Integrated Pest Management

Strategies for Onion and Garlic

R K Mishra • Alok Adholeya • H R Sardana

The Energy and Resources Institute

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FOREWORD

Onion and garlic are the most important allium crops cultivated throughout the world and used as vegetable and spice in various ways. India occupies the second position in area as well as production of both commodities after China; however, the productivity and per capita availability are quite low as compared to other countries. Several factors are responsible for the low productivity of these crops, of which diseases and insect pests are most important and cause considerable damage and should be taken care of.

The practices for production and post-harvest management of different varieties of onion and garlic have been standardized. Plant protection measures for managing diseases and insect pests have also been developed. There is, however, a great scope for boosting the production of onion and garlic through minimizing the losses due to diseases and insect pests.

The indiscriminate and injudicious application of pesticides has resulted in development of resistance among insects and diseases, decimation of natural enemies, and high concentration of chemical residues in onion and garlic after harvest. It is disturbing the ecosystem and resulting in the resurgence of pest populations. It is also leading to failure in fulfilling international standards for export of our commodities. Considering these drawbacks, many components of integrated pest management were developed in the late nineteenth and early twentieth centuries and bio-agents or bio-pesticides

were included as an important tool in insect pest and disease management strategies. These measures are practical, economical, ecofriendly, and protective to both public health and microbial ecosystem.

Information on onion and garlic diseases and insect pests, supported by coloured photographs, has been compiled in the form of a booklet entitled *Integrated Pest Management: strategies for onion and garlic* in such a manner that scientists, students, researchers, farmers, and extension workers in the area of agricultural research will be immensely benefited. This booklet will work as a handy ready reckoner for the management of diseases and pests of onion and garlic.

I hope this compilation will prove most useful to all those interested in research, extension education, and farming of onion and garlic in the country and ultimately help in boosting up the production of quality onion and garlic suitable not only for domestic consumption but also for export purpose.

Dr O M Bambawale
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Preface

Onions and garlic are the most popular cultivated forms of the family *Alliaceae* and consumed by almost every culture on earth. According to the 2001 statistics of the Food and Agriculture Organization, onion is second only to tomato in value of vegetable crops cultivated worldwide. A number of diseases and insect pests attack onion and garlic crops throughout their developmental stages. Onions are normally propagated from seed planted directly into the field, although onion sets and transplants are also used. Garlic has been vegetatively propagated for millennia, by planting cloves. Vegetative propagation results in additional diseases and pest management problems. This booklet covers management of major fungal, bacterial, viral, and nematode diseases and insect pests of onion and garlic, with an emphasis on those diseases and insects that have been the topic of pest management research or for which effective disease and insect management systems have been put into practice. Short descriptions of pathogens and symptoms are included to assist in the identification of specific diseases and insect pests.

Frequent application and large scale use of chemical pesticides for management of pests of onion and garlic have led to the endangerment of agroecosystem. Indiscriminate use of insecticides/fungicides has also resulted in the destruction of parasitoids and natural predators of pests as well as soil microbial population. It has led to

the development of resistance to insecticides among pests and insect resurgence. In the light of these problems, considerable research has been devoted to the elucidation of toxic residues in onion and garlic. Considering the seriousness of pesticide problems, there is an urgent need for developing effective, economically viable, and environmentally safe pest management system for vegetable crops, especially onion and garlic. Exploitation of bio-agents and bio-pesticides, bio-intensive integrated pest management, and need-based use of pesticides have greater role and scope in the overall insect pest and disease management in bulb crops. The publication of this booklet is timely and appropriate for scientists, extension workers, students, and plant protectionists.

Contents

1

Introduction

Onion (*Allium cepa* L.) and garlic (*Allium sativum* L.) are the most important *Allium* species cultivated worldwide and used as vegetable, salad, and spice in the daily diet by a large number of people. India is the second largest producer of onion and garlic after China. It is widely cultivated for domestic consumption as well as export. In India, onion and garlic crops are grown almost all over the country, especially in the states of Andhra Pradesh, Bihar, Gujarat, Haryana, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Uttarakhand, and Uttar Pradesh. Madhya Pradesh is the leading producer of garlic, while Maharashtra is the leading producer of onion accounting for more than 22.83% of area and 28.42% of production, with an average yield of 11.85 tonnes/ha. In India, per hectare yields are highest in Gujarat (24.42 tonnes/ha) followed by Punjab (21.39 tonnes/ha). The area under garlic production during 2010/11 was 0.20 million ha, and the production was 1.26 million tonnes with an average productivity of 5.38 tonnes/ha. In India, per

hectare yields are higher in Punjab (16.67 tonnes/ha) followed by Himachal Pradesh (13.14 tonnes/ha) and Haryana (12.38 tonnes/ha). Onion and garlic are attacked by several insect pests, diseases, and nematodes, which vary from region to region, season to season, and variety to variety at different stages of growth and cause considerable damage/loss in yield as well as quality of both crops. These insect pests and diseases can also affect at production, harvesting, processing, and marketing stages, which lower the quality, reduce the yield, thereby increasing the cost of production and export potential also. Diseases and insect pests alter the cropping pattern and affect local and export markets. In 1993, 60%–80% losses were reported in Maharashtra due to purple blotch disease alone. Consistent use of pesticides and other chemicals to manage diseases and insect pests in bulb crop plants not only poses a serious threat to the environment and mankind but also slowly builds up resistance in these pests. Most of the new-generation pesticides are systemic in their mode of action and thus lead to certain level of toxicity in the plant system, resulting in health hazards as these two crops are consumed as cooked vegetables or raw salad and also as gravies with almost all other vegetables. All these factors have led to a new dimension in research for biological control—an important component of integrated pest management. The effect of diseases and insect pests can be lessened through various cultural, mechanical, chemical, and biological means, interwind into one, termed “integrated pest management”.

2

Integrated Pest Management: Key Strategies

WHAT IS IPM?

Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant/tolerant varieties. The IPM approach has been globally accepted for achieving sustainability in agriculture production system. It has become more relevant due to a number of advantages like safety to environment, pesticide-free food commodities, and low input-based crop production programmes. Pesticides are used only after monitoring, which indicates that these are needed according to established guidelines and treatments are made with the goal of removing only the target organisms. Pest management materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and environment. IPM is a

flexible, evolving strategy, which is continually updated as new information becomes available.

IMPORTANCE OF IPM

IPM programmes emphasize ecosystem-based strategies that provide economical, long-term solutions to pest and disease problems. Pesticides are used only when they are necessary to prevent imminent loss or damage to the managed resource. IPM strategies thus minimize hazards to human health, environment, and non-target organisms. IPM recommendations may include managing water and fertilizer, adjusting cultivation techniques, destructing pest habitats, predators, pathogens, or competitors to help limit pest numbers. Most importantly, in IPM programmes, some or all of these techniques are combined or integrated into an overall strategy to protect crops.

HOW DOES IPM WORK?

IPM focuses on long-term prevention of insect pests and diseases or their damage by managing the ecosystem. With IPM, one can take actions to keep pests from becoming a problem, such as by growing a healthy crop that can withstand pest attacks, using disease-resistant plants, or caulking cracks to keep insects or rodents from entering a building.

Eliminating diseases and insect pests using IPM entails looking at environmental factors that affect pests and their ability to thrive. Armed with this information, one can create conditions unfavourable for the pests.

In IPM, monitoring and identification of correct insect pests and diseases help in deciding whether management is needed. Monitoring means checking the field, landscape, forest or building to identify the pest,

its number or damages that it has caused. Correctly identifying the pest is key to knowing whether a pest is likely to become a problem and determining the best management strategy.

