BEST PRACTICES FOR INTEGRATED PEST MANAGEMENT

IN NEW ZEALAND ALLIUM CROPS

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GUIDE DEVELOPED BY ONIONS NEW ZEALAND

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1.1

What is IPM?

The most sustainable solution to controlling pests (insect, pathogen, mite or weed) is the development and implementation of IPM programmes. The main principle of an IPM programme is to use a compatible combination of control methods (biological, cultural and chemical) to prevent pests from causing unacceptable damage to crops.

Relying on pesticides (chemical control) applied on a regular schedule for a quick fix to pest and disease problems is not a workable, long term solution for horticultural and agricultural crops. This approach is unsustainable because resistance to the pesticides can develop. Also numbers of secondary pests can increase if natural enemies are removed by insecticides. Biological control agents (beneficial organisms that attack on pests or diseases) are encouraged in IPM programmes.

IPM programmes:

- give effective pest control
- produce crops that meet market standards
- involve techniques that emphasise monitoring in some form
- commonly reduce pesticide use, minimising residues on products
- emphasise the use of selective compounds (where available) in preference to broad spectrum compounds
- aim to minimise negative impacts on the environment.

If all of these aspects are included in crop management the crop could be said to be produced using IPM. The key to most IPM programmes is the use of crop monitoring techniques to assess pest population levels (see section 1.2.2). Growers who adopt IPM programmes respond to pest numbers or disease risk and their potential impacts to ensure controls are applied only when required. This maximises pesticide efficiency while minimising yield losses.

1.2

IPM components

The components of IPM can be divided into three categories that are usually employed in the following sequence:

1. Prevention

try to stop pest problems from occurring, e.g. quarantine, cultural controls, plant resistance and aspects of biological control.

2. Decision tools

incorporate techniques such as crop monitoring and action thresholds to look for, assess and react to pest problems.

3. Intervention

if the pest population is such that economic damage is likely then intervention is required, e.g. biological control and pesticide control (including pesticide resistance management).

1.2.1 Prevention

Quarantine

Prevent the entry of a pest into a crop, into a region or onto a farm by putting plant material into quarantine or by moving equipment and machinery into pest or disease free areas. For example, machinery used in an area infested with onion white rot should not be used in areas free of the disease.

Cultural control

Manipulate crop growing practices to make the environment less favourable for pest and disease infestations. These practices help to reduce the pest or disease population and maintain the crop in a healthy state.

Growing practices that can be used include:

- **sowing dates**
  to avoid flights of an insect pest or ensure a less susceptible stage of the crop is present when a pest is migrating
- **crop rotation**
  to prevent soil-borne pests or diseases from building up to levels that lead to epidemics in crops
- **cultivation**
  to reduce soil-dwelling life stages of some pests or diseases, reducing populations in subsequent crops
- **hygiene**
  rouging infested plants to prevent spread of pests and diseases to healthy plants, or destroying crop residues after harvest to reduce carry over to the next crop
- **irrigation management**
  wet or dry conditions can encourage or reduce various pest or disease problems avoid using organic fertiliser
  to prevent seed and seedling pests.

Plant resistance

Use or select resistant or tolerant varieties that can prevent infection, delay or prevent development of infection, or produce a crop that tolerates infection.

E.g. some onion varieties with firmer skins may prevent thrips invasion.

Biological control

Make use of the control provided by natural enemies or biological control agents.

For insect pests these agents are: predators, parasitoids and pathogens.

- A predator is an animal (mainly other insects or arthropods) that captures and consumes insects as a source of food. Predators are general feeders and may consume a wide range of species.

- A parasitoid is an insect that parasitizes another insect and usually kills it (unlike a parasite, which may live on its host without killing it). A parasitoid may lay its eggs either inside, on or near the host insect. The developing larva feeds on the host insect until it is fully grown and then pupates either within or near it.
- Insects can also suffer from diseases caused by pathogens. These diseases often induce high natural mortality in insect populations under the right conditions.

For plant diseases these biological control agents are:
antagonists and competitors.

- Antagonists are micro-organisms that suppress or kill other micro-organisms, usually by producing a chemical such as an antibiotic.
- Competitors are harmless micro-organisms that prevent the pathogenic micro-organism from infecting a potential host.

Biological control agents:

- occur naturally in New Zealand, e.g. brown lacewing predators and hoverflies
- arrive by self-introduction or with new pests, e.g. onion thrips parasitoid
- are deliberately imported (classical biological control), e.g. *Cotesia rubecula*, a parasitoid specific to white butterfly, was introduced to improve biological control of this pest.

Biological control procedures include:

- **conserving** or encouraging existing natural enemies, e.g. ladybirds, lacewings or hoverflies
- arranging the **introduction of a new species** from overseas. The species is introduced and, when established, acts as a new natural enemy that requires no further releases.
- **inoculating** a new area, often while pest numbers are low, e.g. predatory mites in greenhouses. Inoculative releases may be made as infrequently as once a year. This is done to re-establish a species of natural enemy that may be periodically killed off in an area during part of the year, but operates effectively the rest of the year.
- **inundating** an area through mass releases. The objective of inundative releases is to completely overwhelm the pest, with little or no reliance on the survival of subsequent generations of natural enemy, e.g. a predatory mite is broadcast weekly by some European growers of ornamental plants to control thrips.

1.2.2 Decision Tools

Decision tools incorporate techniques to assess and react to pest problems. These include regular crop monitoring, the use of action thresholds and good record keeping. They are the cornerstones of successful IPM programmes.

Crop monitoring

Crop monitoring enables growers to detect plant pests early and to follow the development of pest infestations, allowing them to take appropriate action at the right time to prevent economic damage.

Pests and diseases can be monitored by:

- **using traps**
  These include detection of mobile stages of crop pests as they move into a crop, e.g. aphids on sticky traps, moths in pheromone traps or fungal spores on spore traps.
- **taking plant and soil samples**
  Samples can be sent to a diagnostic laboratory where unidentified organisms, pests or diseases that cannot easily be seen, e.g. nematodes, can be identified.
- **scouting crops**
  This involves making regular, standardised counts of pest populations on plants. Crop scouting focuses on a representative sample of the crop with the intention that the resulting recommendations apply to the whole field.

Action thresholds

Action thresholds work best for insect pests as minor infestations generally do not cause economic damage. The information on insect pest populations is gathered by regular crop monitoring and is compared to an action threshold to determine whether additional control actions are required. Action thresholds are derived from the requirements set by the market for the crop.

