Neurotoxin A substance or agent able to cause disorders of the nervous system</p> <p>NFACP National Feral Animal Control Program</p> <p>NFF National Farmers Federation</p> <p>NGIA Nursery & Garden Industry Australia</p> <p>NH&MRC National Health & Medical Research Council</p> <p>NIASA Nursery Industry Accreditation Scheme, Australia</p> <p>NIMF Nursery Industry Marketing Forum</p> <p>NIR Near-infra-red</p> <p>Nitrogen-fixation The conversion of atmospheric nitrogen into nitrogen compounds by certain bacteria, such as <i>Rhizobium</i> in root nodules of legumes</p> <p>nm A nanometer</p> <p>NNS National Nanotechnology Strategy</p> <p>NMD Number median diameter</p> <p>NOHSC National Occupational Health and Safety Commission</p>	<p>Non-preference Various features of the host plant that make the host undesirable or unattractive to insects for food, shelter or reproduction</p> <p>Non-quarantine pests Pests known to be present in Australia, they are established and not controlled or widely distributed. No active biosecurity measures are taken for non-quarantine diseases</p> <p>Non-selective pesticides. Chemicals which affect a wide range of species, including beneficial species</p> <p>Non-systemic A chemical that is not absorbed by the plant</p> <p>Non-target species Any plant or animal, other than the intended target(s) of a pesticide application</p> <p>NOP National Organic Program</p> <p>Normalized Difference Vegetation Index A numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum; analyses remote sensing measurements and assesses whether the target being observed contains live green vegetation or not</p> <p>Notification (pesticides) A written or printed notice or warning (that pesticides are to be applied on a certain date, place, etc)</p> <p>No-till The only cultivation is for low disturbance sowing using either knife points or disc seeders</p> <p>Noxious weed A plant defined by law as undesirable and that must be controlled</p> <p>NPBN National Biosecurity Diagnostic Network</p> <p>NPBSR National Plant Biosecurity Status Report</p> <p>NRS National Registration Scheme</p> <p>NRS National Residue Survey</p> <p>NSOBP National Standard for Organic and Bio-dynamic Produce</p> <p>NSW New South Wales</p> <p>NT Northern Territory</p> <p>NTQ Northern Territory Quarantine</p> <p>Nucleic acid An acidic substance containing pentose, phosphorus, and pyrimidine and purine bases which determine the genome properties of organisms</p> <p>NUE Nitrogen Use Efficiency</p> <p>Number median diameter A measure of the diameter of droplets in a spray. The number of droplets with a diameter above the NMD equals the number of droplets with a diameter less than the NMD = the median</p> <p>Nutraceutical food A functional food that aids in the prevention and / or treatment of disease(s) and / or disorder(s) (except anemia). Nutraceuticals are regarded as a subset of functional foods. <i>"Bioactive chemicals derived from foods but taken as supplements at much higher concentrations than diet alone could provide"</i> (Scientific American 2008)</p> <p>NVT National Variety Trials</p> <hr/> <p>Obligate parasite A parasite that in nature can grow and multiply only on, or in living organisms</p> <p>OC Organochlorine pesticide</p> <p>OCP Organic Crop Protectants</p> <p>OECD Organization for Economic Co-operation and Development</p> <p>OFA Organic Federation of Australia</p> <p>OFC Organic Food Chain</p> <p>OGTR Office of Gene Technology Regulator</p> <p>OHS, OH&S Occupational Health and Safety</p> <p>OIECC Organic Industry Export Consultative Committee</p> <p>OISCC Organic Industry Standards and Certification Council</p> <p>Ontogenic resistance Age-related resistance of the host</p> <p>OP Organophosphate pesticide</p> <p>OPAC Organic Producers Advisory Committee</p>	<p>OPC Organic Product Certificates</p> <p>ORGAA Organic Retailers and Growers Association of Australia</p> <p>Organochlorines (OCs) Agvet chemicals containing chlorine, carbon and hydrogen; many are persistent in the environment</p> <p>Organophosphates (OPs) A large group of agvet chemicals which contain phosphorus</p> <p>Orphaned herbicides Fungal herbicides found to be effective in the field for specific weeds but have not been developed for sale</p> <p>Osmosis A process by which molecules of a solvent may pass through a semi permeable membrane from a less concentrated solution to a more concentrated solution till equilibrium is reached</p> <p>Outbreak A sudden occurrence of something unwelcome, eg a pest, disease or weed</p> <p>Output The amount of something produced by a person, machine, or industry</p> <p>Overseason (of an insect, plant, etc) How it lives during one of the four periods of the year (spring, summer, autumn, and winter)</p> <p>Oversummer (of an insect, plant, etc) How its lives through the summer</p> <p>Overwinter (of an insect, plant, etc) How it lives through the winter</p> <p>Ovicide A material active against eggs</p> <p>Ozone (O₃) A highly reactive form of oxygen that in relatively high concentrations may injure plants</p> <hr/> <p>P Phosphorus</p> <p>PA Precision agriculture</p> <p>PACC Pesticides and Agricultural Chemicals Committee of the NH&MRC that establishes maximum residue limits (MRLs)</p> <p>PADil Pests and Diseases Image Library</p> <p>Parasite An organism living on, or in another living organism (host) which is used as a source of food</p> <p>Parasitoid An organism that lives on or in a host organism and ultimately kills the host</p> <p>Pasteurization A process which kills harmful bacteria and other organisms in soil, water or food by heating at specific temperatures for certain periods of time, eg 72°C for 15 seconds, then cooling it immediately after removing it from heat</p> <p>Pathogen A microorganism, eg virus, bacterium, fungus, nematode, that can cause disease</p> <p>Pathogenicity A measure of disease isolates (pathotypes) of the pathogen which vary in the rate at which they can invade and sporulate on host plants</p> <p>Pathotypes Subgroups within a species, usually distinguished from the rest of the species by criteria other than morphology, eg a difference in parasitic ability</p> <p>Pathovar (pv.) In bacteria, a subspecies or group of strains than can infect only plants within a certain genus or species</p> <p>PAW Plant Available Water</p> <p>PBI Plant Back Interval</p> <p>PBCRC Plant Biosecurity Cooperative Research Centre</p> <p>PBR Plant Breeders Rights</p> <p>PCN Potato cyst nematode</p> <p>Penetrant An adjuvant added to a spray mixture to enhance the absorption of a product</p> <p>Perennial A plant that lives for > 2 years</p> <p>Perfect stage The sexual stage in the life cycle of a fungus</p> <p>Permaculture The development of agricultural ecosystems intended to be sustainable and self-sufficient</p> <p>Permeable A material (membrane) that allows only fluid substances to move through it</p>
---	--	--

<p>Permit Officially allow (someone) to do something</p> <p>Persistence The length of time it takes for a pesticide to break down into harmless by-products</p> <p>Pest A destructive insect or other animal that attacks crops, food, livestock. Sometimes the term pest is used to cover all insects, mites, snails, nematodes, pathogens (diseases) and weeds that are injurious to plants or plant products (biosecurity)</p> <p>Pest index A list of pests for a species</p> <p>Pest risk analysis The systematic assessment and management of risks associated with the importation, or proposed importation of animals, plants, or goods and if necessary, identification of risk management options to limit the level of biosecurity risk due to exotic pests and diseases</p> <p>PFA Pest Free Area</p> <p>PGR Plant Growth Regulator</p> <p>pH A measure of the acidity/alkalinity of a liquid; acid is < pH 7, alkaline is > pH 7</p> <p>PH Precision horticulture</p> <p>PHA Plant Health Australia</p> <p>Phenoxy herbicides A group of chemicals related to the growth hormone, indoleacetic acid (IAA) and a part of the Group I herbicides, eg 2,4-D, MCPA</p> <p>Pheromone A chemical substance that an animal or insect produces in order to attract other animals or insects and especially a mate</p> <p>Phloem The vascular tissue in plants which conducts sugars and other metabolic products downwards from the leaves</p> <p>PHM Plant Health Management</p> <p>Phosphate-solubilizing bacteria A group of beneficial bacteria capable of hydrolysing organic and inorganic phosphorus from insoluble compounds. The use of PSBs as inoculants increases P uptake by the plant and crop yield</p> <p>Phylloxera (<i>Daktulosphaira vitifoliae</i>) An aphid-like insect that lives on the roots of grapevines</p> <p>Physiological race A subdivision of a species of pathogen, particularly fungi, distinguished from other members of the species by specialization for pathogenicity to different cultivars of a host</p> <p>Phyto Relating to plants</p> <p>Phytoalexins Antimicrobial and often antioxidative substances synthesized by plants that accumulate rapidly at areas of pathogen infection</p> <p>Phytopathogenic Term applicable to a microorganism that can incite disease in plants</p> <p>Phytophthora A fungus that causes devastating diseases of native plants, horticultural crops and garden plants worldwide</p> <p>Phytoplasmas Specialized bacteria that are transmitted by insects and are obligate parasites in plant phloem tissue</p> <p>Phytosanitary measure Any legislation, regulation or official procedure which prevents the introduction and / or spread of quarantine pests</p> <p>Phytoseiidae A family of predatory mites</p> <p>Phytotoxicity Toxicity of a pesticide or pesticide component to plants</p> <p>Phytotoxin A substance produced by a plant that is toxic or a substance that is toxic to the plant as well</p> <p>PIDD Pest Information Document Database</p> <p>Plant-back period The minimum interval which should elapse between the last pesticide application and planting of a particular crop</p> <p>Plant biotechnology Includes tissue culture, embryogenesis, genetic markers, genetic engineering, plant breeding, floriculture</p>	<p>Plant growth regulator Any of various synthetic or naturally occurring plant substances, eg an auxin or gibberellin that regulates plant growth</p> <p>PLANTPLAN National guidelines for response procedures under the Emergency Plant Pest Response Deed (EPPRD) outlining the 3-phase response to an Emergency Plant Pest (EPP) incursion as well as the key roles of industry and government during each phase</p> <p>Point of run off When a spray starts to run or drip from the leaves and stems of plants (or the hair or feathers of animals)</p> <p>POISON (signal heading on a label) A chemical that is very hazardous to the person using the chemical. It can cause poisoning if it enters a person's body</p> <p>Policy A course or principle of action adopted or proposed by an organization or individual</p> <p>Polycyclic Many life or disease cycles in 1 year</p> <p>Polyploidy An organism with other than 2 basic sets of chromosomes</p> <p>Post-emergence herbicide Herbicide applied to foliage</p> <p>Potentiation Enhanced toxicity attained by combining two or more toxicants giving twice or more killing power than the sum of the individual toxicities</p> <p>PPE Personal Protective Equipment</p> <p>Precautionary principle If an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking the action</p> <p>Precipitate A solid substance that forms in a liquid and settles to the bottom of the container</p> <p>Precision agriculture, Site specific agriculture A farm management concept based on observing, measuring and responding to inter and intra-field variability in crops</p> <p>Predator An animal that attacks and feeds on other animals</p> <p>Pre-emergence herbicide A herbicide effective against germinating weed seeds</p> <p>Pre-emptive breeding Anticipatory breeding for resistance to future pathotypes, eg if a disease not currently present in Australia, should enter in the future</p> <p>Pre-sowing Spraying a seedbed before the crop is sown</p> <p>Preventative A measure which can prevent a disease-causing organism becoming established in the plant</p> <p>Primary infection The first infection of a plant by the overwintering or over-summering stage of a disease</p> <p>Primary inoculum The overwintering or over-summering pathogen or its spores that cause primary infections</p> <p>Propagule Part of an organism (seeds, corns, vegetative parts) that may be disseminated by a plant to reproduce</p> <p>Protocols The official procedures governing affairs of state or diplomatic occasions. The established code of procedure or behavior in any group, organization, or situation. Unwritten rules or guidelines that are peculiar to every culture or organization, and are supposed to be observed by all parties in the conduct of business</p> <p>Provenance(s) Populations of a species from different regions, individual trees within provenances, and even different branches of one tree</p> <p>PSB Phosphate-solubilizing bacteria</p> <p>PUBCRIS Public Chemical Registration Information System</p> <p>PUE Phosphorus Use Efficiency</p> <p>pv See Pathovar</p>	<p>QA Quality Assurance</p> <p>QEAC Quarantine Export Advisory Committee</p> <p>Q-fly Queensland fruit fly</p> <p>Qld Queensland</p> <p>QMS Quality management system</p> <p>QNI Queensland Nursery Industry Association</p> <p>Qualitative Descriptions having to do with quality or worth</p> <p>Quality assurance Any systematic process of checking to see whether a product or service being developed is meeting specified requirements</p> <p>Quality management system A set of interrelated or interacting elements that organizations use to direct or control how quality policies are implemented and quality objectives are achieved</p> <p>Quantitative Data that has numerical significance; it can be measured</p> <p>Quarantine pest A pest of potential economic importance to the country endangered thereby and not yet present there, or present but not yet widely distributed and being efficiently controlled. This definition forms a significant basis for pest risk analysis (International Plant Protection Convention)</p> <hr/> <p>® Registered trade mark</p> <p>Race 1. A genetically, often geographically distinct mating group within a species. 2. A group of disease organisms that infect a given set of plant varieties</p> <p>RAMP Risk Assessed Management Plan</p> <p>Rapid manufacturing The use of 3D printing to produce plastic or metal end use parts and custom products reducing the time, cost, tooling and overheads</p> <p>Rate The amount of active constituent applied to a unit area regardless of the percentage of chemical in the carrier</p> <p>RDC Research Development Corporation</p> <p>Record A document which provides evidence that activities have been performed or results have been achieved. Records can be used to show that traceability requirements are being met, that verification is being performed and that preventative and corrective action is being carried out</p> <p>Recycle Processing of wastes to provide materials for a variety of products</p> <p>Redline Biosecurity's telephone number for reporting breaches of Australian biosecurity's laws 1800 803 006</p> <p>Refuge crop A non-genetically modified food crop planted alongside a GM crop</p> <p>ReGen Regenerative Agriculture</p> <p>Registered pesticide A pesticide product which has been approved by the APVMA for the uses listed on the label</p> <p>Regulation A legal instrument to support an Act of Parliament</p> <p>REI Re-entry Interval, Restricted-Entry Interval.</p> <p>Re-entry Interval The period of time immediately following the application of a pesticide during which unprotected workers should not enter a field. These restrictions on entry are to protect persons from potential exposure to hazardous levels of pesticide residues</p> <p>Relative humidity The amount of water vapor in the air compared to the amount required for saturation, stated as a percentage. If air contains only half the amount of water vapor that it can hold when saturated, relative humidity is 50%</p> <p>Repellent A compound that keeps insects, rodents, birds, or other pests away from plants, domestic animals, buildings, or other treated areas</p>
---	---	--