After monitoring and considering information about the pest, its biology, and environmental factors, one can decide whether the pest can be tolerated or whether it is a problem that warrants control. If control is needed, one has to select the most effective management methods and the best time for implementation.

3

Major Diseases and their Management

1. DAMPING-OFF

Pathogen: *Pythium aphanidermatum* (Edson.) Fitz.
P. debaryanum
Rhizoctonia solani Kuehn.
Fusarium sp.
Sclerotium sp.

Symptoms

Damping-off of onion seedlings occurs in two stages: pre-emergence and post-emergence. In the pre-emergence stage, the younger seedlings are killed before they reach the soil surface. They might be killed even before the hypocotyls have broken the seed coat. The radicle and plumule, when come out of the seed, undergo complete rotting. Since this happens below the soil surface and the disease is often not visible, the failure in emergence of seedlings is attributed to the poor quality of seeds.

The post-emergence damping-off is characterized by the toppling over infected seedlings any time after they emerge from soil. It usually occurs at or before

the ground level, and infected tissues become soft and water-soaked. At the advance stages of the disease, the stem becomes constricted at the base and the plant collapses. It is observed that most of the loss is due to the pre-emergence damping-off. It is more common during the *kharif* (rainy) season when temperature and humidity are very high.

Management Strategies

- Prepare a raised bed at about 8–10 cm above the ground level for good drainage. Proper drainage is essential to reduce the damping-off incidence.
- Sow clean and uninfected onion seeds on raised beds.
- Three–four years' crop rotation with non-host crop is effective.
- Solarize nursery beds with transparent polythene for 30 days before sowing.

Figure 1 Onion seedlings infected with damping-off

- Treat seeds with Thiram or Captan @ 2.5 g/kg seed or Carbendazim @ 1.0 g/kg or *Trichoderma viride* @ 4–5 g/kg seed.
- Drench the onion nursery by Thiram @ 2.5% or Carbendazim @ 0.1% or *Trichoderma viride* @ 4–5 g/L.

2. PURPLE BLOTCH

Pathogen: *Alternaria porri* (Ell.) Neerg.

Symptoms

The purple disease is widely distributed throughout the world where onion and garlic are grown. It requires temperatures in the range of 21–30°C for development. It is most serious in hot humid climate with severe crop losses, including reduction of 50% seed and bulb yield. Symptoms appear on leaves as small, whitish, sunken lesions. These spots later enlarge and eventually encircle the leaves. Later, oval-shaped dark zones appear on the surface of the leaves, retaining the characteristic purple colour. The leaves and stems fall over gradually. Concentric zones may develop within the lesions. Onion bulbs may be infected at harvest or in storage through the neck or through wounds in the bulb scales. The rotting bulbs are semi-watery and yellow at first but later become wine red and finally dark brown or black. Diseased bulb tissue gradually dries and becomes papery. The disease is aggravated by heavy dew in desert areas and by foggy and rainy weather in other regions. The fungus is seed borne and is a dematiaceous hyphomycete.

Management Strategies

- Use healthy and quality seed/planting materials from recognized institutes/organizations/seed agencies for better and good quality bulb and seed production.

(a)

(b)

(c)

Figure 2 Crops infected with purple blotch: (a) onion, (b) garlic, and (c) onion seed crop

- Summer ploughing has been found to reduce the incidence of purple blotch.
- Treat seeds with Captan at the rate of 2.5 g/kg seed, Thiram @ 2.5 g/kg or *Trichoderma viride* @ 4–5 g/kg seed before nursery sowing.
- At least two–three years' crop rotation with non-related crops should be followed.
- Spray effective and recommended chemical fungicides like dithane M-45 @ 2.5 g/L, chlorothalonil (Kavach) @ 2.0 g/L, Antracol (Propineb) @ 2.0 g/L, and copper oxychloride (Blitox-50) @ 3.0 g/L at 15 days' intervals.
- Spraying of *Trichoderma viride* @ 5 g/L at weekly intervals would be effective against this disease.
- Grow some tolerant cultivars of garlic like G-1, G-50, and G-323.

3. STEMPHYLIUM BLIGHT

Pathogen: *Stemphylium vesicarium* (Wallr.) Sacc.

Symptoms

Stemphylium blight disease has been recorded on onion and garlic from many part of the world like Europe, Africa, and the USA. In India, the disease was first reported by Rao and Pavgi (1975). Symptoms appear as small, yellow to orange flecks or streaks on leaves. These soon develop into elongated, spindle-shaped to ovate diffused spots, often reaching the tips of leaves. They usually turn grey at the centre, brown to dark olive brown. The spots frequently coalesce into extended patches, causing blight of the leaves and gradually of the entire foliage. In advanced stages, the lesions may girdle and kill leaves and seed stalks.

(a)

(b)

Figure 3 Crops severely affected with stemphylium blight: (a) onion and (b) garlic

Management Strategies

- Spray dithane M-45 (Mancozeb) @ 2.5 g/L of water along with sticker. Spraying has to be started just after the appearance of the disease and repeated fortnightly.
- Spray Sixer (Mancozeb + Carbendazim) @ 2.5 g/L of water with sticker at 15 days' intervals.
- Rotate crops with other vegetables like tomato, capsicum, pea, and cereals like wheat and paddy to reduce the disease severity.
- Deep summer ploughing also reduces the disease incidence.
- Grow tolerant varieties like G-323, G-50, and G-1.

4. CERCOSPORA LEAF SPOT

Pathogen: *Cercospora duddiae* Welles.

Symptoms

The disease appears on leaves as small ash-coloured, irregular-shaped spots on the leaf lamina. The spots coalesce gradually, resulting in blighting of the foliage. High temperature and prolonged wet conditions favour the disease development. This disease is more prevalent during the *kharif* (rainy) season.

Management Strategies

- Spray dithane M-45 (Mancozeb) @ 2.5 g/L of water and copper oxychloride (Blitox-50) @ 3.0 g/L of water at 15 days' intervals for good results.
- Spray chlorothalonil (Kavach) @ 2.0 g/L of water and Sixer (Carbendazim + Mancozeb) @ 2.5 g/L of water at 15 days' intervals.
- Deep summer ploughing is essential to reduce the disease incidence.

Figure 4 Cercospora leaf spot infected onion leaves

5. POWDERY MILDEW

Pathogen: *Leveillula taurica* (Lev.) Arnaud

Symptoms

Powdery mildew of onion cause whitish, circular to oblong lesions of variable sizes on the abaxial surface of leaves, older leaves being infected first. The lesions are covered with a white powdery mass of fine hypae and conidia. In garlic, it causes light yellow lesions on leaves within which single spores (conidia) on clusters of stalks (conidiophores) emerge from stomatal openings. This disease is more prevalent during the *kharif* (rainy) season when temperature and relative humidity remain high.

Management Strategies

- Use sulphur fungicides like Sulfex or wettable sulphur @ 0.2%, Dinocap (Karathane) @ 0.01% at fortnightly intervals.
- Proper drainage is essential.

Figure 5 Whitish powdery mass on onion leaves/scales

6. DOWNY MILDEW

Pathogen: *Peronospora destructor* (Berk.) Casp.

Symptoms

The pathogen can infect both onion and garlic. The first evidence of disease is a fine, furry, grayish white to purple growth on the surface of older leaves. Leaf tissue under the growth becomes pale green, then yellow, and finally collapses. Large, yellowish, circular clumps of infected plants, a few too many feet in diameter. The yellowing patterns often enlarge in the direction of prevailing winds. Disease can quickly develop from an initial infection by airborne spores into an epidemic if humidity and temperatures are favourable. Initial sources of disease can infect bulbs, seeds, and infected plant debris. Pathogen requires cool temperature and the presence of free moisture from rainfall or dew to infect onion plants.