An action threshold is a pest population level at which control is required to produce a crop that meets market requirements. Market requirements may be 'nil' pests or disease on produce for fresh exports or 5% of thrips damage on onion bulbs for example.

If the pest population reaches the action threshold, some form of intervention (see section 1.2.3) is required. Note that some pests and disease preventative actions are justified and are based on crop phenology or weather.

Insect pests

Trials have shown that minor infestations can be tolerated without market standards being exceeded, and applying insecticides only when required can significantly reduce insecticide use.

Natural enemies can have an impact on action thresholds in two ways:

- they can prevent insect pest populations from reaching the action threshold
- they can modify an existing action threshold by being abundant enough to change a prediction of damage, e.g. a floating action threshold for tomato fruitworm control is used in the IPM programme developed for processing tomatoes. The threshold is adjusted based on actual levels of parasitism in the crop as determined by a four day assessment of larval parasitism.

Plant diseases

Control is often difficult once infection occurs, so control procedures rely on preventative cultural techniques and fungicide applications. The use of natural enemies (antagonists, and competitors) on plant pathogens is increasing and may also be applied as a preventative strategy. The timing of control measures for diseases can be based on weather information.

Computer modelling

Pest and disease control is being supported by computer models that may predict the development of insect populations or forecast infection of pathogens. Models already commercially available in New Zealand, include late blight and early blight forecasting systems from overseas, onion downy mildew predictions and onion white rot degree day calendars.

Record keeping

Crop monitoring records should be filed by growers so that over time a historical database develops. This may allow pest problems to be anticipated based on what has occurred in previous seasons, e.g. a pest may regularly appear in a particular part of the field or the appearance of a pest may be related to an event such as the harvest of a nearby crop.

To implement a successful IPM programme, growers need:

1. an accurate sampling/monitoring method to detect the level of pest or disease infestation
2. a defined action threshold for that crop
3. an efficient record keeping system.

1.2.3 Intervention

Biological Control

As mentioned above, biological control involves using natural enemies to reduce pest numbers. Biological control can be used as an intervention method and in some situations can be more effective than pesticides.

Natural enemies can be used in inundative release procedures. This involves releasing large quantities of the natural enemy into the crop to give immediate, temporary control of a pest.

Pathogens can also be used for pest control. For example, large quantities of the bacterium *Serratia entomophila* (Invade®) are injected into new pasture soils to control grass grub. Pathogens that are sprayed onto a crop and do not persist naturally in the environment are usually classed as microbial pesticides.

Pesticide control

Pesticides include insecticides, miticides, fungicides, bactericides, herbicides and molluscicides. The aim of applying pesticides is to selectively kill pest species in order to maintain produce of high quality while leaving no harmful residues. Natural enemies are often more susceptible to pesticides than pests, and their elimination can lead to the resurgence of pests that can recover quickly from a pesticide application. This is known as pest resurgence. Elimination of natural enemies can also cause minor pests (such as aphids) to become major pests. These are known as secondary pests.

Pesticide classes

INSECTICIDES

Insecticides are biological and chemical compounds designed to kill, injure, reduce the fertility of, or modify the behaviour of insects. They have various modes of entry and modes of action.

Modes of entry

- **Contact** insecticides penetrate an insect's body surface when the insect comes into direct contact with the insecticide, either during application or when an insect walks over a surface on which there is a deposit of the insecticide.
- **Fumigant** insecticides are volatile and produce a toxic concentration in gaseous form in the air around an insect. Entry of the insecticide is via the insect's breathing system (spiracles).
- **Stomach poisons** must be ingested and then absorbed from the gut into the insect's body. The two types of stomach poisons are those on the surfaces of plant tissues that are eaten by the insect pest, and systemic insecticides which are absorbed into the plants and may be moved around the plant.

Modes of action

Once an insecticide has entered an insect's body it can kill the insect in a variety of ways. Insecticides are classified based on chemical structures that are common to all members of the class. Each chemical structure affects one main target site in the insect so insecticides in the same group tend to have the same mode of action.

1. **Organophosphates** affect transmission between nerves. The organophosphates form subgroups with slightly different modes of action, e.g. active ingredients such as methamidophos or chlorpyrifos.

2. **Pyrethroids (synthetic and plant-based pyrethrins)** affect the insect's nervous system. They are based on a stabilised pyrethrum molecule which gives increased persistence, e.g. active ingredient such as deltamethrin.

3. **Carbamates** include quick knockdown compounds that are effective against chewing and sucking insects, e.g. Dicarzol - active ingredient formetanate (registered for onions).

4. **Bacillus thuringiensis (Bt)** is a toxin from the bacterium that is formulated into a biological insecticide. The toxins are commonly specific to an insect order, with Lepidoptera (moths and butterflies) being the most common. Currently there are no Bt products registered for use on *Alliums*.

5. **Insect growth regulators** are compounds that disrupt some stage of insect growth and development. Products can be from different chemical groups, e.g. Applaud (buprofezin) – disrupts moulting of small insects.

6. **Spinosyns** are derived from fermentation products, e.g active ingredients such as spinosad or spinetoram. These materials have a rapid mode of action and a low toxicity to the most common beneficial insects found in onion crops. Registered for *Alliums*.

7. **Indoxacarb** has a unique mode of action and acts primarily as a stomach poison. This material has a low toxicity to most beneficial insects. It is not currently registered for use in *Alliums* in New Zealand.

8. **Neonicotinoid insecticides** provide systemic activity and share a common mode of action that affect the central nervous system of

insects, resulting in paralysis and death. Imidacloprid, thiacloprid and thiamethoxam (active ingredients) are able to be used in onions.

9. **Diamides** are relatively new and have the potential to replace neonicotinoids and pyrethroids in vegetable pest management. Cyantraniliprole is registered for use in onions.

Selectivity

Insecticides can be further classified into those that have broad spectrum activity and those that are selective.

- **Broad spectrum** insecticides are active against a range of insects and can have a harmful effect on non-target organisms, such as bees and natural enemies. The use of these compounds should be kept to a minimum and to periods when off-target effects are minimised, e.g. pre or post flowering or when bees are not active. The first three insecticide classes in the above list (1-3) have broad spectrum activity.
- **Selective insecticides** are less toxic to natural enemies than other insecticides and, therefore, help conserve these beneficial species. Use of selective insecticides is less disruptive to natural enemy populations than broad spectrum insecticides and can help to improve biological control levels. The latter four insecticide classes listed above (5-8) have selective activity.