<p>Residual pesticide A pesticide that continues to remain effective on a treated surface or area for an extended period following application</p> <p>Residue 1. The traces of pesticide or its breakdown products remaining in, or on the target after treatment, or in the soil, water or plants remain in or on a product. 2. Materials left in an agricultural field or orchard after the crop has been harvested</p> <p>Resistance 1. Ability of a disease organism, pest or weed to remain uninjured or unaffected by a certain dosage of chemical. 2. Ability of a plant to suppress or retard the activities of disease or pest organisms or other injurious factors</p> <p>Respirator A face mask used to filter out certain toxic gases and dust or spray particles from the air</p> <p>Re-use To use again for the same purpose</p> <p>Revegetation by Design Using endemic vegetation as a refuge for beneficial insects in agricultural systems; a guidebook is available (SARDI)</p> <p>Rhizosphere The area of soil immediately surrounding living roots</p> <p>RHS Royal Horticultural Society</p> <p>Right to know In the context of the United States workplace and community environmental law, it is the legal principle that the individual has the right to know the chemicals to which they may be exposed in their daily living. "Right to Know" laws take two forms: Community Right to Know and Workplace Right to Know. Each grants certain rights to those groups</p> <p>Rinsates Liquid contaminated with chemical produced during the washing of containers or equipment</p> <p>Riparian The interface between land and a river or stream relating to or living or located on the bank of a natural watercourse (as a river) or sometimes of a lake or a tidewater</p> <p>RIRDC Rural Industries Research and Development Corporation</p> <p>Risk A situation involving exposure to danger</p> <p>Risk analysis Assessment of the level of biosecurity risk associated with the importation, or proposed importation of animals, plants, or goods and if necessary, identification of risk management options to limit the level of biosecurity risk. Includes risk assessment, risk management and risk communication</p> <p>Risk assessment The evaluation of the likelihood and the biological and economic consequences of entry, establishment or spread of a pest or disease within the territory of an importing country</p> <p>Risk management The process of identifying, selecting and implementing measures that can be applied to reduce the level of risks</p> <p>RLEM Redlegged earth mite</p> <p>RMIT Royal Melbourne Institute of Technology</p> <p>RMS Resistance Management Strategies</p> <p>RNA (ribonucleic acid) A nucleic acid involved in protein synthesis, the most common nucleic acid (genetic material) of plant viruses</p> <p>Robotics The branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing</p>	<p>Rogueing The removal of an infested or diseased plant, from an otherwise healthy crop and destroying it so that the pest or disease cannot spread from it to neighboring plants or through its seeds to the next generation</p> <p>Rotate To go through a cycle of changes; cause to pass or follow in a fixed routine of succession, eg to rotate farm crops, rotate crop varieties, rotate control methods as in IPM, rotate pesticide groups, rotate pesticides</p> <p>RoundupReady Crops (RR Crops) Crops which are genetically engineered crops that have had their DNA altered to allow them to withstand the herbicide glyphosate (the active ingredient of Monsanto's herbicide Roundup)</p> <p>RR crops RoundupReady Crops</p> <p>RTO Registered Training Organization</p> <p>RWUE Rural Water Use Efficiency</p> <hr/> <p>SA South Australia</p> <p>SARDI South Australian Research and Development Institute</p> <p>SARS Systemic acquired resistance</p> <p>SCARM Standing Committee on Agriculture and Resource Management</p> <p>Schedule 7 chemical The chemical is extremely dangerous to the person using the chemical. Just a small amount of the chemical can cause poisoning and even death if it enters a person's body. There are usually restrictions on the purchase and use that are imposed by State or Territory governments such as training and accreditation requirements</p> <p>Scientific name Name used by scientists, especially the taxonomic name of an organism that consists of a genus and species. Scientific names usually come from Latin or Greek. An example is <i>Homo sapiens</i>, the scientific name for humans</p> <p>Scion A piece of twig or shoot inserted on another in grafting</p> <p>Scout Someone who monitors crops for pests and diseases, to compile reports for control recommendations</p> <p>SDS Safety Data Sheet</p> <p>Secondary infection Any infection caused by inoculum produced as a result of a primary or subsequent infection.</p> <p>Secondary inoculum Inoculum produced by infections that took place during the same growing season</p> <p>Seed bank 1. The soil seed bank is the natural storage of seeds, often dormant, within the soil of most ecosystems. 2. The gene seed bank is the storage of seeds as a source for planting crops in case seed reserves elsewhere are destroyed</p> <p>Selective pesticide A product that is toxic to some pests, but has little or no effect on other similar species or is harmless to beneficial organisms</p> <p>Semiochemicals Non-toxic chemicals such as sex pheromones which modify insect behavior patterns, eg mating</p> <p>Serology A method using the specificity of the antigen-antibody reaction to detect and identify antigenic substances and the organisms that carry them</p> <p>Serum The clear, watery portion of the blood remaining after coagulation</p> <p>Shelf life The duration of efficacy and keeping quality of a product under normal storage conditions</p> <p>SIAA Seed Industry Association of Australia</p> <p>Signal heading The level of hazard of a pesticide on a label which also includes instructions to keep the product out of reach of children, and to read the safety directions before opening or using the product</p>	<p>Silo effect A lack of information flowing between groups or parts of an organization</p> <p>Simulation Imitation of the operation of a real-world process or system over time</p> <p>SIRM Sterile Insect Release Method</p> <p>SIT Sterile Insect Technique</p> <p>SmartTrain A nationally accredited chemical user's training course for commercial operators</p> <p>SMH Sydney Morning Herald</p> <p>Soil injection The placement of a pesticide below the surface of the soil</p> <p>Soil residual A pesticide, usually a herbicide, applied to soil where it remains active for some time after application</p> <p>Soil sterilant A chemical or agent that prevents the growth of all organisms present in the soil; non-selective pesticide</p> <p>Solarization A nonchemical method for controlling soilborne pests using high temperatures produced by capturing radiant energy from the sun. The method involves heating the soil by covering it with a clear plastic tarp for 4 to 6 weeks during a hot period of the year when the soil will receive the most direct sunlight</p> <p>Solubilization To make (a substance such as a fat or lipid) soluble or more soluble, especially in water, by the action of a detergent or other agent</p> <p>Solvent A liquid such as water, oil, xylene or alcohol, which will dissolve another substance (solid, liquid or gas) to form a solution</p> <p>SOM Soil Organic Matter</p> <p>SOP Standard Operating Procedures</p> <p>sp. species</p> <p>Spectrum of activity The range of pest organisms controlled by a pesticide; broad spectrum pesticides control a wide range of different pest species; narrow spectrum pesticides control a limited number of pest species; specific pesticides control a single pest species or a well-defined class of pests</p> <p>SPIPM Systemwide Program of IPM</p> <p>Spore The reproductive unit of fungi consisting of one or more cells, analogous to the seed of green plants</p> <p>Spot treatment Application to small areas</p> <p>spp. More than 1 species</p> <p>Spray deposit The amount of chemical that remains on a sprayed surface after the droplets have dried</p> <p>Spray grazing An integrated approach to weed control using herbicides and livestock</p> <p>Spray topping The late application of herbicides to prevent weed seed-set</p> <p>SQF Safe Quality Food</p> <p>SRS Soil Reduction Sterilization</p> <p>Stacked genes The process of combining two or more genes of interest into a single plant</p> <p>Stakeholder A person or group that has an investment, share, or interest in something, as a business or industry</p> <p>Standards Published documents that set out specifications and procedures designed to ensure products, services and systems are safe, reliable and consistently perform the way they were intended to</p> <p>Sterilization The process of removing or killing all viable organisms from soil, containers, etc by heat or chemicals</p> <p>Stock plants The source plant from which cuttings or explants are made. Stock plants are usually maintained carefully in an optimum state for (sometimes prolonged) explant use. Preferably they are certified-pathogen-free plants</p> <p>Stomach poison A pesticide that must be eaten by an animal in order for it to be effective</p>
---	---	--

Stomates Small openings on leaves, twigs and other plant parts which regulate the flow of water from the plant into the atmosphere and admit carbon dioxide from the atmosphere for photosynthesis

Strain The descendants of a single isolation in pure culture, a group of similar isolates, a race

Suicide gene A gene whose expression in a cell is lethal for that cell

Superweeds Weeds that are immune to the herbicides that used to keep them in check

Surface spray A pesticide which is sprayed evenly over the entire outside of the object to be protected

Surveillance Close observation or monitoring of insects, beneficial insects, etc; counting numbers, recording presence of or behavior, or other changing information

Susceptibility The inability of a plant to resist the effect of a pathogen or other damaging factor

SUSDP Standard for the Uniform Scheduling of Drugs and Poisons

Suspension A chemical mixture of fine particles dispersed or floating in a liquid, usually water or oil

Sustainable The ability to maintain a certain status or process in existing systems

SVI Seed Vigor Index

Swath The width of an area covered by one sweep of an aeroplane, ground sprayer, spreader or duster

Symbiosis A mutually beneficial association of two or more different kinds of organisms

Symptom The external and internal reactions or alterations of a plant as a result of disease

Synergism 1. The concurrent parasitism of a host by two pathogens in which symptoms or other effects produced are of greater magnitude than the sum effects of each pathogen. 2. The effect of two or more chemicals applied together which is greater than the sum of the individual chemicals applied separately.

Synergist A chemical which increases the activity of another pesticide, eg piperonyl butoxide increases the activity of pyrethrum

Synthetic May imply being prepared or made artificially or naturally, but also the combination of two or more parts, by design or by natural processes

Systemic 1. A chemical that is absorbed and translocated within a plant, usually via the vascular system, which has some action against a pest at a point remote from the site of application. 2. An infection that spreads internally throughout the plant

Systemic acquired resistance A mechanism of induced defense that confers long-lasting protection against a broad spectrum of microorganisms

Systems approach –Interrelated processes that make up an organization as an integrated system and which interact with one another to achieve an outcome

Tank mix A mixture of products in a spray tank

Tas Tasmania

TCO Tasmanian Certified Organic

Tetraploid A cell with 4 complete sets of chromosomes

Therapeutic Curative

Threshold A borderline level above which a reaction will take place, eg yield loss

TLV Threshold Limit Values

TM Trade mark

TMV Tobacco mosaic virus

Tolerance 1. The ability of a plant to yield well in spite of disease and pest attack. 2. **Pest organisms** tolerant of stress, weather, pesticides. 3. The amount of **toxic residue** allowable in, or on edible plant parts, under law

TOMCAST A computer model based on field data that attempts to predict certain fungal disease development on tomatoes

TOP Tasmanian Organic Dynamic Producers

Total herbicide, vegetation, or weed control A herbicide which kills all plants, non-selective herbicide

Toxic Poisonous to living organisms

Toxicity A pesticide's capacity to damage organisms other than target pests, eg humans, domestic animals, birds, fish, bees, beneficial insects, fungi and plants; compare with activity

Toxin A compound produced by plants, animals or microorganisms which is toxic to a plant or animal

TQM Total Quality Management

Traceability The ability to verify the history, location, or application of an item by means of documented recorded identification

Trace back To trace the origin or development of something, to find out or describe how it started or developed

Tracking A path or trail that is made by people, vehicles or animals, eg tracking pesticides after application

Trade mark A recognizable sign, design or expression which identifies products or services of a particular source from those of others