Management Strategies

- Use disease-free seeds and bulbs from recognized institutes/organizations.
- Follow three–four years' crop rotation with other vegetables and cereals.
- Grow few red onion cultivars, which are moderate resistant to downy mildew.
- Carry out preventive application of dithane M-45 (Mancozeb) @ 2.5 g/L, copper oxychloride (Blitox-50) @ 3.0 g/L, chlorothalonil (Kavach) @ 2.0 g/L at 15 days' intervals.
- Avoid over-watering during entire cropping period.

Figure 6 Onion bulb crop affected with downy mildew

7. RUST

Pathogen: *Puccinia porri* G. Wint.
P. allii (DC.) Rud.

Symptoms

Rust is primarily a disease of garlic, although onion, leeks, shallots, and wild species of *Allium* are hosts. Small oval-shaped, reddish to dull orange pustules develop on leaf blades. Reddish airborne urediospores are copiously produced within the lesions. Later in the growing season, the lesions may appear dark because black teliospores develop within the pustules. Heavily infected leaves turn yellow and may collapse prematurely. When infection is severe, bulb size and quality are reduced. It is a sporadic disease that generally causes little or no economic damage.

Figure 7 Rust-affected garlic plants

Management Strategies

- Plough under-infected crop residues.
- Select planting dates and schedule irrigation to avoid long periods of leaf wetness when temperatures are high.
- Avoid over application of nitrogen and ensure adequate potassium fertilization.
- Spray of propiconazole, tebuconazole, azoxystrobin or hexaconazole @ 0.1% at fortnightly intervals to provide the best management of rust disease.

8. BOTRYTIS LEAF SPOT

Pathogen: *Botrytis cinerea*

Symptoms

Botrytis leaf spot occurs on onion but has not been reported on garlic. The leaf spot lesion initially has a small white, necrotic centre surrounded by a light green halo. The fungus survives in old bulbs or onion leaf debris as sclerotia or mycelia and in soil as sclerotia. Spores produced from infested soil or plant debris are carried to onion leaves by wind or splashing water.

Management Strategies

- Cultural practices that promote air movement and rapid drying of leaves can help reduce infections and disease severity.
- Crop rotation with non-susceptible crops such as alfalfa or small grains suppresses the build-up of sclerotia in soil.
- Preventive application of recommended fungicides when environmental conditions favour disease development can be an effective disease management tool.

Figure 8 Onion plants are severely infected with botrytis leaf blight

9. ANTHRACNOSE DISEASE (TWISTER)

Pathogen: *Colletotrichum gloeosporioides* Penz.

Perfect stage: *Glomerella cingulata* (Stonem) Schrenk and Spauld

Symptoms

Twister or seven curl disease is reported to be widespread throughout the world but more usual in tropics and subtropics. Curling and twisting of leaves, chlorosis, and abnormal elongation of neck portion are major symptoms. Bulb development is also affected. White oval sunken lesions are developed on leaves. In an advance stage,

(a)

(b)

Figure 9 Crops severely affected with twister disease: (a) curling and twisting of onion plants and (b) crops

roots become sparse and the plant may die. Bulbs are slender and may rot before harvest or during storage. This disease is more severe in Maharashtra. Pathogen survives on onion and garlic debris, and practice of crop hygiene, including destruction of crop residues, reduces the source of infection.

Management Strategies

- Use healthy and quality seed/planting materials from recognized institutes/organizations/seed agencies for better and good quality bulb and seed production.
- Treat seeds with Thiram or Captan @ 2.0–2.5 g/kg of seed before nursery sowing.
- Treat seeds with *Trichoderma viride* @ 5.0 g/kg of seed.
- Treat soil with benomyl or Benlate @ 2.0 g/m^2 and spray Mancozeb @ 2.5 g/L of water for effective results.
- Sanitation and destruction of infected plant debris help in reducing the disease incidence.

10. SOUTHERN BLIGHT

Pathogen: *Sclerotium rolfsii* Sacc.

Symptoms

The early symptoms of chlorotic dieback are similar to those caused by *Fusarium*. There is characteristic growth of pale mycelium on the soil surface around the stem base on which sclerotia are formed. It is active only in the upper surface of soil and is dependent for its activity on the presence of dead or senescent plant tissue.

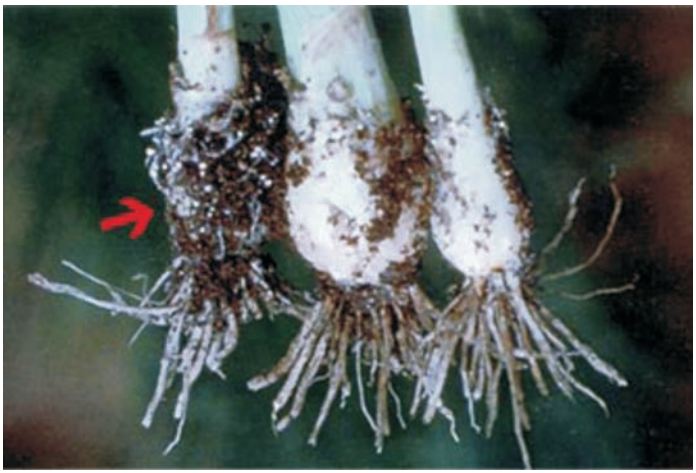


Figure 10 Onion bulb and roots affected with southern blight

Management Strategies

- Rotate crops with cereals to reduce the sclerotia population.
- Solarize soil for two–three weeks using 0.45 mm thick polythene sheet before raising the onion nursery.
- Treat soil with *Trichoderma viride* for reducing infestation.

11. WHITE ROT

Pathogen: *Selerotium cepivorum* Berk.

Symptoms

Pathogen is soil inhabiting and invades the roots and basal part of bulb scales. The first symptoms of the disease are premature yellowing and dying of older leaves, stunting and leaf tip burn, followed by destruction of the root system, shoot dieback, and rotting of the bulb. The

roots are generally destroyed, and there is semi-watery decay of the scale with abundance of superficial white mycelial growth. Brown to black sclerotia is developed on surface or within the tissue. Sclerotia can survive for over 20 years, even in the absence of a host plant. Disease severity depends on sclerotia levels in the soil at planting. Disease development is favoured by cool, moist soil conditions. For infection, soil temperature ranges from 50°F to 75°F, with optimum 60°F to 65°F.

Management Strategies

- Use clean seeds, cloves, and bulbs for planting/ transplanting.
- Light irrigation also minimizes the white rot incidence.
- Removal of infected plants during the *kharif* (rainy) season reduces the sclerotia population and also avoids its incorporation into soil.

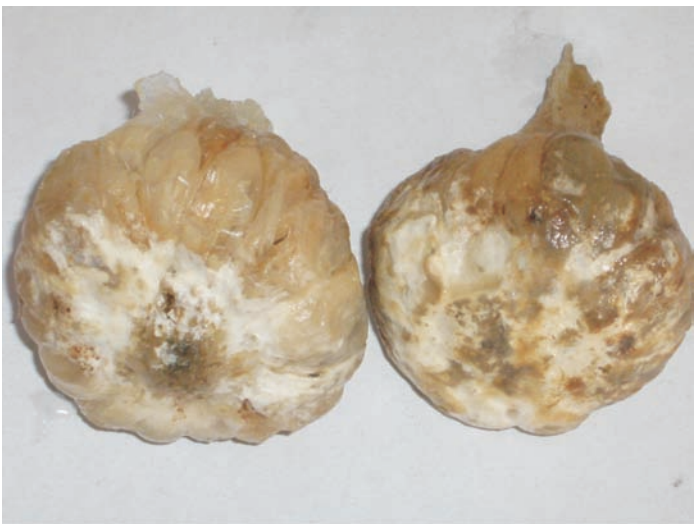


Figure 11(a) White rot infected garlic bulb

Figure 11(b) White rot infected onion plant

- Solarization of soil at high temperature, say, 35°C for 18 hours or 45°C for 6 hours reduces the incidence of white rot disease.
- Spraying of iprodione (Rovral) @ 0.25% and benomyl @ 0.1% has reduced disease incidence.
- *Trichoderma viride*, *Gliocladium zeae*, *Penicillium nigricans,* arbuscular mycorrhizal fungi (AMF), and *Trichoderma harzianum* are reported to be highly effective against this disease.