The exception in the list of insecticide classes is the carbamates. This class of chemicals contains both broad spectrum (e.g. carbaryl) and selective (e.g. pirimicarb) compounds.

FUNGICIDES

Fungicides are chemical compounds that are designed to prevent infection, kill or impair the growth of fungi that cause plant diseases. They are grouped by their modes of action into protectants, systemics and soil fumigants.

Modes of action

Protectant fungicides are commonly older fungicides whose mode of action is to prevent fungal spores from germinating and infecting plants. Because of their multiple mode of action, these fungicides are termed multi-site inhibitors. To be effective, protectants must be applied to all plant surfaces to form a protective barrier. Protectants only kill pathogens on the outside of the plant.

Systemic fungicides can enter a plant and may kill fungi that have recently infected the plant. They interfere with the growth and development of fungal cells. Systemic fungicides have been termed single-site inhibitors. Their action can be restricted to the leaves they were applied to, but some systemics can travel up inside the plant and, therefore, be applied to the soil where they will be taken up by the roots.

Soil fumigants are used to treat the soil before planting to kill spores or other resting stages of fungal pathogens.

Fungicide chemical classes

Individual fungicides are similar to insecticides in that they belong to chemical classes with the same or similar modes of action.

The main chemical classes of fungicides are listed below.

1. **Anilinopyrimidines** are site specific compounds that interfere with the biosynthesis the amino acid methionine and inhibit secretion of enzymes, e.g. active ingredients such as cyprodinil or pyrimethanil.
2. **Benzimidazoles** are systemic compounds that bind to a protein that is important in cell division in the fungus, causing the death of the fungus by inhibiting growth, e.g. active ingredient carbendazim.
3. **Demethylation inhibitors (DMIs)** are a group of fungicides that prevent the synthesis of an enzyme that is important in maintaining the protective cell membrane of the fungus, causing death through leakage of cell contents, e.g. active ingredient triadimenol (several trade names) is registered for the control of White Rot in onions.

4. **Dicarboximides** cause internal damage of cell division within the fungus, e.g. active ingredient procymidone.
5. **Carboxylic Acid Amides (CAAs)** have specific activity against oomycete fungi, and cause cell lysis. They exhibit translaminar movement, e.g. active ingredient dimethomorph.
6. **Dithiocarbamates** are protectant fungicides that provide a protective coating on leaf surfaces to prevent disease establishment, e.g. active ingredient mancozeb (several trade names).
7. **Phenylamides** bind to and thus interfere with proteins in the cell that are important in the proper replication of genetic information, e.g. active ingredient metalaxyl.
8. **Inorganic compounds** include sulfur and copper-based fungicides that prevent the germination of fungi by damaging proteins in spores, e.g. active ingredient copper hydroxide.
9. **Qol inhibitors** such as strobulurins are synthesised derivatives of naturally occurring compounds. These compounds have systemic and curative properties, e.g. active ingredient azoxystrobin.
10. **Succinate dehydrogenase inhibitor** (SDHI) compounds are relatively new and their use will require specific strategies to prevent future resistance. There are several registered for use in onions.
11. **Other compounds** have a range of modes of action, e.g. chlorothalonil blocks the activity of several fungal enzymes, while etridiazole acts as a protectant fungicide and is used primarily as a soil drench.

Pesticide Resistance

If a pesticide is not giving the level of control that is expected it may be because of ineffective spray coverage, equipment failures or incorrect rates. If these factors are in order, then pesticide resistance may be the problem.

1.3.1 What is pesticide resistance?

Resistance to pesticides occurs when the pest population (pathogen, insect, mite or weed) changes from being dominated by genetically susceptible individuals to being dominated by genetically resistant individuals so that the population is less susceptible or sensitive to a pesticide or class of pesticides.

Pesticide resistance is present when a dose of pesticide that is required to kill 50% of a population (measured as the LD50) is significantly more than the dose required to kill 50% of a reference susceptible population. The population may still appear to be controlled in the field, although technically it is resistant to a pesticide.

Field control failure occurs when the level of resistance in a population is high enough that a significant proportion of the population survives after a pesticide is applied.

The level of resistance in a population at which field control failure occurs varies because variations in application and plant stage affect the dose reaching the pest, and variations in the size of the pest and its life stage affect the response.

Additional information on pesticide resistance is available on the NZ Plant Protection website: https://resistance.nzpps.org/

1.3.2 How does resistance develop?

Resistance develops when a genetic character (either existing or a new mutation) in a few individuals favours their survival. This character may serve another purpose or none at all, but when a pesticide is sprayed the new character (thick cuticle, a certain enzyme, or a habit that reduces its exposure such as residing under leaves) becomes an advantage. From this point, the pesticide kills individuals without the character, while resistant parents reproduce so the new character spreads through the population and becomes common enough to cause control failures. In effect, the **use of pesticides *causes resistance,*** and increased pesticide use only increases its rate of development.

Regular spraying with the same insecticide can lead to an increase in resistant individuals in the population due to the susceptible individuals regularly being killed.

Resistance is more likely to develop against single-site inhibitor (systemic) fungicides than multi-site (protectant) fungicides because of the narrow mode of action of the former group compared to the wide mode of action of the latter group.

The level of resistance is determined by the proportion of resistant individuals in a population. Control depends on the resistance level and pest populations.

For example, at a given level of resistance, such as 30% of the population:

- spraying at 3 caterpillars/plant would reduce pest populations to 1/plant, and give adequate control,
- whereas spraying at 30/plant would reduce pest populations to 10/plant, with poor control.

1.3.3 Managing resistance

As previously mentioned, each of the common classes of insecticides and fungicides have different modes of action. Resistance to one member of an insecticide or fungicide class commonly confers resistance to all members of the class because of their common mode of action. This is called **cross resistance**. Resistance does not normally cross between pesticide classes, but there are examples of insects and diseases becoming resistant to more than one group of insecticides or fungicides.

To minimise pesticide resistance, selection that favours resistant individuals should be limited. This means limiting the application of pesticides using a range of non-chemical techniques or rotating between different classes of pesticides. Avoiding the development of resistance to pesticides is one of the main aims of IPM. **It is important not to rely solely on pesticides for pest and disease control.**

The following combination of crop management procedures can limit the development of pesticide resistance.