Trade name, trading name, or business name A name that a business uses for trading commercial products or services

Trait A distinct variant of a phenotypic character of an organism that may be inherited, be environmentally determined or be a combination of the two

Transgenic plants or crops Genetically modified crops. Crops of plants produced by genetic engineering

Translocation Transfer of a pesticide, nutrients, or disease organisms within a plant from the site of entry

Transmission The transfer of a virus or other disease from one plant to another

Transpiration The loss of water vapor from the surface of leaves and other aboveground parts of plants

Trophic Refers to food or feeding - nutrition

Trophic level The position that an organism occupies in a food chain - what it eats, and what eats it

TSWV Tomato spotted wilt virus

TwinLink Technology Combines insect-resistance management of a number of lepidopteran pests (caterpillars) and tolerance to glufosinate-ammonium herbicides (Liberty®). TwinLink technology will be offered to US cotton growers as a stack with GlyTol®, the company's glyphosate tolerance technology. This stacked product will be the industry's first dual-gene herbicide tolerance and dual-gene insect resistance solution for cotton, allowing farmers to manage the pests and weeds as well as prevent or postpone the onset of weed and pest resistance

UAV Unmanned aerial vehicle, a drone

Ug99 A strain of black stem rust of wheat, considered by some to be the biggest threat to wheat production worldwide

Ultrasound An oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range

ULV Ultra-low volume spray

UNE University of New England

Upwind If a person is spraying upwind the spray is moving into the wind

USA United States of America

USDA United States Department of Agriculture

USNOP United States National Organic Program

UV Ultra-violet light

Vapor Gaseous form of a compound which is normally present as a liquid

Vapor pressure The property which causes a chemical to evaporate, the higher the vapor pressure, the more volatile the chemical and the easier it will evaporate

Vector An insect, nematode, mite, or parasitic plant that can transmit a pathogen from one host to another

Vegetative Non-sexual; eg cuttings

Vendor declarations Records of all crop treatments, eg fertilizers, chemicals, etc, applied on the grower's property within a certain distance of the crop, and other information

Verge plantings Plantings along the edge or border of a road, river, etc

Verification A process which uses objective evidence to confirm that specified requirements have been met

Vic Victoria

Virulence The ability of an agent of infection to infect the host

Virulent Capable of causing a severe disease; strongly pathogenic

Virus A submicroscopic infectious organism, a non-cellular structure consisting of a core of DNA or RNA surrounded by a protein coat. Can only reproduce in living cells

Volatility The degree to which a substance changes from a liquid or solid state to a gas at ordinary temperatures when exposed to air

VRA Variable Rate Application

WA Western Australia

Water table The upper level of the water saturated zone in the ground

Webinar A seminar on the Internet

Weed seed wizard A National collaborative project which uses paddock management information to predict weed emergence and crop losses now and in the future

WFT Western Flower Thrips

WHO World Health Organization

WHS Work Health and Safety

WHP Withholding period

Withholding period The minimum period (in days) which must elapse between the last application of the product and the end use

WONS Weeds of National Significance

Worksafe Australia now **Safe Work Australia**

WRA Weed Risk Analysis

WSM Whole System Management

WTO World Trade Organization

WUE Water Use Efficiency

Xeriscape A garden or landscape created in a style that requires little or no irrigation or other maintenance, used in arid regions

Xylem Part of the vascular system that conveys water and dissolved minerals from the roots to the rest of the plant and may also provide mechanical support

Zero No quantity or number; nought; the figure 0, eg zero risk, zero tolerance

Zero-till The only cultivation is for low disturbance sowing using either knife points or disc seeders

Zn Zinc

Zones An area of land having a particular characteristic, purpose, or use, or subject to particular restrictions, eg Fruit Fly Exclusion Zone (FFEZ)

ZT Zero-till

INDEX

- 1st Generation nanomaterials 421
1st Generation OC, OP, carbamate 434, 435
2nd Generation (synthetic pesticides) 436-437
3rd Generation biopesticides 438-440
3rd party audit 350
3D lasers 373
3D printing 10 (see glossary)
3 Generations of pesticides 432-440
4 pillars policy 298, 424
ABC groupings on pesticide labels 288
Abiotic diseases see Non-parasitic problems
Abrasive/absorptive dusts 231
Absorption of pesticides 300
Accidents, incidents and mishaps 311
Accreditation
Agsafe, staff and premises 281
Fertcare 49
nursery 325
organic standards 381-396
pesticide manufacturers 281
pesticide user training 274-280, 312
quality assurance (QA) 320
Acibenzolar-S-methyl (ASM) 158
Acidity 48
Active constituent (AC) 288, 294
Additives 36
Adverse Experience Reporting Program 264
Aerated steam 215
Aeration (grain) 237
AGCAS 325
AgDIS 286
Agdrift 286
Agricultural and veterinary (agvet)
chemicals 259
Agricultural Biotech Council of Australia
(ABCA) 410
Agricultural chemical products 258
Agsafe, manufacturers and retailers 281
DrumMUSTER 282, 309
ChemClear 282, 309
ChemCollect 309
FertCare 31, 49
personnel 281
premises 281
Agvet chemicals 259
Agvet Code 260
Air atomization 88
Air, contamination 224
Algae 61
Alkalinity 48
Allelopathy 59, 150
allelopathy and weeds 93
Allowed products 387
Aluminium foil 235
Analysis
epidemics 406
import risk analysis 180, 181
soil, water, plant) 51
weed risk analysis 181
Animal manure 44, 72
Antagonistic 112, 115
Antibiosis 112, 115, 141
Antibiotic substance 115
Anticholinesterase 149, 434
Anti-drift agents 307
Anti-transpirants 32, 439
Ants, grease bands 246
Aphids 98, 108
Russian wheat aphid 178, 187
woolly aphid 139, 149
Apples and pears
black spot (scab) (photo) 13
biological control 124
IPM program 351
Application
biocontrol agents 88
pesticides 432
Approved Certifying Organizations 388, 389
Approved products 387
APVMA 259-265
AQF 274-280
AQIS see Biosecurity
Arabidopsis 168
Architecture (plants) 62, 145, 148
Area freedom 191, 197, 218
Area wide 151, 244, 310, 338
Assessment 276, 313, 444
Atlas of Living Australia 189
Attractive signals 232
Attractive wavelengths 234
Audit 322
EMS 350, 364
IPM 3rd party audit 350
managing a crop 332
organic systems 386
quality assurance 320-324
Augmentation 125
Auschem 278
AUS-QUAL 323, 389
Australian
Australian Certified Organic (ACO) 388
Australian Dangerous Goods Act 266
Australian Dangerous Goods Code 266
Australian Garden Centre Accreditation
Scheme (AGCAS) 325
Australian Pesticides & Veterinary
Medicines Authority (APVMA) 259
Australian Quarantine & Inspection
Services (AQIS) see Biosecurity
Australian Qualifications Framework
(AQF) 274-280
Australian Standard for Organic and
Biodynamic Products 382
Australian standards see Standards
AusVIT 347
Autumn tickle 62
Avoidance 218

Bacillus subtilis 99, 115
Bacillus thuringiensis (Bt) 99, 108
Bacterial diseases
bacterial canker, stone fruits 68
citrus canker 68
crown gall 115, 122, 409
fireblight 122
Bacteriophage 113
Bait plants 59, 104-105
Bands on trunks of trees, grease 246
Banker plants 107
Bark 67
Barriers 249-252
birds, dogs, mice, rabbits, rats 249
climate control 251
diseases 251
edible coatings 251
filtration, sieving 252
geofabrics, bagasse, Hort Fleece, etc 252
insects, screens, packaging 250, 253
netting, fences, tree guards 249
root barriers, diseases 251
snails barriers 249
Bees 308, 430
bee decline 377
label directions 291
pesticides (IPM) 349
pollination 33
spray guides 130
spread biocontrol agents 88
varroa mite 131
Beetles
beneficial beetles (ladybirds) 108-110, 126
black vine weevil 108
Christmas beetles 35
elm bark beetle, chipping 70
elm leaf beetles 60
eucalypt leaf beetles 105
Japanese beetle 193
Khapra beetle 13, 178
scarab grubs 100, 108, 148
Beneficials
bacteria, fungi, virus, nematodes 100, 112,
122-124, 126
beneficials and pesticides 130, 291, 349
insects, mites 98, 106, 108-111, 126
pests and beneficial triangle 12
BEST MANAGEMENT PRACTICE (BMP) 363
environment 363
fertilizers 52
pesticides 300
water 37, 363
Bicarbonates 439
Biochar 45
Bioclays 119, 422
Biocontrol agents (tables)
diseases 122
insects, mites 108
weeds 94
Biodegradable mulches 47
Biodiversity 151, 362, 378, 393
Bio-dynamic produce 382
Bio-Dynamic Research Institute 389
Biofertilizers 53, 118
Biofortification of crops 411
Biofumigation 47, 57, 156
Biofungicides 112, 158, 439
Bioherbicides 91, 439
Bioinoculants 116-119
Bioinsecticides 99, 100, 108
Biological chemical product 87, 258, 438
BIOLOGICAL CONTROL 83-136
application equipment 88
augmentation 125
biocontrol of diseases 112-124
diseases table 122-124
biocontrol of insects 98-111
insects tables 108-111
biocontrol of weeds 91-97
weeds table 94-97
biosecurity and citrus 132
chemicals with beneficials 125, 130, 349
classical biocontrol 84
effective biological control 125, 131
microclimate 127-129
organic produce & biocontrol 132
red scale citrus 133
suppliers 125
techniques 86
Biological farming 376
Bion 158, 439
BioNew 376
Bionics, Biomimicry 422
Biopesticides 438-440
Biopriming seeds 119
Bioprotectants 156
Biorational pesticides 438-440
Biosecure HACCP 325, 367
BIOSECURITY 171-204
Australian government 172, 175, 177-195
biosecure HACCP 325, 367, 373
border 182-185
certification 194
detector dogs 184
Emergency Plant Pest (EPP) 173, 175,
186, 188, 191, 192, 196
eradication programs 192
exotic plant pest hotline 187
exports 194
fruit fly strategies 195, 197
High Priority Pest (HPP) 173, 175, 178,
186, 191
imports, risk analysis, getting import
approval 179-181
industry manuals 175, 186, 187
industry plans 175, 186, 187
integrated pest management 354
Northern Australian Quarantine Strategy
182, 190
offshore 178-181
on-farm, orchard, nursery 200-202
onshore 186
outbreaks 189
pest free areas 191, 197, 218
post-entry facilities 184, 250
quarantine approved premises 184, 250
quarantine Domestic 196-199
recent incursion, interceptions 185
redline 184