12. BASAL ROT/BOTTOM ROT

Pathogen: *Fusarium oxysporum* f.sp. *cepae* Schlecht.

Symptoms

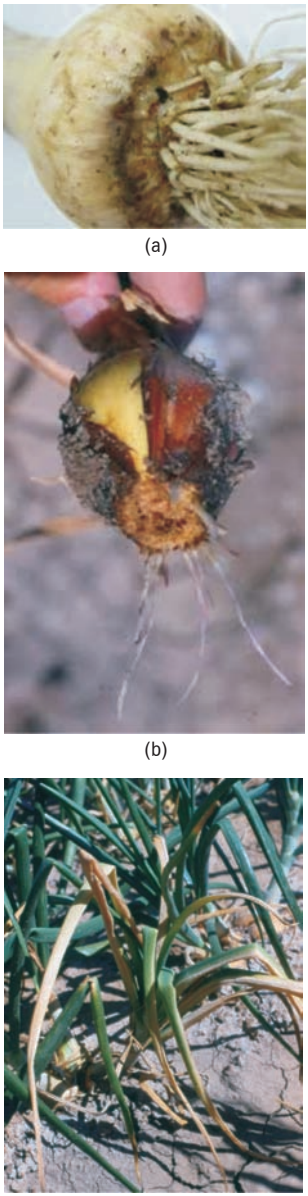
The main symptoms of the disease in onion are delayed seedling emergence, seedling damping-off, stunted

growth, and basal rotting in growing plant accompanied by early maturation and basal rotting in store. Roots may turn pink and gradually decay until the entire root disappears.

In garlic, pre-emergence decay of cloves, stem plate and post-harvest decay of cloves in stored bulbs are main symptoms. Infected garlic shows reddish or reddish purple discolouration on stem and bulb early in the season with some discolouration on bulb sheath at harvest. The fungus survives indefinitely in soil. Infections occur through wounds or in the vicinity of old root scares at the base of the bulb. The disease is favoured by high soil temperatures.

Management Strategies

- Remove infected plants, and use disease-free seeds/ planting materials.
- Proper drainage is essential during the entire cropping period.
- Proper drying and curing of onion bulb is essential before storage.
- Use *Trichoderma viride* and AMF with vermicompost before transplanting.
- Spray Bavistine @ 0.1% before 15–20 days of harvesting the crops.
- Plough deep and avoid injury during cultural practices.
- Avoid fields with a history of basal rot problems and rotate crops with cereals for three to four years.
- Store onion and garlic at cool temperature since infection is favoured by warm conditions.



(a)

(b)

(c)

Figure 12 Basal rot affected (a) garlic bulb, (b) onion bulb, and (c) onion crops

13. BROWN ROT

Pathogen: *Pseudomonas aeruginosa*

Symptoms

Dark brown discolouration on bulb scale is the characteristic feature of this disease. Browning of inner scale along with rotting is the main symptom. Rotting starts from inner scales and spreads to outer scales. Apparently, the bulb seems to be healthy, but when pressed, white ooze is noticed from the neck. In several cases, the whole lot of bulbs gets rotten giving bad odour in storage.

Figure 13 Brown discolouration in onion bulb

Management Strategies

- Proper drying and curing is required before storage.
- Cut the neck about 2.5–3.0 cm above the bulb to reduce bacterial infection.
- Light irrigation is required during the entire cropping period.
- Use maleic hydrazide and isopropyl phenyl carbamate (IPC) @ 20 ml/L before one month of harvest.

14. SOFT ROT

Pathogen: *Erwinia caratovora*

Symptoms

Severe discolouration with soft rotting and water soaking of one or more of the inner fleshy scales of onion and garlic bulbs are the main symptoms of this disease. Severe infection occurs at high temperature. The affected fleshy scale tissues are water soaked, pale yellow to light brown in colour, and become soft as the rot progresses. The whole bulb may break down, and a watery liquid having foul odour may ooze from it, if squeezed. The organisms generally appear just before or at the time of harvest or in storage. The pathogens are soil borne and may spread through irrigation water.

Management Strategies

- Proper curing is required after harvest.
- Proper drainage is required during cropping period.
- Reduce doses of nitrogenous fertilizers.
- Harvest only after onion tops become well matured.

(a)

(b)

Figure 14 Soft rot affected (a) onion and (b) garlic bulb

15. NECK ROT

Pathogen: *Botrytis allii* Munn

Symptoms

Infection usually occurs on the neck tissue and elsewhere occasionally. The first signs include softening of the affected tissue, which takes a sunken cooked appearance. Decaying starts at a later stage, separating the infected part from healthy tissue by a definite margin. A dense greyish mycelial mat develops on the decaying tissue of the scales bearing short conidiophores with conidia. The disease progresses rapidly down the scales of neck tissue. Black sclerotia bodies are developed later. When diseased bulbs are cut open, water-soaked brown tissues are seen near the neck region.

Management Strategies

- Use planting stock free of the disease.

Figure 15 Rot in the neck region of onion bulb

- Seed treatment with benomyl @ 1 g/kg of seed or benomyl + Thiram @ 1 g/kg of seed reduces the disease incidence.
- Pre-harvest spray of benomyl @ 0.1% reduces the fungal infection.
- Proper drying and curing is required after harvest and before storage.
- Cut the neck 2.5–3.0 cm above the bulb to reduce infection.

16. PINK ROOT

Pathogen: *Pyrenochaeta terrestris* de Not.

Symptoms

The characteristic symptom of the disease is the pink colouration of roots, hence the name. The affected roots initially turn yellow but later become soft and ultimately take a distinctly deep pink colour. The new roots growing from the infected plants get immediately infected and become functionless. The affected plants are not killed, but development is retarded and the number of leaves and their size get reduced. Bulbing starts earlier, but the size is reduced at maturity. The disease is confined to the roots only. Fungus is a common soil inhabitant that penetrates onion and garlic roots directly. Wounds are not necessary for infection, but weak plants are more susceptible. It can spread through water and on dirty equipment.

Management Strategies

- Following five–six years' crop rotation with non-host crops gives good control over the pink root disease.

(a)

(b)

Figure 16 Pink discolouration on (a) base of onion bulb and (b) root

- Solarize soil for two–three weeks using 0.45 mm thick polythene sheet before raising the onion nursery.
- Proper sanitation and drainage is required.
- Plant host resistance species.

17. BLACK MOULD

Pathogen: *Aspergillus niger* van Tiegh.

Symptoms

Black mould occurs on both onions and garlic. Fungus infects the neck of bulbs and occasionally penetrates from side and basal end of the bulb, where damage to the dry skin has exposed the bulb scales. In advance stages, the entire surface of bulbs turns black and all scales get infected. The fungus survives on decaying organic matter such as plant debris. It reduces the market value of the bulb.