1. Use disease and pest free transplants.
2. Monitor crops regularly to identify and assess disease and pest problems.
3. Base decisions on action thresholds (insecticides), infection periods (systemic fungicides) or crop phenology (justified preventative applications).
4. Select and use controls carefully
    - use selective pesticides wherever possible
    - **ALWAYS read and follow the label**
    - apply at the recommended rate with good coverage
    - rotate between different pesticide classes.

Pesticides should not be used at doses higher than label recommendations. High doses will usually not control resistant individuals since they will often survive 10-100 times the label rate.

High doses will speed the development of resistance and increase residues on crops. Recommendations for the use of insecticides and fungicides to avoid the development of resistance follow.

INSECTICIDES

For insecticides, the use of different classes in various combinations is a traditional way of attempting to increase their efficacy.

They include:

- **mixtures (DO NOT USE)**
  This is the **worst way** to use insecticides. When resistance does occur, the efficacy of both insecticides in the mixture may be lost at the same time so each insecticide lasts half as long as it would if applied separately.

- **alternations**
  Alternating between two or more insecticides is effective as long as:
  - the insecticides are from different classes, i.e. there is no cross resistance
  - the interval between classes is greater than one generation of the pest.
  - use clusters of applications of the same insecticide in the same generation of a pest, e.g. onion thrips
  - growers within a confined area or region coordinate their insecticide alternations. This is important because individual grower alternations can form a mosaic pattern over a region and the insects in effect are exposed to a mixture of insecticides as they move between properties. For pests with wide host ranges, such as tomato fruitworm, insecticide alternation should also be coordinated across all potential host crops.

- **rotations based on 'windows'**
  Rotations aim to limit the effects of applying mixtures by defining lists of insecticides to be used during a particular period (window) of the year or season.

FUNGICIDES

The two main fungicide groups have quite different uses and the first step in resistance management is to apply them correctly.

- **Protectant** fungicides need to be applied regularly to maintain a complete barrier as the plants grow or the existing barrier is weathered away.

- **Systemic** single-site inhibitor fungicides are effective at eradicating diseases in the early stages of infection, but are also prone to resistance developing amongst target pests. Systemics are most effective if they are applied about the time of, or shortly after, infection. For many diseases, the conditions favouring infection are known and applications of systemic fungicides can be timed to 'infection periods'.

The following recommendations apply for all fungicides:

- **mixtures**
  Proprietary fungicide products are often mixtures of systemic and protectant compounds to avoid resistance developing against the systemic compound. Other systemic fungicides should be applied in a mixture with a protectant fungicide, where practical.

- **rotations**
  The use of systemic products is commonly restricted to a number of applications per crop or per year. When a fungicide class is used against more than one pathogen, the number of applications should not exceed the number recommended for any one disease.

Allium White Rot (Onion White Rot)

Sclerotium cepivorum Berk

Photos: Ed Kurtz,
Image Number: Left - 1635372 , Right - 1635374, Bugwood.org

Description

In onions, white rot causes very young seedlings to die and shrivel. In older plants, growth is stunted, tips of leaves yellow and die back while the inner leaves of the plant have a characteristic dark blue-green colour. Underground plant parts are surrounded by a fluffy white fungal mass. Later, affected bulb tissue turns black as the fungus forms thousands of minute black fungal resting bodies (sclerotia).

Sometimes the affected area dries out before the plant dies. In that case the bulb often splits at the position of the infection. Under moist conditions the fungus can spread from bulb to bulb along the plant rows. This method of spread can cause extreme losses of spring onions.

In garlic, the fungus attacks underground leaf bases above the seed piece soon after emergence causing the plant to wilt and die.

The disease often occurs in discrete patches in fields, often extending along tractor spray tracks, reflecting the movement of infested soil along the rows.

Disease cycle

The fungus survives in the soil between crops as minute (smaller than pin-head size) black fungal resting bodies known as sclerotia. The sclerotia are formed in infected bulb tissue and remain in the soil when the bulb has disintegrated. Sclerotia can remain alive in the soil in the absence of an *Allium* host for many years. When a new *Allium* crop is planted, sulphite compounds generated by the plant roots stimulate the sclerotia to germinate. The fungus infects roots and moves upwards to the base of the plant where it invades and rots the tissue, and produces thousands of new sclerotia. The fungus is spread whenever infested soil is moved from one area to another. This can be by soil erosion, soil on vehicle tyres, on machinery or on bins. It can also be spread in infected bulbs particularly when grading rejects are dumped in the field or fed to livestock.

When first introduced to an area, numbers of diseased plants will be low and may go unnoticed for several crop cycles. With each cycle however, there will be over a thousand-fold increase in numbers of sclerotia reintroduced to the soil. Significant losses could be expected within relatively few successive crop cycles.

The disease is most active in moist soil when the temperature is 9- 25°C. In the South Auckland/Waikato area, the disease tends to be most prevalent in late winter and spring (August-November) with numbers of new infections dropping as the plants approach maturity. In the Canterbury region the disease tends to occur mid to late season with severe infection occurring close to harvest if soil conditions are moist.

Hosts

The disease affects only members of the family Alliaceae (onion, garlic, chives, leek and shallot). Onion weed (*Asphodelus fistulosus L.*) is not affected.

Geographic Distribution

The disease occurs in all major growing districts in New Zealand.

2.1 CONTROL STRATEGIES

Non-pesticides strategies:

Time of sowing

In the Pukekohe area, onions planted from May to early July tend to suffer greater losses than those planted in August or September. In many cases a strategy of late planting to avoid the disease is only feasible if irrigation is available to assist bulbing during the dry summer months.

Rotations

Because the sclerotia of white rot can survive for extended periods in the absence of a crop, short term rotations of two to three years are of limited value. Severe losses may be sustained after a short rotation due to the majority of sclerotia being 'conditioned' for germination and germinating en masse when exposed to an Allium crop. The viability of sclerotia will decline with time but long term rotations will not eliminate the disease from an area.

Hygiene

Rigorous attention to hygiene is the only way to prevent introducing the disease to new areas. Soil on vehicles, machinery, bins and even footwear are common means of spreading the disease. Techniques to correct this include the use of separate machinery for infested and non-infested areas, working disease-free areas before infested areas, and washing machinery between areas. Infested soil can be transported during any farming operation, not just when *Allium* crops are being grown. The disease can be spread over long distances in mud carried under wheel arches of vehicles when soil is deposited on roadways from farming operations in wet weather.