- BIOSECURITY** (contd)
 sanitation 77, 78
 State/Territory/Regional 196-199
 surveillance and monitoring 190
 training (Bolt, etc) 188
 treatments 184
Biostimulants 53
 Biosurfactant producing bacteria 113
Birds, anti-roosting coils, netting 249
 gas guns, other frightening devices 232
 sticky gels 246
Black spot
 apples, pears (photo) 13
 rose (photo) 139
 Blue traps 247
 Boiling 73
 Boom and bust cycles 162
 Boots, shoes 74
 Border Biosecurity 182-185
 Botanical extracts 440
 Botrytis *see* Grey mold
Brand names
 pesticide label 288
 programs 324, 360, 366
Brassicas
Arabidopsis 168
 cabbage white butterfly 84
 canola (black leg) 165
 club root 48
 color, resistance 148
 Break crops 142
 Breakdown of resistance 162
 Breeding conventional and GE 154
 British Retail Consortium (BRC) 323
 Broad mite 111
 Brushcutters, mowers, vehicles, etc 76
 Brushing off bark 67
Bt see Bacillus thuringiensis
Buffer zones
 GM crops 415
 pesticides 263
 pesticide spray drift, no spray zones 307
Bulbs
 biosecurity 181, 183
 contaminated bulbs 208, 214
 crop rotation 56
 daffodils 208
 heat treatments 214
 plant protection districts 218
 rogueing 69
 virus-tested planting material 222
 Burning 73, 242
 Burying 73
Butterflies and moths
 cabbage white butterfly 84
 cactoblastis moth 94
 codling moth 246
 cardboard bands on trunks 246
 lures 245
 pheromones 101-102
 sanitation 67
 virus disease of codling moth 108
 currant borer moth 108
Helicoverpa spp. (budworms) 133
 biological control 108
 lightbrown apple moth
 habitat manipulation 107, 132
 pheromones 101, 102, 108
 virus bioinsecticide 99
 oriental fruit moth 101, 102, 196
 potato moth
 habitat manipulation 107
 pheromones 101
 virus bioinsecticide 99
-
- Calendar spraying (reduced) 336, 347
 Callistemon 93, 153
 Canopy Chlorophyll Content Index (CCCI) 373
 Carbamates 434
 Carbon 45
 Cardboard 246
Carnations
 certification scheme 222
 contaminated planting material 208
 frost 34
 meristem culture 217
 vegetative propagation material 222
- CAUTION** (label) 288
 Certification 320-325, 350 (IPM)
Certification schemes 219-222
 certified potatoes 222
 Citrus Nursery Certification Scheme 156
 disease-tested 219-222
environment / sustainable
 Ecohort, Enviroveg, Freshcare 367-369
 GEO Certified 371
 interstate certification 197
 management 223 226
organic standards
 approved certifying organizations 383, 388
 certification requirements 386
 certified organic 386, 388-389
 conversion to organic 386
pesticide training 273-280
 Agsafe accreditation 281
 Auschem/Chemcert accreditation 278
 certified Nursery Professional 325
 SmartTrain accreditation 280
 phytosanitary certification 219
 plant protection districts 218
 preventing reinfestation, etc 223-225
 quality assurance (QA) 320
 seed certification schemes 221
 steps in certification schemes 219, 220
 Toolangi Plant Projection District 218
 vegetative propagation schemes 222
- Challenges**
 biological control 134
 biosecurity 203
 control methods 28
 cultural methods 63
 disease-tested planting material 227
 environmental management 379
 genetic engineering 416-418
 holistic management 402
 integrated pest management 357
 management & quality assurance 326
 nanotechnology (issues) 422-444
 organic 394
 pesticides (issues) 297-316
 physical methods 255
 resistant varieties 169
 sanitation 81
- Checklists**
 apples and pears IPM 351
 integrated pest management 350
 nurseries 351
 pesticides 432
 ChemCert 278
 ChemClear 282, 309
 ChemCollect 309
 chemicals in plants (resistance) 149
 Chemical user training 274-280, 312
 Chemwatch 293
 Chilling 145
 Chipping trees and shrubs 70
 Chitin, chitosan 158
 Chromosomes 140
Chrysanthemum
 contaminated planting material 208
 meristem culture 217
 tip cuttings, Verticillium-free 216
 white rust (photo) 193
- Citrus**
 certification scheme 325
 citrus canker (sanitation) 68
 citrus gall wasp (sanitation) 69
 citrus pests (biocontrol) 109
 cross protection 156
 shoot tip grafting 216
 wind damage 38
- Climate**
 Climag 41
 climate change 41, 152
 Climate Kelpie 41
 CLIMEX 347
 Closed measuring systems 300
- Codes of practice**
 biosecurity 176
 environment 362
 pesticides 270, 271
 Collars around plants 249
 Collecting, picking off insects 67
 Color 148
 Colored shade clothe 235
 Color film 235
- Colored sticky traps 247
 Colored light 234
 Commonalities of control methods 25
 Commonwealth legislation APVMA 259
 Communication signals 232
 Community health and safety 299
Companion plantings 104-105
 repellent plants 105
 trap plants 104
 Competition for food/space 114
 Competitive crops 62
 Compliance and enforcement 265
 Composting 71, 243, 431
 Conductivity 160
 Conferred resistance 141
 Conflict resolution 27, 297
 Conformity Assessment Bodies (CABs) 323
 Confusing terms (sustainability) 360, 361
 Cons *see* Pros and Cons
 Conservation agriculture 57, 62, 121, 374
 Conservation tillage (CT) 54-55, 374
- Containers**
 biosecurity 183, 300
 pesticides (*DrumMUSTER*) 282, 309
 plant pots, tubes, etc 75
Contaminated plant material 208-211
 testing 212
 treatments 213-218
 Contingency plans 178, 186, 188, 189, -191
 Contraceptive for weeds 93
- Contractors**
 biosecurity 183, 187, 191, 200
 pesticides 78, 80, 272
 Controlled traffic (farming) 37, 54, 55, 372
- Control methods**
 general 15-28
 commonalities 25
 crop stages 22
 exclude, eradicate, contain, manage 20
 management & QA 317
 people 27
 pest / control triangle 21
 pest triangle 16
 preventative and curative 19
 time 26
methods 15
 biological control 83
 biosecurity 171
 cultural methods 29
 disease-tested planting material 205
 pesticides 257
 physical methods 229
 resistant varieties 137
 sanitation 65
- Control of Use (pesticides)**
 legislation (state/territory) 259, 268-269
 training 274-280
 Conversion to organic 386
 Cooling treatments (fruit fly) 238
Copper compounds 430, 435, 437
 liquid formulations 437
 persistence 430, 434
 toxicity to plants 306, 435
- Cotton**
 biocontrol agents 108
Bt cotton 412
 cotton hygiene 79
 cotton myBmp, etc 399
Helicoverpa trap plants 104
 Cover crops 93
 Crop diversity 59
 Crop, farm, area, region 338
 Crop improvement programs 143
 Croplife Australia 303
 Crop management 327-332
 Cropmate 41
 Crop residues 54
 Crop rotation 56, 142, 374
Crop stages 22, 330
 establishment 22, 330
 harvest, postharvest 22, 332
 maintenance 22, 331
 selection 22, 330
 Cross protection 156
 Cross-resistance 303
 Cultivation 54, 236, 394
CULTURAL METHODS 29-64, 342, 347
 Curative control methods, decision-making systems, warning systems (IPM) 347-349

- Dak.pot **101, 245**
 Dangerous Goods diamond **292**
 Dangerous goods, diamonds **266, 292**
DANGEROUS POISON (label) **288**
 Decision-making **347**
 Decision Support Systems (DSSs) **347-349**
 Defense activators **156, 157, 165, 433**
 Deficiencies nutrient **48-52**
 Degradation, land **43, 54, 371, 374-376**
 pesticides residues **308, 429**
 Demeter biodynamic **389**
 Dermal absorption **300**
 Detector dogs **184**
 Diagnostics **see Identify the pest, disease or weed**
 Diamond hazard shapes on labels **266, 292**
 Diazotrophs **117**
 Digging **69, 236**
 Directions for use **289**
 Disease break **56**
 Disease cycle (inoculum) **405**
 Diseased and infested plant material **67, 208**
 Disease eradication **20, 192**
 Disease resistance standards **161**
 Diseases **see Bacterial diseases, Fungal diseases, Nematode diseases and Virus diseases**
 Disease-suppressive soils **120-121**
DISEASE-TESTED PLANTING MATERIAL 205-228
 contaminated air **225**
 contaminated soil **225**
 contaminated water **225**
 disease-tested or disease-free? **207**
 disinfection **75, 214**
 disinfestation **213, 223**
 management **223**
 non-systemic chemicals **213**
 reinfestation, reinfestation **223-225**
 seed certification schemes **221**
 systemic chemicals **215**
 testing plant material **212**
 vegetative propagation certification schemes **222**
 Disease triangle **see Triangles**
Disinfectants 75
 pruning tools **74**
 Disinfection **75, 214**
 Disinfestation **213**
Disposal and recycling 70-73
 animal manure **72**
 composting **71, 431**
 disposable PPE **300**
 green waste **70**
 infested plant material **67-69**
 nursery run off **72**
 pesticide containers (DrumMUSTER) **282, 309**
 pesticide label **292**
 pesticides (Chemclear) **282, 309**
 pesticides (ChemCollect) **309**
 safety data sheet **293**
 water **72**
 Ditches **250**
 DNA **7, 140, 189**
 Documentation **see Records**
 Dogs, detector quarantine **184**
 Domestic quarantine **196**
 Domsday vault **151**
 Double knockdown application **436**
 Downy mildews **see Fungal diseases**
Drift (pesticides) 263, 307
 buffer zones **263, 307, 363**
 Drift Reduction Technologies (DRTs) **307**
 drift retardants **307**
 drift (spray drift) **263, 290, 307**
 droplet size (label) **290**
 pesticide registration **263, 286**
 training **307, 312**
 weather **263**
 Drift Reduction Technologies (DRTs) **307**
 Droplet size **263, 290**
 Drought and flood tolerance **144**
 DrumMUSTER **282, 309**
- Dual salt technology **437**
 Dung pads **90**
 Dusts, abrasive and absorptive dusts **231**
 Duty of care **272**
- Ecohort **325, 367**
 Ecologically sustainable development **370**
 EcoNaturalure **102, 391**
 Economic injury threshold **346**
 Electric discharges **231**
 Electric fences **231**
 Electric grid lights **235**
 Electromagnetic Induction (EMI) **373**
 ELISA **212**
Emergencies
 biosecurity 192
 Emergency Plant Pest (EPP) **173, 188, 191**
 Emergency Plant Pest Response Deed (EPPRD) **173, 192**
 High Priority Pests (HPP) **173, 187, 190, 195**
 pesticide label (First Aid) 292
 Emerging pests **172 see also Upsurges**
 Endogenic heat **71, 243**
 Endophytes **116, 150, 156**
 English as a second language **312, 443**
 Envirofeast (attracts beneficials) **102**
ENVIRONMENTAL MANAGEMENT 359-380
 code of practice, standards **362, 369**
 ecologically sustainable development **370**
 environmental assurance for horticulture **366-369**
 environmental gases **232**
 green code **369**
 integrating EMS with other controls **377**
 nanotechnology **419-424**
 pesticide labels (livestock, plants) **291**
 pesticide residues in food **308, 429-430**
 safety data sheets **293**
 standards **362-364, 367, 370, 377**
 Enviroveg **368**
 Envy (antitranspirant) **32, 439**
 Epidemics **403-408**
 Equipment, machinery **74, 77-80**
 Eradication (host removal) **20, 68, 192**
 Eradicoat **440**
 Escape (resistant plants) **140, 141, 162**
Eucalypt
 Eucalypt Canopy Condition Index (ECCI) **373**
 eucalypt leaf beetles **105**
 Eurogap (now Global gap) **322**
 European and Mediterranean Plant Protection Organization **119**
 Evaluation **see Audit**
 Evasion **218**
 Exclude, Exclusion zones **20, 197, 218**
 EXDOC **194**
 Existing Chemical Review Process **264**
 Exotic Plant Pest Hotline **190**
 Expert systems **325, 347**
Expiry dates
 biocontrol agents **125**
 inoculants **119**
 organic certification, approved certifying organizations **288**
 pesticide products **262**
 pesticide training **277, 281**
 respirators **300**
 Export organics/trade **387**
 Export, trade and surveillance **194,**
 Exposure to pesticides, safety data sheet **293**
- Fact Sheets **329, 341**
 Following **58**
 Farm biosecurity **200, 356**
 Farm Chemical Users Course **274-280**
 Farmers Markets **376**
 Farm Management System (nursery production) **325, 367, 400**
Fertilizers 49-52
 liquid **52**
 nanotechnology **421**
 NPK **50**
 Nutrient tests, soil, water, plants **51**
- Field crops see also Cotton**
 barley (loose smut) **214**
 canola (black leg) **165**
 cereal diseases **164, 354**
 cereal rusts **5, 142, 159, 162-164, 178**
 certification schemes **221**
 wheat (resilience) **375**
- Films **235**
 Filtration **252**
FIRST AID
 label **292**
 safety data sheet **293**
 Fit for purpose products **44, 52**
 Flame guns **242**
 Flexible decision making **41, 348**
Flies
 fruit flies **see Fruit flies**
 fungus gnats **109**
 house flies **109, 235**
 sheep blowflies **103**
 Flooding **35, 144**
 Floors **75**
 Florabank **159, 210**
 Flying spore traps **248**
 FMS EcoHort Guidelines **325**
 Food, Food chain **308**
 Food miles **361, 366**
 Food safety **262, 266**
 Food Standards **266, 410**
 Footwear **74, 200**
 Forecasting diseases **see Warning services**
 Formulations (new) **437**
 Foxes **89, 244, 246**
 Freezing **238**
 Freshcare **369**
 Frightening devices **232**
 Frost **34, 249, 251, 252**
 Frost tolerance **34, 159**
Fruit see also apples and pears, citrus, stonefruit, strawberry
 certification schemes **222**
 cherry **77**
 disease rating **161**
 mango **77, 93**
 sanitation **67**
 strawberries
 washing fruit **69**
Fruit flies 245
 augmentation **103, 125**
 biosecurity **178, 188, 190, 191, 195, 197**
 cool treatments **238**
 Dak.pot **101, 245**
 Fruit Fly Exclusion Zone (FFEZ) **195, 197**
 heat treatments **239**
 homemade traps **244**
 integrated pest management **338**
 irradiation **233**
 lure & kill **102**
 Male Annihilation Technique (MAT) **102**
 parasitic wasps **103, 125**
 pheromones **101, 102**
 sanitation **67, 73**
 sex traps **245**
 sterile Insect Technique (SIT) **103**
 Fumigants **132, 306**
 Functional foods **411**
Fungal diseases 122-124 see also black spot, grey mould (Botrytis), Phytophthora diseases, rust diseases, soilborne diseases, Verticillium wilt,
 biological control **122-124**
 black leg (canola) **165**
 black spot (scab) pome fruits **124**
 black spot (rose) **37, 139** (photo)
 brown rot (stone fruit) resistance **69, 148**
 bulbs **237**
 chestnut blight **122, 192**
 club root (brassicac) **48**
 common scab (potatoes) **48**
 downy mildews **23, 162, 237, 435, 439**
 Dutch Elm disease, chipping **70**
 Eutypa dieback **122**
 heart rot, wood rot **123**
 loose smut of barley **214**
 necrotrophic fungi **153, 157**
 powdery mildews **68, 69, 142, 435**
 pre- and post-harvest diseases **122, 232**
 spore assays **7, 248**