Management Strategies

- Proper drying and curing of onion and garlic bulbs is necessary after harvest.
- There are no chemicals for direct control of black mould fungus.
- Handling of bulbs to avoid bruising can also reduce injury and invasion sites for the fungus.
- Bulbs should be dusted with calcium carbonate and warehouses fumigated with nitrogen trichloride @ 430 mg/m^2.

(a)

(b)

Figure 17 Black powdery mould on (a) onion and (b) garlic bulb

18. BLUE MOULD

Pathogen: *Penicillium corymbiferum* Link ex Fr.

Symptoms

Blue mould generally appears during harvesting and storage. The first symptoms of the disease are pale yellowish blemishes, watery soft spots, or occasionally a purplish red stain on the scales. A green to blue green mould may develop on the surface of lesions when bulbs are cut longitudinally, one or more of the fleshy scales may appear water soaked and exhibit a light tan or grey colour. In advanced stages, infected bulbs may disintegrate into watery rot.

Figure 18 Garlic bulb infected with blue mould

Management Strategies

- Properly dry and cure after harvest and before storage.
- Injury should be avoided during post-harvest handling.
- Mercurial dip of bulb/cloves can be practised before drying in case of bulbs kept for planting.
- Store bulbs at 5°C or less temperature with low relative humidity.

19. ONION SMUT

Pathogen: *Urocystis (Burkholderia) cepulae*. (Frost.) Kolar Dt.

Symptoms

The disease appears first on the cotyledons of young plants, soon after they emerge from the soil. The lesion consists of dark, slightly thickened area involving leaf or cotyledon; the lesion may be from one to several millimeters. Sometimes, the major part of a leaf has a single lesion and in such cases, the leaf tends to curve downward abnormally. The lesions on plants break open and expose a black powdery mass of spores. The fungus does not produce a rot in storage, but the affected bulb may become prone to invasion by other pathogens.

Management Strategies

- Treat seeds with Thiram @ 2.5 g/kg for effective control of the disease.
- Treat soil with formaldehyde solution.
- Phosphatic and potassic fertilizers also help in reducing smut infection.

Figure 19 Onion bulb affected with smut

20. ONION SMUDGE

Pathogen: *Colletotrichum circinans*

Symptoms

It occurs on white onion varieties and reduces the market value of bulbs. The disease is characterized by small dark green to black spots, which appear on outer scales.

Management Strategies

- Thorough curing of bulb after harvesting and storing bulbs in well-ventilated rooms can control the disease.

Figure 20 Onion smudge infected bulbs

21. SOUR SKIN

Pathogen: *Pseudomonas cepacia*

Symptoms

Affected outer scales become yellow and slimy giving vinegary sour smell. Externally, bulbs look healthy but the neck region may soften. In advanced stages, healthy scales can slip off during handling.

Management Strategies

- Use balanced fertilizers.
- Ensure proper drainage.
- Rotate crops with vegetables like tomato, capsicum, pea, and cereals like wheat and paddy.
- Proper curing is essential after harvest.

Figure 21 Sour skin affected onion bulb

22. BULB CANKER/SKIN BLOTCH

Pathogen: *Embellissia allii.* (Campan.) E.G. Simmins

Symptoms

The initial symptoms of the disease are small blackish dark spots on the outer scales of bulbs, which later enlarge and cover whole of the bulb with black powdery mass. Under advanced conditions, decay of cloves and bulbs has been observed, which can reduce the market value.

Management Strategies

- Properly cure bulbs before storage.
- Seeds and cloves should be treated with Bavistine @ 1.0 g/kg of seed before planting/sowing.
- Avoid overdoses of nitrogenous fertilizers to reduce the disease incidence.
- Spray Carbendazim @ 1.0 g/L before 15–20 days of harvest.

(a)

(b)

Figure 22 Bulb affected with canker/skin blotch disease: (a) garlic and (b) onion

23. GARLIC MOSAIC

Pathogen: Virus

Symptoms

Garlic plants infected with several complexes of viruses show typical symptoms of chlorotic mottling and stripes on the emerging leaf, followed by pale yellow broken stripes resulting in typical mosaic pattern on matured leaves. Yellowish dots on leaves, whitish leaf margin, or twisting of leaves are also recorded on some cultivars. Generally, symptoms are more pronounced in young leaves. Infected plants are stunted, and bulb size is reduced.

Figure 23 Garlic plants infected with mosaic disease

Management Strategies

- Virus-free stocks should be produced from meristem tip culture and multiplied in areas free of commercial garlic to prevent reinfection by insects.
- Spray monocrotophos @ 0.05%, endosulphan @ 0.25% or methyl dematon @ 0.075% at 10–15 days' intervals.
- Use HNPV and some neem-based botanicals at weekly intervals.

24. IRIS YELLOW SPOT VIRUS (IYSV)

Pathogen: Virus (*Tospovirus*)

Symptoms

The disease symptoms vary among onion and garlic bulb and seed crops, but often appear as straw-coloured, diamond-shaped lesions on leaves and flower-bearing stalks of onion plants. Some lesions have distinct green centre with yellow or tan borders, while other lesions appears as concentric rings of alternating green and yellow/tan tissue. Infected plants can be scattered or generalized throughout a field. Large necrotic region may develop on scapes and cause a collapse of the escape. Diseased plants may be scattered or widespread across a field, but the highest incidence of disease is often found on the field edges. The virus infects most of the *Allium* species.

Management Strategies

- Iris yellow spot virus (IYSV) is a top virus, similar to tomato spotted wilt virus, which is currently thought to be vectored solely by onion thrips (*Thrips tabaci*). So alternate spray of softer insecticide formulations (spinosad, neem extract) and organic mulches (straw) is effective against IYSV.

(a)

(b)

(c)

Figure 24 (a) Onion bulb crop, (b) seed crops, and (c) garlic plants severely affected with Iris yellow spot virus

- Spraying of Deltamethrin @ 1 ml/L gives best performance.
- Fipronil @ 1 ml/L of water and spionsad @ 1 ml/L of water offer best control of this pest.
- An integrated approach is essential for management of IYSV.
- Eliminate weeds in and around onion fields, especially volunteer onions and wild *Alliums*.

25. ONION YELLOW DWARF VIRUS (OYDV)

Pathogen: Virus (Poty virus)

Symptoms

Onion yellow dwarf virus (OYDV), an aphid-borne poty virus, is one of the major viral pathogens of onion and garlic. It restricts seed production in both crops. Leaves of OYDV-infected onion show irregular yellow striping to almost complete yellowing and also downward curling, flattening, and crinkling followed by stunting. In garlic, OYDV produces symptoms depending on virus isolate and cultivars. Reduction in growth and bulb size also occurs. Infection by other viruses such as leek yellow stripe virus, garlic common latent virus, and shallot latent virus may aggravate the symptoms. However, OYDV is recognized as a major element of the virus disease complex in garlic. It is spread from plant to plant by the green peach aphid *Myzus persicae* and other aphids in a non-persistent manner.

Management Strategies

- Collect healthy seeds from disease-free plants.
- Use virus-free planting materials, which are produced through tissue culture.
- Remove virus-infected plants from field.

(a)

(b)

Figure 25 Garlic plants severely infected with onion yellow dwarf virus

- Alternately spray systemic insecticides like Deltamethrin (Decis) and Cypermethrin @ 0.1% with neem-based botanicals.

4

Major Insect Pests and their Management

1. ONION THRIPS

Scientific name: *Thrips tabaci* Lindeman

Geographic Distribution

- Thrips are spread worldwide.
- These are important pests of onions, garlic, and several other crops in most parts of the world.
- Thrips can colonize crops from sea level up to 2000 m above sea level.
- They can be a problem in several other crops such as chilli, capsicum, cabbage, cotton, celery, tomato, beans, cucumber, and pineapple.
- Thrips can be found in almost any cultivated and weedy plants.