Pesticide control:

The standard chemical control strategy involves the application of fungicides to the soil surface commencing approximately at flag leaf stage and followed by two or more applications at monthly intervals. Because the site of action of the fungicide is the soil, fungicide applications will be most effective when applied during or just before rain which will help carry the fungicide to the soil. Seed coatings are available, however their use requires consideration of resistance management when additional fungicide applications are considered. Manufacturers label recommendations should be followed for each of the fungicides registered for use against white rot.

Biological control

Some success has been achieved with applications of bio-fungicides such as *Trichoderma*. Granular treatments are applied at seeding, but are unlikely to provide season long disease control especially in high risk areas.

Disease Forecasting Model

A disease prediction system based on cumulative degree days from planting has shown that the first diseased plants can be found at approximately 250 white rot degree days after planting. The most effective control is achieved when a fungicide programme is commenced at approximately 100-150 white rot degree days. This model is currently active in the Pukekohe region. Commercial providers offer access to disease forecasting models: www.hortplus.metwatch.co.nz or www.inta-ag.co.nz. Registration is required.

Recent studies have shown that the same modelling concept would be successful (after modification) in Hawke's Bay and Canterbury growing regions.

2.2

Bacterial Soft Rot

Pectobacterium carotovorum subsp. carotovorum (Jones, 1901) Hauben et al. 1999

Photos: Howard F. Schwartz, Colorado State University,
Image number: Left - 5361478, Right - 536229, Bugwood.org

Description

In the field, the first visible symptoms of soft rot on onion plants are small (2-5 mm) water-soaked lesions on the foliage. The lesions expand rapidly to produce a slimy, grey-brown rot, which may extend down to the leaf bases and can cause complete collapse and rotting of entire plants. Rotted plants have a strong, vinegar-like odour.

Externally, infected bulbs often appear sound, although when pressure is applied, infected bulbs often feel softer than healthy ones, and a watery, foul-smelling liquid may exude from bulb necks. When an infected bulb is cut in half, infected scales (one or more) show a cooked or water-soaked appearance and a yellowish-brown discoloration extending downward from the neck to the basal plate. Rotting often tends to progress downward within the affected fleshy scale rather than spreading to adjacent bulb scales, until infection reaches the basal plate where the other scales are infected. Ultimately the entire bulb becomes completely decayed. In advanced stages, the rotted bulb dries out and shrivels.

Disease cycle

Soft-rotting bacteria survive as saprophytes or on infected plant debris in the soil. These organisms are normally regarded as opportunistic pathogens that infect onions through wounds when conditions that favour infection occur. The bacteria are transmitted by water, and disease has been associated with rainstorms, flooding and irrigation.

All parts of onion plants can be affected by bacterial soft rot, which can occur at any stage of plant development, from seedling emergence through to storage and shipping. The main factors that influence the incidence of soft rot during the growing season are damage to leaf tissue and the prevailing weather conditions. Soft-rotting bacteria require moisture for infection and disease can be severe if wind or hail damage to the onion foliage is followed by extended periods of wet weather.

Bacteria enter bulbs through infected leaves, mechanical wounds, or damaged areas caused by insects or other diseases. The maturity of onions at lifting (percent top-down), the prevailing weather conditions during field curing and the method of leaf removal (topping) are the main factors that influence the incidence and severity of bulb rots in storage. Soft-rotting bacteria gain entrance to bulbs when the tops are cut at harvest. Wet weather during field curing greatly increases the chances of soft rot occurring. Once bacteria have entered the fleshy tissue of a bulb, deterioration can be very rapid. Infected onions rot in transit if storage and shipping conditions favour disease development (25-30°C). In storage, pathogenic bacteria from rotted bulbs can infect other bulbs that are damaged or wounded, but do not infect healthy, properly cured bulbs.

Hosts

E. carotovora and *P. marginalis* have wide host ranges. As well as onion, most fleshy vegetables (incl. bean, beet, carrot, celery, crucifers, cucurbits, lettuce, potato, spinach and tomato). *B. gladioli pv. alliicola:* Onion, *Iris sp., Narcissus sp., Tulipa sp.*

Geographic Distribution

E. carotovora and *P. marginalis* occur worldwide. *Burkholderia gladioli pv. alliicola:* Egypt, India, Indonesia, Thailand, Australia, Hungary, Spain, Russia, USA and New Zealand.

2.2 CONTROL STRATEGIES

Non-pesticides strategies:

Fertilisers

Do not over-fertilise with nitrogen (N). Although applications of N late in the growing season can increase onion yields, they also can cause onions to have thick necks that are prone to wounding when topped, making them more likely to be invaded by soft-rotting bacteria.

Weed control

Maintain good weed control. Excessive weed growth, especially during field curing, slows down the evaporation of water around onions, and an increased incidence of diseased bulbs can occur under prolonged moist conditions.

Herbicides

Avoid herbicide damage to the growing crop, through which soft-rotting bacteria can enter the plant.

Harvest

The crop should be lifted when onions are at 70-90% top-down (foliage collapse), and the tops should be allowed to desiccate as much as possible after lifting and before topping. Onions should be lifted in dry conditions and, where possible, when the forecast is for continuing fine weather. This is especially important for the early stages of field curing as soft rot bacteria more readily colonize damaged green leaf tissue than desiccated leaves.

Careful handling of onions during lifting, curing, and harvest operations to avoid cuts and bruises which allow soft-rotting bacteria to enter bulbs.

Avoid cutting foliage off too close to bulbs during topping to help prevent wounding; it is preferable to make the cut several cm above the neck of each bulb.

Curing

Forced warm air drying (artificial curing) of harvested bulbs is a very effective, but expensive, control option for onion soft rot.

Storage

Onions should go into store only after they have been fully cured and dried. Careful inspection at grading and any bulbs that are diseased, misshapen, or have thick necks should be discarded.

Store bulbs in cool, well ventilated stores – ideally at 2-8°C and less than 75% RH. In storage it is essential that bulbs are supplied with sufficient ventilation to avoid build-up of moisture on the bulbs.

Controlled temperature shipping at 2-8°C and less than 75% RH will stop development of bacterial soft rot of bulbs in transit. However, infected bulbs will continue to rot when returned to warmer ambient temperatures on arrival at expert destinations.