<p>FUNGICIDES see also Pesticides 3 generations of pesticides 432-440 biofungicides 112, 439 Nogall (<i>Agrobacterium</i>) 115, 122, 439 Tricho (<i>Trichoderma</i>) 124 copper 435, 437 disease resistance and fungicides 143 formulations (new) 437 fungicide resistance 428 phosphanates, phosphites 439 protectant fungicides (biocontrol) 134 residues, persistence 308, 429 resistance, development of 427, 303 seed treatments 215, 437 soil fungicides 314 sulphur 435 systemic / non-systemic fungicides 435 thiram 435</p>	<p>Grey mold (<i>Botrytis</i>) (contd) relative humidity 37, 237 smart films 235 temperature for spore germination 127 <i>Trichoderma</i> sp. 113 Groundcover 46 Growcom 293 Growing the crop 327-332 audit 332 establishment (crop) 331 harvest and postharvest (crop) 332 improve 332 maintenance (crop) 331 selection (crop) 330 Grow-me-instead 377</p>	<p>Identify the pest, disease or weed (contd) flying spore traps 7, 248 GM material 415 host, pest, beneficial relationships 340 key pests and beneficials 339 nanotechnology 421 pest triangle 16 pest triangle and beneficials 340 pest triangle and control 21 plagues and epidemics 403-408 protocols 189, 194, 212 remote microscopic diagnosis 189 tests, new tests 13 Incidents and mishaps (pesticides) 311 Immunity 141 Importing plants and plant materials 179 import approved 179 Import Risk Analysis (IRA) 180, 181 Improve crop management 332 Improvement programs 153 Indexing 212 Indicator plants 212 Industry Biosecurity Manuals 187 Industry Biosecurity Plans 187 Industry waste reduction scheme 282, 309 DrumMUSTER 282, 309 chemclear 282, 309 chemCollect 309 Inert ingredients 432 INFFER 365 INFINDER 293 Infopest 258 Information, communication & technology prelims <i>ix</i> biological control 88 biosecurity 174, 175 control methods 17 cultural methods 30 crop management 32, 329 diagnostics, identifying the pest 3-5, 7 disease-tested planting material 206 environmental management 365, 373 holistic management 397, 401 IPM 334 management 318, 319 organic standards 385 pesticides 258-261, 268, 270, 274, 283, 299 physical methods 230 quality assurance 320, 321, 301, 312 resistant, tolerant varieties 138 sanitation 66 Infrared burners 242 Inhalation, of pesticides 300 Inoculant standards 118, 119 Inoculum 404-405 Inputs on-farm Biosecurity 200 organic standards 385, 386</p>
<p>GE crops (GM crops) 152, 154, 409-418 Gene banks 151, 152 GeneEthics Network 416 Genes 140 Genetically manipulated plants 409-418 Genetically modified organisms (GMOs) 409-418 biocontrol agents 88 cultural methods 31 Genetic engineering 409-418 buffer zones 415 chromosomes 140 control methods 413 detecting GM contamination 415, 417 elicitors 55 food standards 410 functional foods 411 gene regulators (promoters) 154 gene shears 409 Gene Technology Act 273 Gene Technology Regulator (GTR) 410 healthcare 411 herbicide resistant crops from biotechnology (HRCB) 165, 414, 415 industry 411 management 415 marker genes 409 multiple traits 166 nutraceutical foods 411 pyramid strategy 154, 166, 412 resistant varieties 152, 154 stacked genes 154, 166, 412 uses 411 GEO Certified 371 Geofabrics 252 Geographic Information Systems (GIS) 373 Giant African snail 178 GlobalGap 322 Global Positioning System (GPS) 373 Glyphosate 370 see also Herbicides double knockdown application 436 herbicide resistant crops from biotechnology (HRCB) 165, 414, 415 resistance 203, 427 Roundup Attack with IQ Inside 436 Roundup Dual Salt Technology 437 Roundup Ready crops 165, 415 Roundup Ready Flex Technology 414 GM crops 152, 154, 409-418 Golden rice 411 Good Manufacturing Practice 323 Grapevine certification scheme 222 Grazing and mowing 70 Grease bands 246 Green bridge 58, 68, 164, 224, 415 Greenhouses see Nurseries Greenseeker technology 52, 373 Green vegetable bug 109 Green waste 70 Grey mold (<i>Botrytis</i>) 61 <i>Bacillus subtilis</i> 114, 115 bees 88 biocontrol of weeds 94-97 hot air 239 nectrotrophic fungus 153 postharvest 22, 123 reflective films 251</p>	<p>Habitat manipulation 106, 107, 132 Habituation 232 Handpicking pests 67 Hands 74 HACCP 322 Harmonizing legislation (pesticides) 260, 268, 273, 298 Harrington Seed Destructor 236 Harvest, postharvest 42, 332 Hazardous products 288 in the workplace 300 pesticide label 432 safety data sheet 293 Health monitoring 300 Heat treatments 214, 239-243 endogenic heat 71, 243 hot air 239 hot water 239 soil steam 240 solar heat 215 solarization 241 sterilization & pasteurization 240 stored grain 253 Henry Doubleday Research Association of Australia (HDRA) 390 HERBICIDES see also Pesticides 3 generations of pesticides 432-440 bio-herbicides 91, 439 glyphosate see Glyphosate herbicide injury (phytotoxicity) 147 Herbicide Resistant Plants from Biotechnology (HRPB) 165, 415 hormone herbicides (2,4-D) 147, 307 persistence 430 phenoxy acid herbicides 147, 307 plant-back times 262, 291 resistance 427 Roundup see Glyphosate selective herbicides 307 spray drift see Drift (pesticides) HOLISTIC MANAGEMENT 397-402 Hormone herbicides 147, 307 Horticulture Australia (HAL) 62 Horticulture for Tomorrow 366, 369 Horticulture Fresh Australia (HFA) 160 Hortideck 251 Host eradication 68, 192 Host, pest, beneficials, environment 128 Hot air 239 Hot water treatments 213, 214, 239 Humidity 37, 237 Humming lines 232 Hybridization 154 Hydroponic lettuce (diseases) 133 Hydrosmart 231 Hygiene see Sanitation Hyperparasite 113 Hypersensitivity 149</p>	<p>Identify the pest, disease or weed 1-14 biological control 126 biosecurity diagnostic network 189 data collection 373 diagnosis and control 12-13, 17 diagnostic networks and resources 189 diagnostic road map 8 diagnostic services 9-11 drones 372, 373 ELISA 212 field diagnostics kits 9</p>

Insects and allied pests *see also* aphids, beetles, bees, butterflies and moths, mealybugs, mites, fruit flies, flies, mosquitoes, scale insects, storage pests of grain, termites, thrips, wasps, whiteflies
3 generations of insecticides 432-440
biocontrol of insects 98-111
biocontrol of insects (list) 108-111
bioinsecticides 99
disease resistance and insecticides 428
earwigs, traps 246
fruitspotting bugs 109
predators and parasites 98, 113
predatory insects 98
residues, persistence 308, 429
resistance, development of 427, 303
seed treatments 215, 437
soap 440

INTEGRATED CROP MANAGEMENT 351
INTEGRATED DISEASE MANAGEMENT 353, 428

black leg 165
foliage diseases of cereals 354
nursery 354
root and foliar diseases 392
salinity 354
soil fungal diseases 353
sugar industry 354

INTEGRATED PEST MANAGEMENT 333-358, 428

pests 352
quality assurance 343
systemwide program for IPM 378
Integrated Weed Destructor 236

INTEGRATED WEED MANAGEMENT 60, 62, 355-356, 427

resistance 355
school grounds 356
seedbank 356
tactical groups 355

INTEGRATION (piggybacking programs)

Australian Garden Centre Accreditation Scheme (AGCAS) 325
Biosecure HACCP 367
Certified Nursery Professional (CNP) 325
crops, livestock & forests 399
environmental management 377, 378
FMS Ecohort, 367
Management/QA programs 325
Nursery production FMS 202

Interceptions and Recent incursions 185
International Federation of Organic

Agricultural Movement (IFOAM) 390
International Maize & Wheat Improvement Centre 153

Interstate/Regional quarantine 196

Inundative release 105, 125, 131

Invasive species 377

Irish blight 353

Irradiation 233

Irrigation management 36, 37

ISSUES OF CONCERN

genetic engineering 416
nanotechnology 419, 422
pesticides 297-316, 425-431

JAS-ANZ 323

Jasmonic acid 157

Kauri dieback 77

Key performance indicators (KPIs) 350

Kites, bird-scaring 232

Labels

off-label use, permits 285
organic standards 387
pesticide label 283-292

Land degradation 43, 54, 371, 374-376

Land management and ownership 402

Language, IT and maths 312, 443

Leaves, fallen 67

LEGISLATION

biological control 87
biosecurity 176
cultural methods 30
disease-tested planting material 206

LEGISLATION (contd)

duty of care 272
environmental management 362
genetic engineering 410
integrated pest management 336
irradiation 233
nanotechnology 419
organic standards 382, 384
pesticides 259-272, 297
commonwealth (APVMA) 259
control of use (state/territory) 268
disease-tested planting material 206
health surveillance 300
in the workplace 300
label (read the label) 283
licensing, farm chemical users 273
life cycle stewardship 310
limitations and prohibitions 288-292
local government (pesticides) 270
personal protective equipment 300
restraints 289
safety data sheets 293
state/territory 268, 274
storage & disposal (label) 292
users' training 274
physical methods 230
quality assurance 328
resistant varieties 138
sanitation 66, 70, 72, 73
Life cycle stewardship 310
Light induced phenomena 38, 234
Light traps 234, 248
Light, wavelengths 38
Locusts and grasshoppers 109
Lucerne 106, 107, 127
Lucid tools 9
Lure and kill 102, 440
Lures (pheromones) 101-102, 245