Damage and Importance

- Thrips attack onion and garlic at all stages of crop growth.
- Thrips have a very peculiar feeding behaviour.

Figure 1 Thrips population at the base of onion plant

Figure 2 Onion field infested with Thrips

- They start feeding by piercing and rasping the leaf surface with their mouth to release liquids from plant cells.
- In this process, thrips release substances that help predigest the onion plant tissue. Later, with their mouth they suck up the plant content.
- Thrips prefer to feed on young plant tissue on newly emerged leaves.
- Plant cannot adequately photosynthesize.
- The plant losses more water than normal through the damaged tissue.
- Plant pathogens penetrate the injured plant easily.
- Bulbs may mature faster, and their size becomes reduced.
- More than 60% of an onion and garlic crop may be lost. Thrips may also serve as vectors of some viruses and other plant diseases, especially fungus, purple blotch *(Alternaria porri)*, and Iris yellow spot virus.

Economic Threshold

A reliable treatment threshold has not been developed; however, a threshold of 30 thrips per plant during mid-season has been considered. For small onion producers, the recommended economic threshold is 20% of plants infested with thrips. The threshold is three thrips per green leaf. The cumulative thrips-days are 500–600 (that is, 50–60 thrips for 10 days).

Management Strategies

- Colour-sensitive mulch: aluminium-coated mulch repels pest by 33%–68%.
- Intercropping with maize and carrot may also reduce thrips population.

- Lack of adequate soil calcium may invite higher population of thrips.
- High nitrate levels invite thrips.
- Irrigation of onions is very important to control thrips.
- Use sprinkler irrigation to simulate rainfall and control thrips.
- If onion plants encounter water stress, damage by thrips may be magnified because the plants lose large amounts of water from the damaged tissue.
- It is very important that onion seedlings are clean of thrips before transplantation.
- Spraying of Deltamethrin @ 1 ml/L gives best performance.
- Fipronil @ 1 ml/L of water and spionsad @ 1 ml/L of water offer best control of this pest.
- At high temperature, profenophos @ 2 ml/L gives good control.
- Alternately use chemical groups.
- Spinosad is a recently discovered insecticide, derived from the fermentation of actinomycetes bacteria, commonly found in soil.
- The National Organic Board has recommended that spinosad be allowed in organic production.

2. ONION MAGGOT

Scientific name: *Delia antique* Meigen.
D. Platura

Distribution

- Maggot is an onion pest and does not generally cause economic damage to garlic.

- Onion maggot can cause losses from 20%–90% in many temperate regions.
- Onion maggot adults are one-fourth of an inch, gray brown, bristly, humpbacked flies.
- Eggs are white and elongated, with characteristic surface ridging and hexagonal pattern.
- The one-third of an inch maggots are legless, cylindrical, tapering at the head, and creamy white. They pupate with in a chestnut brown puparia.
- These flies lay eggs in small batches on the soil surface near the base of seedlings.
- Female mates only once, but males are capable of repeated mating. Maggots prefer soils heavy in organic matter where they can survive and move to seeds.

Management Strategies

- Avoid planting in soils that are high in undecomposed matter.
- Avoid planting where crop rotations are not followed.
- Employ biological control.
- No promising natural enemies exist, which can be successfully employed for control of this pest at field level.
- Only braconid, *Aphaereta pallipes*, *Staphylinid,* and *Aleochara bilineata* have significantly increased the mortality of onion maggot, but the performance in field is poor.
- Ground beetle is an onion maggot predator, and establishing grassy refuse stripes in an onion crop enhances beetle population and reduces maggot population.
- An entomogenous fungus *Entomophthora muscae* was reported from Canada. Under laboratory conditions,

Figure 3 Onion bulb severely infected with maggot

Figure 4 Adult maggots feeding on onion leaves/scales

entomophyllic nematodes *Steinenema faltiae* and Heterorhabditis caused 63.3%–100% mortality of *Delia antiqua.*

3. TOBACCO CATERPILLAR

Scientific name: *Spodoptera exigua*
S. litura

Damage and Importance

These are minor pests of onion. Eggs are laid in groups on the leaf surface. Early instars are gregarious, and the larvae feed on leaf surface, bore into the leaf, and feed. Leaves with big holes and faecal matter are seen on attacked plants. Pupation occurs inside the soil.

Figure 5(a) Egg mass of tobacco caterpillar

Figure 5(b) Larva of tobacco caterpillar

Management Strategies

- Specific application of any treatment is not required as the insecticides recommended for thrips control can check this pest also.
- Use of *Sl*NPV and *Bt* alone and in combination are recommended for control of this pest.
- Installation of pheromone traps for mass collection of adult moths can help in reduction of pest incidence.
- Collection and destruction of egg masses.

4. GRAM CATERPILLAR

Scientific name: *Helicoverpa armigera* Hubner

Damage and Importance

This polyphagous pest occurs sporadically on onion grown for seed. Larvae feed inside the stem and move

(a)

(b)

Figure 6 Onion seed crop (umbels) damaged by *Helicoverpa* larvae

upwards to reach the base of the umbel at the early stage of flowering. As a result, complete drying of flowers and complete loss of seed occur.

Management Strategies

- Specific application of any treatment is not required as the insecticides recommended for thrips control can check this pest also.
- Use of *Ha*NPV and *Bt* alone and in combination are recommended for controlling this pest.
- Release of the egg parasite *Trichogramma chilonis* @ 1.0 lakh/ha for 3–4 times at weekly interval.
- Monitoring of adult moths through installation of pheromone traps.

5. LEAFMINERS

Scientific name: *Liriomyza* spp.

Description

Adults are small black and yellow flies. Females puncture the leaf to feed on plant sap and to lay eggs within the leaf tissue. Eggs hatch within two to four days, and small white to yellow larvae tunnel within the leaf tissue. Larger larvae may feed inside the hollow leaves of onions or garlic, but still produce the characteristic "mines" visible from the outside of the leaf. Larvae exit the leaf upon completion of their development and pupate in the soil or in the leaf axils on plants. Many generations occur each year.

Damage

Damage caused by leafminers is primarily cosmetic in green bunching onions; contamination by pupae and larvae, however, is a problem. Damage to dry onions and

Figure 7 Onion leaves damaged by leafminers

garlic is of little concern unless populations become so high that the foliage has to be prematurely killed.

Management Strategies

Biological Control

Natural enemies, especially parasitic wasps, are commonly found reducing leafminer numbers. These parasitic wasps are very susceptible to insecticide sprays and may not be important in fields where insecticides have been used.

Cultural Control

Leafminers attack a wide variety of crops in coastal California. Close proximity to crops such as lettuce, celery or spinach will increase the potential for damage by leafminers in onions. It is also important that fields being planted with onions that were previously in one of these susceptible crops be worked thoroughly and that sufficient time be allowed to pass before planting into these fields to allow pupae in the soil to emerge.

Organically Acceptable Methods

Biological controls are often effective in controlling this pest in organically grown onion and garlic crops. Supplementary release of parasites is rarely economically justified; cultural controls are critical. Neem products are allowed as restricted use materials.

5

Nematodes and Mites and their Management

1. STEM AND BULB NEMATODE

Pathogen: *Ditylenchus dipsaci*

Symptoms

The invaded cotyledon may swell and seedling may collapse. After 10 days of invasion, leaves are deformed and stem splitting takes place. When the nematode multiplies in the leaves, it becomes swollen and distorted, giving a bloated appearance. Auxiliary buds may sprout creating multi-stemmed plants, which may be swollen and stubby. The inner leaves may coil in the sheathing leaves and fail to emerge completely.