Pesticide control:

No effective chemical control measures have yet been developed to control bacterial soft rot of onion. Recent studies evaluating foliar treatments of copper showed that bacterial soft rot infection in the field could be reduced, but only when applications were made on the same day damage (e.g. hail) occurred.

2.3

Black Mould

Aspergillus niger van Teigham

Photo: Howard F. Schwartz, Colorado State University,
Image number: 5360332, Bugwood.org

Description

A conspicuous black dusty mould develops between the outer scale leaves of the bulb, extending from the neck towards the plate. It is most commonly seen on the outer surface of the first storage leaf and dry bulb scale, but in severe cases can be found between the outer layers of fleshy leaves. The mould is often associated with injuries to the outer scales such as that caused by onion thrips.

Disease cycle

The fungus is a common inhabitant of soil where it lives on plant debris and other organic matter. The fungus produces vast numbers of minute spores that can survive for extended periods in the soil. Spores are carried onto the bulbs in soil by rain splash and particularly in the dust when bulbs are lifted. The fungus can establish in the bulb in the area of the neck during normal curing. This can be worse when bulbs are machine or hand topped.

An optimum temperature of over 30°C is required for black mould to develop. When stored under cool conditions the disease will rarely develop. The characteristic black mould grows down between the bulb scales when stored under conditions of high temperature and humidity. Black mould infection is related to the numbers of spores in the soil where the onions are grown. The greater the numbers of spores in the soil, the greater the risk of loss if bulbs are stored at high temperature.

Bulbs from a high risk site will normally show no symptoms after normal storage but may develop mould during transit through the tropics en route to Europe. It was previously considered that the disease was only a problem in New Zealand onions if there was significant thrips damage to bulbs. More recently it has been shown that if storage conditions favour the fungus it can be a significant problem in its own right.

It is now understood that black mould is also a seed-borne fungus. After infecting onion seedlings, it continues to remain viable in the plant; however this hasn't been seen in New Zealand.

Hosts

Onions, garlic, shallots and other fruit and vegetables.

Geographic Distribution

The fungus is found worldwide. It is widely distributed in New Zealand but is found less commonly in onions in the South Island.

2.3 CONTROL STRATEGIES

Non-pesticides strategies:

- Keep records of black mould incidence from different production areas and avoid exporting onions from areas that have consistent problems from black mould.
- Keep storage areas well ventilated particularly the removal of hot air from the tops of the stacks of bins.
- Have soil tested for presence of black mould spores to determine risk fields.
- Ensure effective control of thrips in the field.
- Provide adequate control of foliar diseases.
- Avoid digging green onions (bulbs) on hot, calm days.

Pesticide control:

There are no registered chemical control options for black mould in New Zealand *Allium* crops. Australia has a registration for disease suppression using Switch. In NZ Switch is registered on onions for Botrytis control. Seed treatment with benomyl + thiram overseas has reduced disease levels.

2.4

Botrytis neck rot

Botrytis allii Munn. (Botrytis aclada Fresen)

Photos: Howard F. Schwartz, Colorado State University,
Image number: Left - 5364059, Right - 5361510, Bugwood.org

Description

Onion neck rot is a troublesome disease as it only becomes evident 3–4 months after bulb storage, often after reaching an overseas port.

In onions, it first appears as watery decay in the neck then moves downwards, causing scales to become soft, watery and translucent. The necks of affected bulbs soften and become sunken, a white to grey mycelial growth eventually develops between the bulb scales, and masses of black sclerotia may develop on the outer scales around the neck. Neck rot is often exacerbated by secondary pathogens that occur in storage. Recent work has indicated that *B. allii, B. aclada,* and *B. byssoidea* are each valid species associated with neck rot disease of onion. *Botrytis squomosa* causes botrytis leaf blight. In onions grown for seed production, *B. allii* has been the cause of superficial leaf flecks, scape blight and flower blight.

Disease cycle

Infection by *B. allii* can occur at any stage of the onion life cycle. Infected seed has been indicated as the main source of infection of onion bulbs in storage. The fungus invades seedling cotyledons and remains symptomless in the leaf tissue until it colonises the tissue in the necks of bulbs, causing neck rot. Other potential sources of infection in onion crops are air-borne conidia originating from volunteer onions, infected debris and cull-piles. Primary infection can also originate from sclerotia (resting bodies) surviving in plant debris and soil.

Where infected bulbs are used for seed production, the disease can infect flowers, which leads to the production of *B. Allii* infected seed. The relative importance of air-borne and seed-borne infection is not known in New Zealand.

Disease progress is affected by the percentage of infected seeds sown and weather conditions during the season. Conidia disperse when rain showers are frequent. Free water is required for conidium germination, so most infection events will occur during moderate temperatures with high humidity (>80%) after prolonged wet conditions caused by rainfall or overhead irrigation.

The fungus grows optimally at 21ºC and invades the leaves in which it develops until they senesce and become necrotic. The conidiophores are then produced and continue to infect *Allium* crops. Neck rot can be particularly severe if prolonged wet periods occur during field curing when onion necks are still succulent. The presence of wounds also provides entry points for the pathogen.

Hosts

Common onion, garlic, leek, shallot and multiplier onions.

Geographic Distribution

Neck rot is an important postharvest disease of *Alliums* in the cool temperate conditions that occur in New Zealand, Australia, North America and Europe. It is also present in North and East Africa, South-East Asia, Middle East and Central and South America

2.4 CONTROL STRATEGIES

Non-pesticides strategies:

Seed quality

Use certified disease-free seed or treat seed before planting. When onion bulbs are used to establish seedlings (seed production) they should be heat-treated to kill infection by exposing them to the sun for 12 days during which the temperature must exceed 40°C for about 4 hours. Infected onions should not be used to establish seedlings.

Cultivar

Select quick-maturing cultivars so that neck tissues dry before storage.

Soil quality

Try to plant seed in light, well-drained, well-prepared fertile seedbeds. Avoid heavy soils, heavy seeding rate, overcrowding, poor air circulation and planting too deep.

Rotation

Rotate crops by not planting onion or its relatives for at least two years.

Fertilisation

Strive for steady vigorous plant growth, not soft luxuriant growth. Use fertiliser sparingly on the basis of a soil test but not at the end of the season.

Irrigation

Do not irrigate excessively and especially not when tops are drying.

Harvest

Follow practices that help plants fully dry down at the end of the season, allow tops to mature well before harvest. Undercut and windrow onions until inside neck tissues are dry. Before topping close to the neck ensure tissues are dry. Dry before storing or during the first few days of storage, avoid injury during harvest and storing.