Machinery, vehicles, farm biosecurity

harvesters 76, 79

Magnet Insect 440

Magnet Med 102, 440

Maintenance, plant management 331

Male Annihilation Technique (MAT) 102, 245, 440

MANAGEMENT & QUALITY ASSURANCE

biosecurity 77, 172-176

disease-tested planting material 223

environmental management 377-378

environmental risk 425

GM crops 415

holistic management 397-402

management / QA 324, 325

management systems 318, 325

managing a crop 327-332

establishment 331

harvest & postharvest 332

maintenance 331

selection 330

pesticide resistance 263, 303, 427

pesticides 314

physical methods 253

plant resistance 164-168,

Quality Assurance 317-326

responsibilities 311, 31-326,, 422

MANAGING A CROP

Manufacturers & retailers (Agsafe) 281

Chemclear 282, 309

Chemcollect 309

DrumMUSTER 282, 309

industry waste reduction scheme 282, 309

personnel 281

premises 281

Mathematics and IT 311, 443

Maximum Residue Limit (MRL) 194, 262,

308, 429 431

trade 429-431

withholding period 289, 429-431

Mealybugs

biological control 109

mealybug ladybird 109

Measuring and mixing pesticides 300

pesticide label 290

Standard Operating Procedures 301, 302,

311, 312

Mechanization 372

Medical screening 300

MERI 365

Meristem culture 217

Metarhizium 88, 99, 100, 108-110

Methylated spirits (pruning tools) 74

Methyl bromide 265, 306

Methyl jasmonate 157

Mice 244, 246

MiCOR 194

Microbial pesticides

3rd generations of pesticides 438-440

biofungicides 112

bioherbicides 91

bioinsecticides 99

Microclimates

diseases and pests 40

natural enemies 40, 127-128

Microwaves 241, 243

Milk 439

Minimizing use of (hazardous) pesticides 310

Minimum disease resistance standards 161

Minimum tillage 54

Mini-till and vegetables 62

Minor use (pesticides) 260-262

Mites

European red mite (biocontrol) 111

predatory mites 111

redlegged earth mite 57, 111, 347

twospotted mite

biological control 111

moisture 35

overwintering hosts 68

spacing plants 42

tolerant plants 147

varroa mite 131

Miticides *see* Insecticides

Mixed cropping, plantings 59

Moisture 35-37

Mollison, Bill 390

Monitoring

air monitoring (spore assays) 7, 248

biological control 101, 190

health, PPE 300

IPM 343-345

pesticide resistance 263, 290, 303, 427

pesticides 263

quality assurance 321, 322

resistant varieties (black leg) 165

timing 26, 344

Monocultures 151, 162

Morphology 148

canopy, root architecture vigor 145

Mosquitoes 99, 105, 109, 248, 250

Moths *see* Butterflies and moths

Mowers, harvesters, brushcutters 76

Mowing 70

Mulches 46, 235

Mutations 152, 163

myBMP 399

Mycorrhiza 116, 150

My Results 400

Myrtle rust 12, 147

Nanotechnology 419-424

fertilizers 421

issues of concern 422

organic 424

pesticides 421, 436

standards 419

National

National Action Plan IPM 23, 310, 314,

335, 342, 348, 377

National Association for Sustainable

Agriculture, Australia 388

National Framework for EMS 365

National Fruit Fly Strategy 195

Nationally Accredited Training Courses

274-282

National Occupational Health and Safety

Commission (NOHSC) 271

National organic logo 391, 395

National Plant Biosecurity Diagnostic

network (NPBN) 189

National Plant Biosecurity Status Report

173

National Registration Scheme (NRS) 259

National Standard for Organic and Bio-

dynamic Produce 382

<p>National (contd)</p> <ul style="list-style-type: none"> National Toxics Network (NTN) 298,424 National Variety Trials (NVT) 159 National Association for Sustainable Agriculture, Australia 388 Natural enemies 84, 98, 112 Near-Infrared (NIR) 373 Necrotrophic fungi 153, 157 Neem (<i>Azadirachta indica</i>) 440 Nematodes diseases <ul style="list-style-type: none"> beneficial nematodes 100, 108-111 biosecurity 193 nematode bioinsecticides 110 potato cyst nematode (biosecurity) 183, 194, 197 root knot 35, 44, 56, 58, 62 soybean cyst nematode (biosecurity) 193 trap plants (root knot nematode) 59, 105 vineyards 167, 314 Netting 249 Nitrogen 50 Nitrogen drawdown 46 Nitrogen-fixing bacteria 117, 118 Nitrogen Use Efficiency (NUE) 50 No data, no market 298, 424 Nogall 115 Non-parasitic problems (abiotic) 144-146 <ul style="list-style-type: none"> acidity and alkalinity 48 deficiencies and excess nutrients 49-52 hormone herbicide injury 147, 307, 309 humidity 37, 237 irrigation 35-37 light, seedlings 38 oedema 35 photo damage (eucalypts) 38 salinity 145, 147, 153, 160 soil structure 44 temperature 33, 34 traits being looked at today 144-146 water stress 35 wind (citrus) 38 Non-symbiotic organisms 118 Nonsystemic chemicals 213 Normalized Difference Vegetation Index (NDVI) 373 Northern Australia Quarantine Strategy (NAQS) 177, 182, 190 No-till 54 Nozzles 290, 307 NPK 50 Nuflora 159 Nurseries <i>see also</i> Greenhouses <ul style="list-style-type: none"> benches, containers, equipment 74-75 biosecurity 77-80, 187, 351, 367 coloured shade netting 235 disinfectants 74 greenhouses (sanitation, biosecurity) 78 humidity 37, 237 insect screening 250 integrated pest management 351, 354 irrigation 35-37 Nursery Industry Accreditation Scheme Australia (NIASA) 78, 325 Nursery Production Farm Management System (FMS) 325, 367, 400 nursery runoff 72 reflective films 251 relative humidity 37, 237 sanitation 75, 78 UV light 235 Nutraceutical foods 411 Nutrients 48 Nutrition, plant resistance 49, 50, 150, 155, 164 <hr/> <ul style="list-style-type: none"> Oak leafminer (photo) 139 Oedema 35 Off-label use 285 Offshore Biosecurity 178 Oils <ul style="list-style-type: none"> horticultural oils 440 oil glands, plant resistance 149 vegetable oils 439 On-farm biosecurity 77-78, 80, 200 Onshore Biosecurity 186 Ontogenic resistance 168 	<p>Oral intake (pesticides) 300</p> <p>Organic</p> <ul style="list-style-type: none"> advisory groups 390 amendments 44 farming 376 manures 43-45 organic matter 43-45 products 376, 381-396 Organic Food Chain (OFC) 389 ORGANIC STANDARDS 381-396 <ul style="list-style-type: none"> approved certifying organizations 388 audits 386 certification 384-387 documentation, records 386 HDRA 390 labeling 386, 387, 391, 395 legislation 384 managing organic growing 392 marketing 387, 395 Organic Federation of Australia (OFA) 390 Organic Knowledge Hub 390 organic standards (nanotechnology) 424 pests, diseases, weeds 385 planning 384 production requirements 385 soils, water 385 specific crops 385 training 384 weeds 242 Organochlorine insecticides 434 Organophosphates 434 Ornamentals <i>see also</i> carnations, chrysanthemums, roses <ul style="list-style-type: none"> certification schemes 222 fungal diseases 353 Overseasoning, overwintering, over-summering 68 Outbreaks (exotic plant pests) 190 Outputs, inputs (on-farm biosecurity) 200 Oxygen, lack of in disease control 232 <hr/> <ul style="list-style-type: none"> Packing sheds 74 Parasites 98, 113 <ul style="list-style-type: none"> parasitic fungi, hyperparasites 113, 108-110 122-124 parasitic wasps 88, 98, 108-110, 126, 130 Parasitoids 98 Pasteurization (soil) 240 Pathogen-tested planting material 207 People, pests, diseases and weeds 27, 168, 305, 311, 406 Perceptions 27 Permaculture 376, 390 Permits 261, 262, 285 Pest flare ups, upsurges 304, 308, 315, 394 Pest free area 191, 197, 218, 226 Pesticide labels 283-292 Pest management <i>see</i> Integrated Pest Management Pest races, strains 5, 163 Pesticide chemical labels 283-292 PESTICIDES <i>see also</i> Fungicides, Herbicides and Insecticides. <ul style="list-style-type: none"> absorption, pesticides 293, 300 Agsafe accreditation 281 Agvet code 259 application (effective and safe) 432 application equipment 433 APVMA 259 beneficials 130, 349 buffer zones 263, 307 ChemCert /Auschem 278 chemical reviews 264 cleaning up 80, 300 codes of practice 266, 271 community 299 compliance 265 contractors 78, 80, 272 disposal <ul style="list-style-type: none"> ChemClear 282, 309 ChemCollect 309 DrumMUSTER 282, 309 label 292 drift reduction technologies 307 drift retardants (anti-drift agents) 307 droplet size 290 duty of care 272 	<p>PESTICIDES (contd)</p> <ul style="list-style-type: none"> emergency responses 288, 292, 295 environment 307-309 Farm Chemical User Course 278 First Aid 292, 295 <ul style="list-style-type: none"> spills and leaks 311 formulations 437 genetic engineering 412-414 hazardous pesticides 292, 295, 432 health surveillance 300 integrated pest management 349 issues of concern, opportunities 297-316 legislation 259-274 life cycle stewardship 310 management 314 manufacturers and retailers 281-282 maximum residue limits (MRLs) 262, 266, 308, 410 429 minimize pesticide residues 334 minor use 260-262 mishaps 311 moving, tracking 309 nanotechnology 421 nozzles 290, 307 permits 261, 262, 285 persistence 308, 429, 434 personal protective equipment 292, 295, 300 pesticide chemical labels 283-292 <ul style="list-style-type: none"> Understanding pesticide labels 287 Warnings and product description 288 Directions for use 289 General instructions 290 Precautions 291 <ul style="list-style-type: none"> First Aid, storage and disposal 292 pesticide failures 305 pesticide free areas, zones 307 pest resurgences 5, 304, 308, 315 phytotoxicity (plant injury) 307, 309 Poison Information Centre 287 prevent back siphoning 431 read the label 287-292, <i>see also</i> pesticide chemical labels above records 301, 336 registration 259 residues <i>see</i> Residues (pesticides) resistance <i>see</i> Resistance (pesticides) safety data sheet 293-296 selection criteria (pesticides) 304 selectivity (2,4-D) herbicides 307 self-dispensing, ready-to-use packs 437 Smarttrain 280 spray drift 290, 291, 307 standard operating procedures 301, 302, 311, 312 standards 266, 267, 271 storage 292, 295 toxicity, toxicology 295, 261, 429 tracking 309 user training 274-280 user licensing 273 using pesticides with beneficials 130, 349 why pesticide fail 305 work, health and safety 300 <p>Pests, type of pests</p> <p>biosecurity 173</p> <ul style="list-style-type: none"> Emergency Plant Pest (EPP) 173, 175, 186, 188, 191, 192, 196 High Priority Pest (HPP) 173, 175, 178, 186, 191 key, occasional, potential, non-resident and migratory pests 5, 6 re-emerging pests 5 upsurges 308, 315, 349 <p>Pest-suppressive crops and landscapes 106</p> <p>Pest triangles <i>see</i> Triangles</p> <p>Pest upsurges 308, 315, 349</p> <p>pH 48</p> <p>Phasing out pesticides, restricting use 306</p> <p>Pheromones (codling moth, lightbrown apple moth, oriental fruit moth, potato moth, etc) 101-102, 245</p> <p>Phosphate solubilizing bacteria 118</p> <p>Phosphine 253</p> <p>Phosphorous acid, phosphite 254, 439</p> <p>Phosphorus Use Efficiency (PUE) 50</p> <p>Phylloxera 76, 168, 197</p>
---	--	--

<p>PHYSICAL METHODS 229-256 barriers 249 climate control 251 cooling treatments 238 dusts 231 frightening devices 232 geofabric 252 habitation 232 heat treatments 239 irradiation 233 thermal weed management 242 traps 244 weed seed destructors 236 Phytoalexins 149 Phytophthora diseases Management for biodiversity 401 <i>Phytophthora cinnamomi</i> 5, 13, 60, 147, 401 <i>Phytophthora dieback</i> (kauri) 77 <i>Phytophthora</i> diseases of cut flowers 254 <i>Phytophthora infestans</i> (Irish blight) 353 Phytophthora Certification Manuals (PHYTO) 194, 219 Phytotoxicity 49, 147, 309, 433 Piggybacking 202, 325 Plagues and epidemics 403-408 Planning environmental management 364 integrated pest management 336, 342 integrated weed management 355 legislation (IPM) 342 management 319 management and quality assurance 321 managing a crop 329 organic standards 384 planning the crop 334 quality assurance <i>see</i> Quality Assurance records (IPM) 342 risk analysis 342 Plant activators 156, 157, 439 Plant architecture, vigor 62, 145, 148 Plant back 262, 291 Plant Breeders Rights (PBR) 160 Plant breeding 154 Plant growth regulators 31, 439 Plant Health Australia 173, 175 Planting dates 42 Planting depth, pollination, pruning 42 Planting, spacing pruning 42, 69 Plant injury 307-308 PLANTPLAN 186, 192 Plant Protection Districts 218 Plant quarantine <i>see</i> Biosecurity Plant resistance 137-170 Plant scan 373 POISON (label) 288 Poison Information Centre 287 Policy (Environmental Management) 364 Pollination <i>see</i> Bees Polymers 158, 439 Polyphenols 149 Postharvest diseases 122, 232, 237-239 Potassium phosphonate 439 Potting mixes microwave radiation 241, 243 pasteurization 240 Powdery mildews <i>see</i> Fungal diseases Precautionary principle 298, 299, 310, 424 Precautions and prohibitions 289, 291 Precision agriculture / horticulture 372 cultural methods 31 fertilizers 52 fungicides, herbicides, insecticides 31 irrigation 37 Predators and parasites 98, 113 Predatory insects 98 Predatory mites 111 Pred Dicta B test 12 Predictive services <i>see</i> Warning services Pre-emptive breeding 143, 181 Preference versus non-preference 141 Preventative control methods 19, 342- Prickly plants 249</p>	<p>Priority pests 178 195 Emergency Plant Pest (EPP) 173, 175, 186, 188, 191, 192, 196 High Priority Pest (HPP) 173, 175, 178, 186, 191 Problem solving <i>see</i> Identify the pest, disease or weed Propagation material (contaminated) 208-212 Pros and cons control methods 28 biological control 134 biosecurity 203 cultural methods 63 disease tested planting material 227 pesticides (issues of concern) 297 physical methods 255 resistant varieties 169 sanitation 81 management & quality assurance 326 environmental management 379 genetic engineering 416-418 holistic management 402 integrated pest management 257 nanotechnology 422 organic standards 394 Prosecutions biosecurity 176 pesticides 265 Protectant fungicides 213 Protocols diagnostic protocols 189 194, 212 Nagoya Protocol (GM material) 410 pesticides (school grounds) 310 Provenances 152 Pruning, pruning tools 42, 69, 74 PUBCRIS 261 Public Release Summaries 261, 265 Pyramid strategy 154, 166, 412 Pyrethrum 440 Pyrolisis 45</p> <hr/> <p>QUALITY ASSURANCE (QA) 320-325 audit 350 disease-tested planting material 212 integrated pest management 343 pesticide compliance 265, 301 pesticide training, 277 QA standards 322 QA, trade, records 301 Quarantine <i>see</i> Biosecurity</p> <hr/> <p>Rabbit control 89, 249, 254 Races 141 Radiation, irradiation 233 Rats 90 Re-accreditation Agsafe 281 Organic Standards 383-386 pesticides 312 trained teachers 313 user's pesticide training 278, 280 Recall, pesticides 264 Recent incursions into Australia 185 Records best management practice 363 crops rotation 56 disease-tested 207 environmental management 364 fertilizers 51, 52 integrated pest management 336 managing a crops 328 organic standards 386 pesticides 301, 336 quality assurance 322 trade 301 work, health and safety (WHS) 300 Recycling <i>see</i> Disposal and recycling Redline 184 Reducing exposure 299, 300 pesticide use 295, 310 tillage 54, 374 ReduCondens, ReduHeat, ReduSol 38 ReduFuse 235 Re-entry interval (REI) 262, 291, 300 Reflective films 251 Refrigeration 238</p>	<p>Refuge crops (for predators) 107 Registration of pesticides 259 cancelled registration 264 Regulations 271 Re-infestation, re-infection 223-225, 253 Relationships people, pests, diseases, weeds 27, 168 pests, control, beneficials <i>see</i> Triangles Relative humidity 37, 237 Repellent plants 105 Repellent signals 232 Residues (crop, plant) cultural methods 54--59 disease-tested planting material 223-225 sanitation 67 Residues (pesticides) 308, 429-431 biosecurity and trade 194 environment 308, 430 food 266, 308, 431 food chain 431 Maximum Residue Limits (MRLs) 262, 429 MRLs, WHPs, Trade 289, 429-431 persistence 434 pesticide labels 290 residual activity, need for 434 residue violations 430 soil, media, compost 29, 431 trade, vendor declarations 430 water 431 withholding periods 262, 289, 430 Resilient agriculture/landscapes 375 Resistance (nanotechnology) 423 Resistance (pesticides) 263, 288, 290, 303 A, B, C groupings on labels 288 fungicide resistance 428 herbicide resistance 427 insecticide resistance 428 managing resistance 263, 303 pesticide labels 290, 298 resistance groups 263 resistance management 303, 427 resistance warnings on labels 288, 290 RIM (Resistance and Integrated Management (weeds) 62, 355 warnings on labels 290 RESISTANT VARIETIES (plants) 137-170 breakdown 162 cold tolerance 116, 145, 150 cross protection 156 drought, cold, heat tolerance 150 Herbicide Resistant Crops from Biotechnology (HRCBs) 414, 415 hormone herbicide 147 integrated pest management 164 interactions 141 multi-gene trait resistance 142, 166 <i>Phytophthora</i> 147 plant activators 156, 157, 439 polymers 158, 439 polyphenols 149 prolonging plant resistance 164-166 pyramid and stacked genes 154, 166, 412 Resistance Integrated Management 355 resistant varieties 137-170 resistant varieties (table) 147 salinity tolerance 147 systemic acquired resistance 156-158 tough nuts 167 Resources <i>see</i> Selected resources Respirators 300 Responsibilities biosecurity 174, 181 management 311, 318 nanotechnology 422 pesticides (management) 442 shared (biosecurity) 174-175 Restrictions (pesticides) 289 Restricted chemical products 264, 289 Restricted entry interval (REI) 291 Retailers & manufacturers (Agsafe) 262, 281 Chemclear and DrumMUSTER 282 DrumMUSTER 282 Industry waste reduction scheme 282 Industry waste reduction scheme 282 personnel 281 premises 281 Revegetation 378</p>
---	---	--