Management Strategies

- Use certified nematode-free seeds.
- Follow three–four years' crop rotation with other non-host vegetables and cereals.
- Eliminate weeds to control the population of nematodes.

(a)

(b)

Figure 1 Stem and bulb nematode affected (a) onion and (b) garlic bulbs

- Deep summer ploughing can reduce the nematode population in soil.
- Fumigate onion seeds with methyl bromide while nursery raising.
- Use phorate @ 10 kg/ha or neemagon @ 10–15 kg/ha at the time of transplantation of onion and garlic.

2. ROOT-KNOT NEMATODE

Pathogen: *Meloidogyne incognita*
M. javanica
M. chitwoodi

Symptoms

The root-knot nematode is widely distributed, and various species are obligate parasites with wide host range. Typical symptoms include round spindle-shaped swelling on roots. The galls are smaller on onion (1–2 mm in diameter). The infected secondary root systems are shorter and have less roots and root hairs. Plant stunting, poor plant stand, and yellowing are also associated with the infestation of root-knot nematode. The optimum temperatures of 15–30°C are suitable for infestation and life cycle of the nematode. It is more severe in sandy textured soil.

Management Strategies

- Use certified nematode-free seeds.
- Follow three–four years' crop rotation with other non-host vegetables and cereals.
- Eliminate weeds to control the population of nematodes.
- Deep summer ploughing can reduce the nematode population in soil.

- Fumigate onion seeds with methyl bromide at the time of nursery raising.
- Use phorate @ 10 kg/ha or neemagon @ 10–15 kg/ha at the time of transplantation of onion and garlic.

3. RICE ROOT-KNOT NEMATODE

Pathogen: *Meloidogyne graminicola*

Symptoms

Several plants of onion and garlic showed yellowing of leaves, and these plants wilted during the day but recovered their turgidity at night. Diseased plants were easily pulled from the soil due to the almost complete destruction of the root systems. Numerous galls (averaging 15–20 galls/plant) were found on affected roots, compared with healthy plants. The size of each gall was around 1.0–1.5 cm, and they were round to oval in shape.

The morphological characters of the second-stage juveniles of the root-knot nematode were examined under light microscope. The average size of eggs was 90.4 × 38.2 µm and that of second stage juveniles was 440 × 16.6 µm. The sizes of male and female were 1221 × 32 µm and 535 × 380 µm, respectively.

Management Strategies

- Crop rotation with other solanaceous and cucurbitaceous vegetables can reduce the nematode population in onion and garlic.
- Apply vermicompost @ 2–3 tonnes/ha and neem cake at the time of transplantation.
- Avoid excess irrigation.

(a)

(b)

Figure 2 *Meloidogyne graminicola* infested (a) onion and (b) garlic plants

4. BULB MITES

Scientific name: *Rhizoglyphus* spp.
Tyrophagus spp.

Symptoms

Bulb mites are shiny, creamy white, bulbous mites that range in size from 0.02 inches to 0.04 inches (0.5–1 mm) long. They have four pairs of short brown legs and look like tiny pearls with legs. They generally occur in clusters inhabiting damaged areas under the root plate of onion bulbs or garlic cloves. They have a wide host range, feed on many kinds of bulbs, roots, and tubers, and can infest bulbs in storage or in field. Bulb mites can survive on decaying vegetation in the field until it is completely decomposed.

Damage

Bulb mites damage bulbs by penetrating the outer layer of tissue and allowing rotting organisms to gain entry. This pest is most damaging when plant growth is slowed by cool, wet weather. Bulb mites can reduce plant stands, stunt plant growth, and promote rotting of bulbs in storage. On seeded onions, they can cut off the radicle before the plant becomes established.

Management Strategies

- Rapid rotation from one crop to the next fosters survival of mites on the leftover vegetation in the soil from the previous crop. Decaying cole crops, especially cauliflower, may harbour very high bulb mite populations.
- Fallow fields to allow complete decomposition of organic matter; this reduces field populations of the mite. Avoid planting successive onion or garlic crops.

- Flood irrigation or heavy rains during the winter may reduce mite levels in the soil. Garlic growers must insist on clean seed cloves. Hot water treatment of seed garlic before planting may reduce mite infestation.

Annexures

Annexure 1 Major pests of onion and garlic and their causal organisms

Disease/insect pest	Causative agent
Damping-off	*Pythium aphanidermatum* (Edson.) Fitz. *P. debaryanum* *Rhizoctonia solani* Kuehn.
Purple blotch	*Alternaria porri* (Ell.) Neerg.
Stemphylium blight	*Stemphylium vesicarium* (Wallr.) Sacc.
Cercospora leaf spot	*Cercospora duddiae* Welles.
Powdery mildew	*Leveillula taurica* (Lev.) Arnaud
Downy mildew	*Peronospora destructor* (Berk.) Casp.
Rust	*Puccinia porri* G. Wint. *P. allii* (DC.) Rud.
Botrytis leaf spot	*Botrytis cinerea*
Anthracnose disease (twister)	*Colletotrichum gloeosporioides* Penz. *Glomerella cingulata* (Stonem) Schrenk and Spauld
Southern blight	*Sclerotium rolfsii* Sacc.
White rot	*Selerotium cepivorum* Berk.
Basal rot/bottom rot	*Fusarium oxysporum* f.sp. *cepae* Schlecht.
Brown rot	*Pseudomonas aeruginosa*
Soft rot	*Erwinia caratovora*
Neck rot	*Botrytis allii* Munn
Pink root	*Pyrenochaeta terrestris* de Not.
Black mould	*Aspergillus niger* van Tiegh.
Blue mould	*Penicillium corymbiferum* Link ex Fr.

Contd...

Annexure 1 *Contd...*

Disease/insect pest	Causative agent
Onion smut	*Urocystis (Burkholderia) cepulae*. (Frost.) Kolar Dt.
Sour skin	*Pseudomonas cepacia*
Bulb canker/skin blotch	*Embellissia allii.* Campan. E.G. Simmins
Garlic mosaic	Virus
Iris yellow spot virus	Virus (Tospovirus)
Onion yellow dwarf virus	Virus (Poty virus)
Stem and bulb nematode	*Ditylenchus dipsaci*
Root-knot nematode	*Meloidogyne incognita* *M. javanica* *M. chitwoodi*
Rice root-knot nematode	*Meloidogyne graminicola*
Onion thrips	*Thrips tabaci* Lindeman
Onion maggot	*Delia antique* Meigen. *D. platura*
Tobacco caterpillar	*Spodoptera exigua* *S. litura*
Gram caterpillar	*Helicoverpa armigera* Hubner
Bulb mites	*Rhizoglyphus* spp. *Tyrophagus* spp.
Leafminer	*Liriomyza* spp.