Sanitation

Eradicate weeds, especially perennial and wild onions in and near paddocks. Remove unharvested plant parts and destroy infected plant debris after harvest.

Storage

Cure onions with forced heated air at 27–35°C for a few days at the beginning of the storage period. Ideal storage conditions are 0–1°C at 65–75% humidity. Do not circulate warm air over cold onions as this will cause bulbs to sweat and moulds to develop. Open the storage doors when the air outside is cool and dry to exhaust warm moist air.

Pesticide control:

Seed treatment

Onion seed can be pelleted and the chemicals for disease control included in the seed coating. Seed treatment fungicides currently registered for use on onions against smut and white rot are carbendazim, captan, iprodione and procymidone. These also have efficacy against *Botrytis spp*.

Foliar treatment

Fungicide applications during the season and prior to harvest may reduce the incidence of neck rot, but fungicide applications cannot overcome improper cultural or storage practices. Fungicides currently registered for control of neck rot in onions in New Zealand are carbendazim, thiophanate-methyl (chemical group: benzimidazole), mancozeb (chemical group: dithiocarbamate), azoxystrobin (strobilurin) and cyprodinil + fludioxonil (anilinopyrimidine + phenylpyrrole), pyrimethanil + fluazinam.

Recently in New Zealand, a number of *B. allii* isolates from onion bulbs and seeds were found to be resistant to carbendazim.

Biological control

The antagonistic activities of fungi against *B. allii* have been investigated for several years. Some success has been achieved with *Trichoderma* and *Ulocladium* species when alternating them with other biological or chemical treatments.

Disease forecasting models

Disease forecasting systems have been developed overseas to help manage fungicide use against *B. squamosa*, the causal agent of leaf blight of onions. They attempt to identify meteorological conditions associated with high infection risk. Initial testing of these systems for their relevance to botrytis neck rot has been carried out in New Zealand, but their application is complicated by the non-symptomatic nature of *B. allii* in the field.

Further info:

Lorbeer JW, Seyb AM, Boer Md, Ende JEvd 2004. Botrytis species on bulb crops. In: Elad Y, WIlliamson B, Tudzynski P, Delen N ed. Botrytis: biology, pathology and control. Dordrecht, The Netherlands, Kluwer Academic. Pp. 273–294.

2.5

Downy Mildew

Peronospora destructor (Berk.) Casp. In Berk.

Photos: Howard F. Schwartz, Colorado State University,
Image number: Left - 5361482, Right - 5362264, Bugwood.org

Description

Oval or cylindrical areas of varying sizes develop on infected leaves and seed stalks. These areas are pale greenish-yellow to brown in colour. Symptoms often appear first on older leaves. If weather conditions are moist and temperatures are low, masses of grey to violet fungal spores envelop leaves, which become girdled, collapse, and die. Downy mildew seldom kills onion plants, but bulb growth may be impeded. Bulb tissue, especially the neck, may become spongy and the bulb may lack keeping quality. This disease is one of the most destructive of onion seed production world-wide.

Disease cycle

The downy mildew fungus can rest in infected onion bulbs left in the field and in cull piles. Resting sexual spores (oospores) may persist in the soil to infect seedling onions planted the following season. During the onion growing season the fungus produces spores (conidia) that are carried by wind to infect new onion plants. Spores are produced on rainless nights with high humidity and moderate temperatures (4-25°C) with an optimum temperature for sporulation of 13°C. The spores mature early in the morning and are dispersed during the day. They remain viable for about 3-4 days. For germination the spores require free water and the optimal temperatures 7-16° C. Rain is not needed for infection when dew occurs continuously during the night and morning, and actually inhibits the sporulation process.

After the fungus is established, it completes its life cycle in 11 to 15 days. New spores infect new plants or leaves. As the upper portion of the onion leaf is killed, the fungus can infect the next lower part of the leaf. The entire leaf may thus become infected and die. During favourable weather conditions the infection may result in a severe epidemic. During dry weather, the spores usually disappear and the number of lesions declines. However, the disease cycle recommences when wet, cool weather recurs.

Hosts

Onion, garlic and other plants of the *Allium* family.

Geographic Distribution

Americas, North, East and South Africa, West, South, and East Asia, Europe, Australia, and New Zealand. This fungus is present where temperatures are cool.

2.5 CONTROL STRATEGIES

Crop Monitoring:

The best way to manage the disease is on a preventive basis. Inspect the tips of old onion leaves twice a week for plants with disease symptoms. Downy mildew produces spores in periods with no rain and low to moderate temperatures at night (<24°C) and with relative humidity 95% between 2.00am and 6.00am. Infection may occur the night following sporulation if the temperature is 6-22°C and dew is present on the leaves within the first five hours of darkness for a span of at least three hours.

Non-pesticides strategies:

Irrigation

Avoid the use of overhead irrigation. If overhead irrigation is used, apply it at night, during the hours of dew formation (2am-6am). Alternatively, irrigate early in the afternoon, allowing time for the crop to dry. Downy mildew sporulates at night under high humidity, but not when the leaves are continuously wet. Avoid damp growing conditions and maintain good soil drainage.

Sanitation

Destroy volunteer onion plants and crop debris as soon as the crop is harvested. Make a compost heap with the crop residues and cover with a layer of soil. Do not use this compost on onions or any downy mildew-susceptible crops.

Rotation

Rotate crops by not planting onion or its relatives for at least two years and preferably not for four years.

Reducing leaf wetness duration

Methods to reduce leaf wetness duration to reduce the incidence and severity of Downy mildew include (1) increasing plant spacing in seedbeds to facilitate air movement and rapid drying of the foliage, (2) aligning rows of plants to follow the direction of the prevailing wind, and (3) irrigating crops during the late morning or early afternoon to allow leaf surfaces to dry rapidly.

Pesticide control:

Fungicide recommendations

When environmental conditions exist for the disease sporulation and infection, apply protectant fungicides (dithiocarbamates, copper). When early symptoms of the downy mildew are detected in the field a suitable systemic fungicide (dimethomorph, fenamidone or mefenoxam) may be included with the protectant mix. Use of protectant fungicides should be rotated using seven day intervals when the weather is cool and damp and up to ten day intervals if the weather is dry. Overhead irrigation and rainfall will wash the fungicides off the plants. Fungicides should be applied after an irrigation cycle and may have to be re-applied after a heavy rainfall.