- Review of chemicals **264**
- Review questions & activities**
- biological control **135**
 - biosecurity **204**
 - control methods **28**
 - cultural methods **63**
 - disease tested planting material **228**
 - environmental management **379**
 - holistic management **402**
 - identify the pest, disease or weed **14**
 - integrated pest management **357**
 - organic standards **396**
 - pesticides **315**
 - physical methods **256**
 - resistant varieties **169**
 - sanitation **82**
- Rhizobia **118, 119**
- Rhizosphere **43**
- Right to know**
- genetically modified **417**
 - nanotechnology **424**
 - pesticides **298**
- Riparian vegetation **363, 377**
- Risk analysis, assessment etc**
- biosecurity **180, 181, 183**
 - environmental **302, 425**
 - GM crops **425**
 - pesticides **302, 425-426**
 - plant epidemics **408**
 - seed **210, 218, 226**
 - standards **425**
 - workplace **300**
- RNA silencing **158**
- Robotics **372**
- Rogueing **69**
- Rooftops (city) **79**
- Root barriers **251**
- Root rots **see Soilborne diseases**
- Roses**
- black spot (photo) **139**
 - diseases, pests & weeds **329**
 - grey mould (*Botrytis*) **61**
 - humidity **37**
- Rotate**
- control methods **17**
 - crop rotations **56, 374**
 - crops, crop varieties **17**
 - mixed cropping **17, 59**
 - pesticide mode of action groups **17, 288, 303, 427-428**
 - pesticides **17**
- Rotenone **440**
- Roundup **see Glyphosate, and Herbicides**
- Rudolf Steiner **389**
- Run off**
- nursery **72**
 - nutrients **50**
 - pesticides **308, 309**
 - water **50, 61**
- Rust diseases**
- cereal rusts **5, 142, 159, 162-164, 178**
 - chrysanthemum white rust (photo) **193**
 - geranium (photo) **139**
 - myrtle rust **12** (photo), **147, 254**
 - skeleton weed (photo) **85**
 - snapdragon (photo) **139**
 - western gall rust **193**
-
- Safe Food Production Quality (SFQ) **389**
- Safety 273**
- flamers **230, 240, 242**
 - pesticide chemical labels **283-292**
 - pesticides in the workplace **300**
 - Safety Data Sheets **293-296**
- Salicylic acid **157**
- Salinity, salt tolerance **145, 147, 153, 160**
- SANITATION 65-82**
- biosecurity **76, 187, 201**
 - hands, boots, shoes, equipment, soil, , pruning, packing sheds, vehicles **74**
 - harvesters mowers, vehicles, etc **76**
 - pressure water cleaners **75**
 - trolleys, benches, greenhouses **75**
- SC27 (bioinoculant) **119**
- Scales (black scale, red scale, San Jose scale, white wax, etc) 109**
- gumtree scale (photo) **139**
- Scarecrows **232**
- School grounds **356**
- Sclerotium stem rot of bulbs **345**
- Screens (greenhouses) **250**
- Seedbanks**
- seed vaults, gene banks **151, 210**
 - weeds **60, 62, 236, 427**
- Seedborne diseases **209-211**
- Seeds 209**
- biosecurity **179**
 - certification schemes **221**
 - contamination **209**
 - disinfection **214**
 - disinfestation **213**
 - mechanical sieving **252**
 - seedbank in soil **60, 62**
 - seed banks, seed vaults **151, 210**
 - seed testing 210, 211**
 - testing for diseases and pests **212**
 - testing services **210, 211**
 - seed treatments 213-215**
 - bioinoculants **116-119**
 - biopriming **119**
 - biostimulants **53**
 - pesticides **213, 215**
 - traceability **210**
- Selected resources**
- biological control **135**
 - biosecurity **204**
 - control methods **28**
 - cultural methods **64**
 - disease tested planting material **228**
 - environmental management **380**
 - genetic engineering **418**
 - holistic management **402**
 - identify the pest, disease or weed **14**
 - integrated pest management **358**
 - management & quality assurance **326**
 - nanotechnology **424**
 - organic standards **396**
 - pesticides **316**
 - physical methods **256**
 - resistant varieties **170**
 - sanitation **82**
- Selection criteria**
- pesticides 300, 304, 310**
 - personal protective equipment **300**
 - pesticide label **292**
 - safety data sheets **292-296**
 - plants 40-42, 330**
- Serology **212**
- Shadehouses **see Greenhouses**
- Shared responsibility **174, 175**
- Shocks **236**
- Shoes, boots, staff (sanitation) **74**
- Shooting **230**
- Shoot tip grafting **216**
- Shut off hose fitting **302**
- Sieving **252**
- Signal headings **266, 288**
- Site, planting **42**
- Smart films **235**
- SMARTtrain **280**
- Snails**
- barriers **250**
 - giant African snail (biosecurity **178, 183, 185, 187, 193**)
 - traps **245**
- Soaps **440**
- Sodium Green Imaging **160, 373**
- Soil 43-45 see also Soil organic matter**
- alkalinity and acidity **48**
 - biosecurity **183-185, 196-197, 200**
 - competition for space **114**
 - conservation tillage (CT) **54**
 - contaminated soil **74, 77**
 - cultivation **236**
 - diseases **74, 77, 120, 124**
 - fallowing **58**
 - heat treatments **240**
 - land degradation **43, 54, 371, 374-376**
 - microwave radiation **241, 243**
 - mulches **46**
 - nutrient deficiencies and excesses **49-52**
 - organic amendments **44**
 - plant back (herbicides) **291**
 - wetting agents **36**
- Soilborne diseases 61, 124, 133, 167, 353**
- armillaria rot **123**
 - crown gall **115, 122, 409**
 - damping off **124**
 - fusarium **124**
 - phytophthora **60, 124, 147, 167, 401**
 - potato cyst nematode **183, 194, 197**
 - rhizoctonia **124, 167**
 - root knot nematode **35, 44, 56, 58, 59, 62**
 - sclerotinia stem rot **124, 167**
 - sclerotium stem rot **167**
 - take-all **124**
 - verticillium wilt **216**
- Soil Organic Matter (SOM) 43-45**
- degradation **43, 54, 371, 374-376**
 - diseases **see Soilborne diseases**
 - pasteurization **240**
 - pesticide residues **308, 429-431**
 - pests **121**
 - seedbanks **236, 356**
 - soil reductive sterilization (SRS) **241**
 - soil, water and plant analysis **51**
 - solarization **241**
 - standards **30, 43**
 - sterilization **240**
 - suppressive soils **120**
 - symbiosis **116**
- Solarization **241**
- Solar radiation **32, 235, 38**
- Sorbic acid **439**
- Sound responses **232**
- Spacing plants **42**
- Spills **311**
- Spinosad **391, 440**
- Spore traps **7, 248**
- Spray drift **see Drift**
- Spray droplets **263, 290**
- Spread (biosecurity) **183**
- Stacked genes **154, 166, 412**
- Staff, plants machines **76-80**
- Standard Operating Procedures (pesticides) **302, 311, 312, 426, 442**
- Standards 271**
- dangerous goods **266**
 - ecologically sustainable development **370**
 - environmental management **362-364**
 - erosion control **377**
 - food standards (pesticides MRL) **194, 261, 266, 308, 410, 429 431**
 - GM food **410**
 - green waste **66, 70**
 - inoculants **119**
 - management **319, 321**
 - minimum disease resistance standards **161**
 - nanotechnology **419, 422**
 - organic standards **382**
 - pesticides **266, 267, 271**
 - potting mix, soil, compost, mulches **43, 66, 70**
 - quality assurance (QA) **320, 322**
 - risk assessment (pesticides) **302**
 - silos standards **78**
 - standards, codes **271**
- State/Territory legislation (pesticides) **274**
- Steam treatments**
- seed **215**
 - soil **240, 241**
 - weeds, steam wands **242, 243**
- Steps in:**
- certification (quality assurance) **320-323**
 - certification schemes (disease-tested) **219-222**
 - growing a crop **330**
 - holistic management **398**
 - integrated pest management **333**
 - management systems **319, 321, 359, 364**
 - organic standards **381, 384**
 - phytosanitary (biosecurity) **194**
 - risk assessment and management **425**
- Sterile Insect Techniques (SIT) **103**
- Sterilization (soil) **240**
- Sterilizing containers, pruning tools **74, 75**
- Sticky traps **247, 345**
- Stone fruits**
- bacterial canker **68**
 - brown rot **42, 148**
 - eutypa **113, 122**
 - oriental fruit moth **101, 102**