Annexure 2 List of different fungicide/bio-agent formulations used in onion and garlic

Common name	Trade name	Concentration (%)
Mancozeb	Dithane M-45, Indofil M-45, Dhanuka M-45	0.25
Carbendazim	Babistin, Dhanustin, Ridomil	0.1
Captan	Captan, Dhanutan	0.2–0.25
Thiram	Thiaride, Hexaire	0.2–0.25
Dinocap	Karathane	0.2
Copper oxychloride	Blitox-50, Phytolan, Blue copper, Dhanucop, Tracop	0.3
Sulphur	Sulfex, Agrisulf, Dhanusal, Thiovit	0.2
Tidemorph	Calixin	0.2
Penconazole	Topas	0.1
Propineb	Antracol	0.2
Chlorothalonil	Kavach	0.2
Tebuconazole	Folicure	0.1
Diafeniconazole	Score	0.1
Hexaconazole	Cantaf, Sitara, Hexzole	0.1
Propiconazole	Tilt	0.1
Copper hydroxide	Kocide	0.2–0.25
Mixed fungicides (68% Mancozeb + 12% Carbendazim)	Companian, Saaf, Bright, Sixer	0.2–0.25
Metalexil + Mancozeb	Ridomil, Metco, Unilex, Egron	0.2–0.25
Azoxistrobin	Amister	0.1
Bittertanol	Bencor, Veliton	0.05
Trichoderma viride	Bioderma, Ecoderma, Trichodex	0.4–0.5
Azadirachta indica	Indoneem, Bioneem, Ozoneem	0.5

Annexure 3 Area and production of onion, by state (2010/11)

State	Area ('000 ha)	Production ('000 MT)	Yield (tonnes/ha)
Andhra Pradesh	40.40	628.70	15.56
Assam	8.00	22.10	2.76
Bihar	54.00	1080.00	20.00
Chhattisgarh	11.20	174.20	15.55
Delhi	1.40	25.00	17.86
Gujarat	62.00	1514.00	24.42
Haryana	22.20	383.40	17.27
Himachal Pradesh	2.00	33.90	16.95
Jammu and Kashmir	2.60	64.80	24.92
Jharkhand	14.70	305.50	20.78
Karnataka	148.30	2 379.50	16.05
Madhya Pradesh	58.30	1 021.50	17.52
Maharashtra	414.00	4 905.00	11.85
Odisha	33.10	318.10	9.61
Puducherry	0.00	0.20	0.00
Punjab	8.20	175.40	21.39
Rajasthan	48.50	750.00	15.46
Sikkim	0.30	1.60	5.33
Tamil Nadu	33.80	338.90	10.03
Uttar Pradesh	23.60	370.90	15.72
Uttarakhand	4.20	45.00	10.71
West Bengal	21.30	298.00	13.99
Total	1012.10	14 835.70	–

Source Directorate of Economics and Statistics

Annexure 4 Area and production of garlic, by state (2010/11)

State	Area ('000 ha)	Production ('000 MT)	Yield (tonnes/ha)
Andhra Pradesh	0.40	4.00	10.00
Bihar	4.25	29.75	7.00
Chhattisgarh	3.90	21.10	5.41
Gujarat	40.00	275.00	6.88
Himachal Pradesh	3.60	44.70	12.42
Jammu and Kashmir	2.30	32.00	13.91
Karnataka	4.20	30.20	7.19
Madhya Pradesh	54.00	228.00	4.22
Maharashtra	3.50	34.10	9.74
Odisha	11.00	35.80	3.25
Others	13.29	104.74	7.88
Punjab	3.70	40.50	10.95
Rajasthan	25.00	150.00	6.00
Tamil Nadu	0.40	3.10	7.75
Uttar Pradesh	35.10	190.50	5.43
Uttarakhand	1.20	7.30	6.08
West Bengal	3.50	33.90	9.69
Total	209.34	1264.69	–

Source Directorate of Economics and Statistics

Annexure 5 Area and production of onion in major producing countries

Country	Area ('000 ha)	Production ('000 MT)
China	1 001 171	20 817 295
India	804 600	8 178 300
Pakistan	153 100	2 015 200
Turkey	75 000	2 007 120
Russia	128 600	1 900 000
Egypt	52 885	1 728 410
Iran	50 000	170 000
Brazil	63 639	129 981
Mexico	42 998	1 252 440
Japan	24 500	1 165 000
Netherlands	26 200	113 000
Spain	21 100	109 940
Ukraine	62 000	1 049 200
Bangladesh	125 226	889 200
Indonesia	91 780	824 062
Myanmar	60 000	740 000
Uzbekistan	23 000	728 000
Argentina	24 000	70 000
Algeria	38 000	70 000
Morocco	27 900	66 214
Peru	18 879	63 439

Source <www.far.org>

Annexure 6 Area and production of garlic in major producing countries

Country	Area ('000 ha)	Production ('000 MT)
China	692 400	12 088 000
India	147 000	645 000
Uzbekistan	2 500	30 300
Italy	3 000	30 000
Japan	2 000	20 000
Sudan	1100	17 500
Netherlands	220	10 000
Armenia	800	10 000
Turkmenistan	400	7 000

Source <www.far.org>

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About the Authors

Dr R K Mishra is presently working at The Energy and Resources Institute (TERI) and is associated with research and development and implementation of mycorrhizal technology of different horticultural/ agricultural crops in different states. Prior to TERI, he worked at the National Horticultural Research and Development Foundation, Karnal, Haryana, on disease management of onion and garlic. During this period, he was associated with the All India Networking Research Improvement Program (AINRP) on onion and garlic and All India Coordinated Research Projects (AICRP) on vegetable crops. He has also worked on environmentally safe pesticides and has tested new molecules for management of onion and garlic pathogens. He has published more than 30 research papers and popular articles, and has edited technical bulletins on various aspects of horticultural/vegetable crops.

Dr Alok Adholeya, PhD in Microbiology, is presently Director, Biotechnology and Management of Bioresources, TERI. His distinguished career has been largely devoted to finding and developing ways to harness the power of microbes, particularly mycorrhizae, to increase the productivity of crop plants, restore degraded lands, and remediate contaminated soil. He has a strong experience and expertise in soil fertility, soil and plant microbiology, nutrient cycling, bioremediation using microbes and plants, molecular characterization, commercialization of

mass production technology for mycorrhizae biofertilizer using transformed root organ cultures and bioenergy particularly from Jatropha and algal system. Dr Adholeya has handled more than 30 research projects, published over 85 research papers in reputable national and international journals, and is a member of the editorial boards of many of them. He has often chaired many advisory committees on agriculture, fertilizer, and bioremediation and is chairman of Department of Biotechnology's taskforce on biofertilizers in India.

He has been awarded the Gwalior Ratna in 2000, Paryavaran Sanrakshan Samman in 1999, Young Scientist Award in 1999, and the Biotech Product and Process Development and Commercialization Award 2004 by the Ministry of Science and Technology, Government of India, and Innovation for India Award 2010 by Marico Innovation Foundation.

Dr H R Sardana is presently working as Principal Scientist (Entomology) at the National Centre for Integrated Pest Management (NCIPM) and is associated with the development and implementation of IPM programmes in vegetable crops. He has developed IPM technologies for important vegetable crops like tomato, brinjal, lady's finger, bell pepper, and chillies. Prior to joining NCIPM, he worked on ecological and pest management aspects of sugarcane crop at the Sugarcane Breeding Institute, Regional Centre, Karnal, Haryana. He has made significant contribution to the "root borer-wilt complex" aspect of sugarcane. Dr Sardana has published more than 100 research papers/technical bulletins, 10 book chapters, and has edited three books.

Integrated Pest Management

Strategies for Onion and Garlic

R K Mishra • Alok Adholeya • H R Sardana

Onion *(Allium cepa L.)* and garlic *(Allium sativum L.)* are the most important Allium species cultivated worldwide and are used as vegetable and spice in our daily diet. These crops are widely cultivated for domestic consumption as well as for export purposes. They are attacked by many insect pests and diseases, which vary with region, season, and variety. This lowers the quality and yield, thereby increasing the cost of production and reduces export potential.

Integrated Pest Management: strategies for onion and garlic discusses methods and tools used to minimize the incidence and severity caused by diseases and insect pests. It also focuses on the symptoms of diseases caused by various pathogens.

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