<p>Storage and disposal (pesticides) ChemCert 278 ChemClear 282, 309 ChemCollect 309 pesticide label 292</p> <p>Storage pests (grain) 13 aeration 237 bins, packing sheds 74 controlled atmosphere 232 heat treatments 253 identify pests 13 pests 232, 253 sanitation 78</p> <p>Strains 140 Strategic tillage 55, 374</p> <p>Strawberry botrytis (grey mould) 61 plant protection districts 218 virus-tested runners 222</p> <p>Substitution principle 298, 424 Sugarcane 353, 354 Sulphur 430, 435 Sunscorch 33, 35 Superweeds 418 Suppressive crops and landscapes 106 Suppressive soils 120</p> <p>Surveillance biosecurity 190, 191, 202 health checks 300 integrated pest management 343-345</p> <p>Survivor species 151</p> <p>Sustainability 370-376 biological farming 376 confusing terms 360, 361 conservation agriculture 374 ecologically sustainable development 370 environmental management 359-380 integrated pest management 335, 342 organic 393 precision agriculture, horticulture 372 resilience 375 use of pesticides 298, 335, 342 vegetables 146</p> <p>Swatting insects 67 Switching gene promoters 154</p> <p>Symbiotic organisms 116, 124 endophytes 116 mycorrhiza 116 nitrogen fixation 117, 118</p> <p>Symptoms on plants 5, 6, 8, 9, 13, 51, 305 Systemic acquired resistance 156-158, 165 Systemic pesticides to treat seed etc 215 Systems thinking 397-402 Systemwide Program for IPM (SPIPM) 335, 378</p>	<p>Thrips 234, 247 biological control 110 gladiolus thrips 148 onion thrips 148 screens 250 sticky traps 247 western flower thrips 110</p> <p>Tillage conservation tillage 54-55, 374 mini-till (vegetables) 62, 353 reduced tillage 54, 374 strategic tillage 55, 374</p> <p>Time and timing crop management 329 epidemics 403-408 harvest time 42 holistic management 400 integrated pest management 344 monitor and test 6 real time 26 seed testing 210 testing soil before planting 12 time 406 time framework 26 timing 329, 344</p> <p>Tin collars 249 Tip cuttings 216 Tissue culture 217</p> <p>Tissue propagation systems 216 meristem culture 217</p> <p>Tolerance levels disease in disease tested material 207, 209 GM material in non-GM crops 394, 415 pesticides in food (MRLs) 429 pests 209 seeds 219, 221 weed seeds (<i>Setaria</i>) 209</p> <p>Tolerant varieties see Resistant varieties</p> <p>Toolangi Plant Protection District (PDD) 218</p> <p>Tool kits EMS 365 Topics 313 Topwatch 190 Total Quality Management (TQM) 323</p> <p>Toxicology, toxicity (pesticides) community 299 pesticide label 261, 288-292 safety data sheet 293, 294 work, health and safety 300</p> <p>Traceability 323 organic 210 pesticides 308</p> <p>Trace back (biosecurity) 200 Tracking 307-309</p> <p>Trade biosecurity 176, 194 pesticides 301, 430 quality assurance 320 trade name 288 vendor declarations 226, 320, 321, 430</p> <p>Training (general) 441-444 assessment 274, 276, 278, 279, 281, 444 Australian Qualification Framework (AQF) 276-275 biological control 125 biosecurity (Bolt etc) 188 certification see Certification Schemes cultural methods 31 environmental management 362 Fertcare (fertilizers) 49 formal 311, 441 formats 276, 443 in-house 277, 311, 312, 442 integrated pest management 337 language, IT, mathematics 312, 443 management / QA 443 management responsibilities 311, 442 mandated 442 manufacturers and retailers 281 organic standards 384 pesticides 273-282 Agsafe accreditation 281 Auschem 278 ChemCert 278 Farm Chemical User Courses 278 licensing 273 SmartTrain 280</p>	<p>Training (general) (contd) physical methods 230 practical 312 quality assurance & trade 313, 444 reaccreditation pesticides 279, 280 sanitation 66 spray drift see Drift (pesticides) trainers providers 313, 443 use by date 278, 280, 281 work experience 312, 442</p> <p>Transgenic plants 409 Trap plants 104, 105</p> <p>Traps 244, 248 colored sticky traps 247 food 244 light 248 mosquito trap 248 pheromones 101-102, 245 pitfall traps 248 sex 245 shelter 246 soil plugs 248 spore traps 7, 248 track traps 246 trap plants (cotton) 104 trap plants (nematodes) 105 window frame traps 248</p> <p>Trees certified seed, tree centre 221 chipping trees and shrubs 70 fruit-tree borer 79 heart rot, wood rot 123 how plants defend themselves 148-150 Kauri dieback 77 Melbourne's urban forest renewal 40 Protection Acts 66 storm water 72 street trees 78 re-infestation of timber 253 tree guards 249 tree implants 92, 437 TRENET 160 tree surgery 68</p> <p>Triangles host, pests, beneficials, environment 128, 340 pests, diseases and weeds 16, 403 pests, diseases, weeds and control 21</p> <p>Trich-A-Soil 113 Trichoderma 113 Turf grass trials 159, 400 TwinLink Technology 414 TwinN-nitrogen 116 Twospotted mite 111, 315</p>
<p>Tactical groups (weeds) 340, 355</p> <p>Targets biological control targets 85 biosecurity target lists 178, 193 courses 313 pesticides 299, 300, 304-307, 312, 314 pests (diagnostic - key, occasional, potential, non-resident, migratory) 5, 6</p> <p>Tasmanian Organic Dynamic Producers (TOP) 389</p> <p>Temperature 33-34, 238-243 atmosphere 33-34 climate change 41 cooling treatments 238 disinfection 214 disinfestation 213 drift see Drift (pesticides) flame guns 242 growth at high temperatures 217 heat treatments 213, 214, 239 hot air 239 hot water 214, 239 meristem culture and heat 217 microwaves 241, 243 soil 33, 43-45 solarization 241 steam 215 sterilization, pasteurization 240 sudden changes in temperature 34</p> <p>Termites 110, 250 Testing diseased plant material 212 Thresholds (IPM) 346</p>	<p>Ultrasound 243 Ultra-violet light (UV) 234, 235 Unmanned aerial vehicles (UAVs) 372, 373 Upsurges of pests 304, 308, 315, 335, 349 User licensing 273 User training (pesticides) 274-280, 312-313</p>	
	<p>Variable rates (fertilizers) 52 Varroa mite 131 Vegetable oils 439 Vegetables see also Brassicas certification schemes 222 disease 353 mini-till 62 potatoes common scab (potatoes) 48 Irish blight 353 potato cyst nematode 183, 194, 197 root knot nematode 35, 44, 56, 58, 59, 62 sugarcane 353 Vegetative plant material 208 Vehicles 74, 200 Vendor declarations disease-tested 226 pesticides 430 quality assurance 320, 321 Ventilation 237 Verge plantings 79</p>	

Vertebrate pests
 barriers 249
 biological control 89
 light 234
 rabbits 89
 rats, cats, cane toad, manure 90
 sound, scarecrows, etc 232
 traps 244, 246, 249
 Verticillium wilt, tip cuttings 216
 Vigor (plant) 62, 145, 146, 148
 Virally-vectored immune contraceptive (VVIC) 89
 Virulence & avirulence 141
Virus diseases
 diseases of insects 99, 108
 disease-tested material 207
 vector proof shadehouses 250
 Viruses (resistance to drought/heat) 150
 Virus-tested planting material *see* Disease-tested planting material
 Virus vectors 235, 250
Visitors
 biosecurity 80, 201
 pesticides 299
 Vitamin A 411

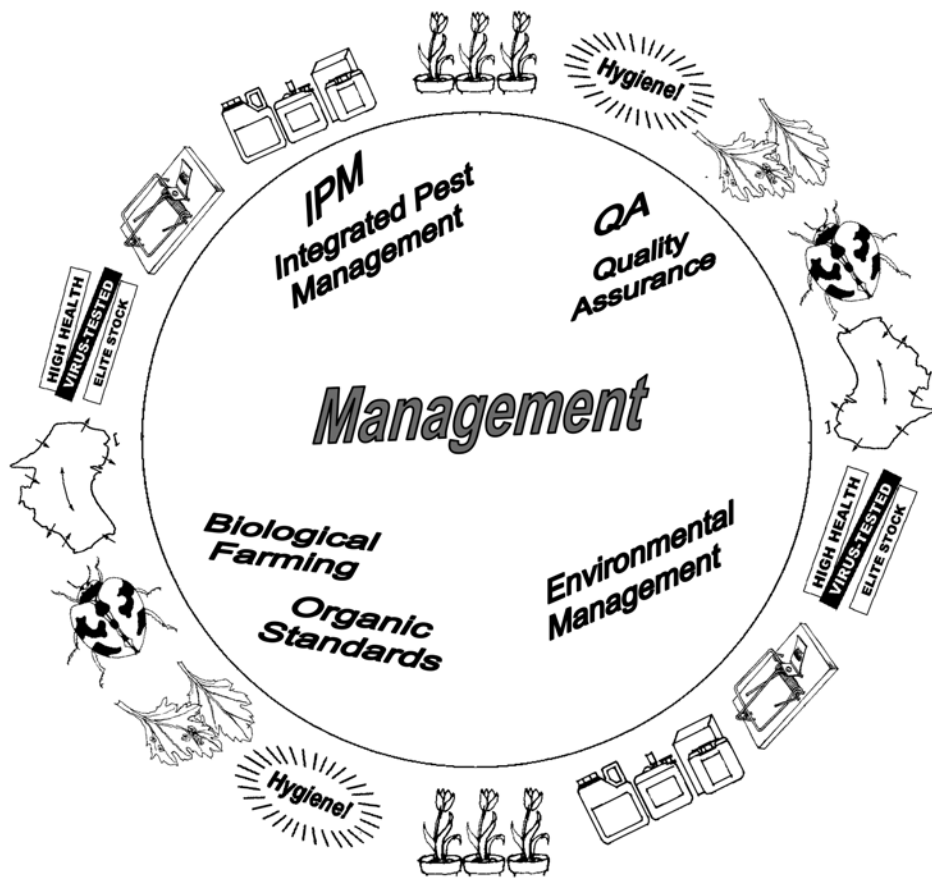
Warning services (predictive services) 26, 307, *see also* Drift, Weather Decision Support Services) 347
 forecasting epidemics 407, 408
 Weather Wizard 39
Washing 74, 75
 boots, machinery, etc 77-80
 fruit and vegetables 69, 79
 personal protective equipment 80
 potato tubers (nematodes) 79
 pruning tools 74
 nursery equipment 78
Wasps
 citrus gall wasp 69, 110
 European wasp 110
 parasitic wasps 98, 125, 108-110
 siren wood wasp 110
Waste 70-73
 green waste 70
 contaminated compost 71
 contaminated water 72
Water, irrigation 35-37
 additives 36
 contamination 72, 385
 diseases, pests 72
 nutrients (P pollution) 61
 pesticides 72, 308, 430, 431
 weeds 377
 filtration 252
 irrigation 36, 37
 nursery run off 72
 recycling water 72
 sterilizers (UV) 235
 water pressure cleaners 75
 Water Use Efficiency (WUE) 37
Weather *see also* Warning services
 drift 307
 effect on parasites 127, 128
 still accidents and mishaps 311
 temperature *see* Temperature
 water, rain *see* Water
 why pesticides fail 305
 wind 38
 Weather Wizard 39
 Weed seed destructors 236
 Weedicides *see* Herbicides
WEEDS
 3 generations of herbicides 432-440
 allelopathy 93
 biocontrol of weeds 91-97
 bioherbicides 91
 biosecurity 181, 191, 195
 burning 242
 competitive crops 62
 composting 71
 conservation tillage 55
 contraceptive for weeds 93
 crop rotation 56
 cultivation, digging 55, 69, 236, 250
 dormancy of weed seeds 12
 fallowing 58

WEEDS (contd)
 flame heat, flame guns 242
 geofabrics 252
 green bridge 68, 415
 green waste 70
 herbicide resistance 427
 herbicide-resistant crops by biotechnology (HRCB) 414, 415
 herbicides *see* Herbicides
 infra red burner 242
 integrated weed management 60, 62, 355
 legislation 66, 269, 362, 363
 list of weeds 94-97
 microwaves 243
 mulches 46
 organic systems 392, 395
 overseasoning weed host plants 68
planning
 IPM 336
 IWM 355, 356
 management 319
 quality assurance 321
 plant back times 262, 291
 prickly pear 94
 resistance *see* Resistance (pesticides)
 steam wands 242
 superweeds 418
 tactical groups 340, 355
 thermal weed control 242
 weed risk assessment 181
 weed seedbank 60, 62, 236, 427
 weed seed destructors 236
 weeds of national significance 195, 356, 365
 Wizard (weed seeds) 62
 Weeds of National Significance 195, 356, 365
 Wetting agents (soil) 36, 437
 What can I bring into Australia? 184
Wheat *see* Field crops
 Whiteflies 105, 110, 124, 126
 Whitewash 234
 Whole System Management *see* Holistic Management
 Why pesticides 'fail' 305
 Wind 38 *see* Drift
 Withholding period 262, 289, 430
 Wizard (weed seeds) 62
 Woolly aphid damage (photo) 139
Work, Health & Safety
 flammers (weed control) 242
 genetic engineering 417
 nanotechnology 423
 pesticides 263, 267, 300
 steam 242

Xeriscape 36

Yeast 115
 Yellow traps 234, 247
 Yield Profit 50

Zero food miles 361
 Zero till 54
 Zero tolerance 207, 222 *see also* Tolerance levels



THE AUTHOR'S AIMS in this series of manuals, is to provide users with the systematic understanding of Plant Protection and Plant Management required of modern horticulture.

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.

ADRIENNE WALKINGTON trained in architectural drafting in Adelaide and in Horticulture in Canberra. She was a technician in the Department of Horticulture in the Canberra Institute of Technology for many years.

PLANT PROTECTION SERIES:

1. Pests, Diseases and Weeds
2. Control Methods and their Management
3. Selected Ornamentals, Fruit and Vegetables
4. How to Diagnose Plant Problems

ISBN 978-1-875907-08-3



9 781875 907083 >

ROOTROT PRESS

22 Lynch Street, Hughes, Canberra, ACT, Australia 2605

☎ (02) 6281 3650

ISBN 978-1-875907-08-3 (print)

ISBN 978-1-875907-09-0 (ebook)