Fungicide Resistance Management

Systemic fungicides used for management of onion downy mildew are at risk of becoming ineffective through organism resistance. Each chemical has its own restrictions (on the label), but the following principles are appropriate in most circumstances:

- Limiting numbers of applications of the at-risk fungicide group.
- Mixing the at-risk fungicide with a fungicide from a different cross-resistance group to ensure that no spores survive when the at-risk fungicide is used.
- Alternating the at-risk fungicide with fungicides from a different cross-resistance group.
- Following non-chemical disease management practices, including crop hygiene to minimize inoculum carry-over and crop canopy management to make the crop environment less suitable for disease development.
- Using at-risk fungicides when disease levels are low, but the risk of disease is high.

Spray techniques

Always follow label directions. Due to the nature of onion leaves (narrow, upright cylinders), it is important that the sprayer is slow enough to ensure the whole plant is coated thoroughly, but not so much that it runs off the plant. The addition of a suitable adjuvant may assist thorough spray coverage.

Disease Forecasting Models

Computer models are available that predict the likelihood of sporulation and infection occurring, using local weather station data. Such models are able to offer reductions in the number of fungicide applications required for disease control by restricting applications to times of most need (days of likely sporulation or infection). A model is currently active in the Pukekohe region. Commercial providers offer access to disease forecasting models: www.hortplus.metwatch.co.nz or www.inta-ag.co.nz.


2.6

Fusarium basal rot

Fusarium oxysporum f.sp. cepae (Hanz.) Snyder & Hansen

Photos: Howard F. Schwartz, Colorado State University,
Image number: Left - 5474199, Right - 5361503, Bugwood.org

Description

Onion bulbs may become infected by *Fusarium oxysporum* at any time during the growing season, but the disease more commonly occurs on mature plants. The first above ground symptoms of the disease are tip dieback and yellowing of the leaves. The yellowing and dieback progresses downward until entire leaves shrivel and decay. Usually the older outer leaves are affected first, and the extent of foliage symptoms depends on the amount of basal plate rot.

Infected plants are often stunted and can be pulled from the ground easily. Pulled infected bulbs appear lopsided when only one side of the basal plate is infected. The roots of infected onions are normally killed when the tissue of the bulb to which they are attached decays. Infected plants are restricted in growth, and severely infected plants eventually die.

In the early stages of disease development, infected and healthy bulbs cannot readily be distinguished from each other. However, when an infected bulb is cut through longitudinally a pinkish-brown, semi-watery rot of the basal plate is evident. The brown rot progresses upward through the bulb from the basal plate in a broad front. A white to pink fungal growth can often be seen between and on bulb scales.

At later stages, the basal plate tissues become pitted and exhibit a dry rot, and most of the roots rot away. If secondary organisms follow, a wet rot can result. When moisture and temperature conditions are favourable, abundant white, mouldy fungus growth appears on the basal plate. Under dry conditions, infected bulb tissue gradually dries and shrivels, and dry outer bulb scales crack and/or fall off.

Decay usually progresses slowly, and onion bulbs infected with *F. oxysporum* late in the growing season and at harvest may not show outward symptoms of disease. Such infected bulbs develop basal rot symptoms during transit and storage at warm temperatures.

Disease cycle

Fusarium oxysporum can survive in soil for many years as chlamydospores or as a saprophyte on crop residues. The fungus produces three types of spores: (1) chlamydospores, which are thick-walled resting spores which enable long-term survival of the pathogen, (2) microconidia, which are one-celled thin-walled spores, and (3) cresent shaped, mostly three-septate macroconidia. Spores from decaying onions affected by basal rot are disseminated in water, soil, and air.

The fungus enters onion roots or basal plates through wounds (caused by cultivation, pink root infection, insects, and damage at harvest), or directly through unwounded root tissues. The increased incidence of basal rot when plants are under stress from high temperatures and drought may be a response to tissue damage. Infection also occurs directly from the soil into the basal plate via the natural wounds which develop when roots emerge from within the basal plate tissue, when pathogen levels are high. Once inside the basal plate, infection often remains localized for several weeks or months before spreading to the outer fleshy leaf bulb scales and causing the characteristic basal rot symptoms.

Temperature is the main factor governing the activity of *F. oxysporu*m in the field as well as the incidence and severity of basal rot. Fusarium basal rot of onion is seen rarely when soil temperatures are under 15°C but becomes more prevalent as temperatures approach the optimum for disease development (25-28°C) and soil moisture is high. Moisture is also important – the disease is often severe when onions are grown in poorly drained soils and stored where humidity is high. In the field, the pathogen can be spread within and between fields through contaminated farm equipment, irrigation water, air and insects. There is no evidence of spread of disease from bulb to bulb during storage. Storage decay progresses most rapidly at 28°C, and is very slight at 8°C.

Hosts

Onion, shallot and garlic.

Geographic Distribution

Basal rot occurs in most countries, but tends to be associated with hot growing conditions. *F. oxysporum* has officially been reported in Europe (Greece, Italy), Asia (India, Japan), Israel, USA and South Africa.

2.6 CONTROL STRATEGIES

Non-pesticides strategies:

Soil-borne diseases, including basal rot of onion, are managed, but not eliminated, by using carefully implemented integrated approaches to crop production and protection. These approaches reduce disease pressure and plant stress.

Crop rotation

Crop rotation plays an important role in helping to reduce the amount of infested onion debris and pathogens during non-host crop cycles. Onions should not be planted more than once every four years in a field, especially if basal rot has been a problem in that field.

Ground preparation

Onion seed should be sown in well-prepared beds. The soil should be free-draining and fertile. Avoid soil compaction.

Seed treatment

The pathogen may be transmitted in seed. Treat seed with a fungicide (thiram or captan).

Crop management

Avoidance of fertiliser injury (e.g. damage to lush foliage), adequate control of soil insects and foliage diseases are important steps that help reduce losses from basal rot. It is important to apply pesticides, especially herbicides, according to label directions to minimize root stress and predisposition to soil-borne problems.

Irrigation

The soil around the root plate should be moist but not wet, and never dry.

Harvest

Care should be taken to minimize mechanical damage to bulbs during harvest and handling operations. Bulbs should be harvested carefully after the tops dry down, and should be properly cured before being put into storage.

Grading

Handle the bulbs carefully during grading.

Storage conditions

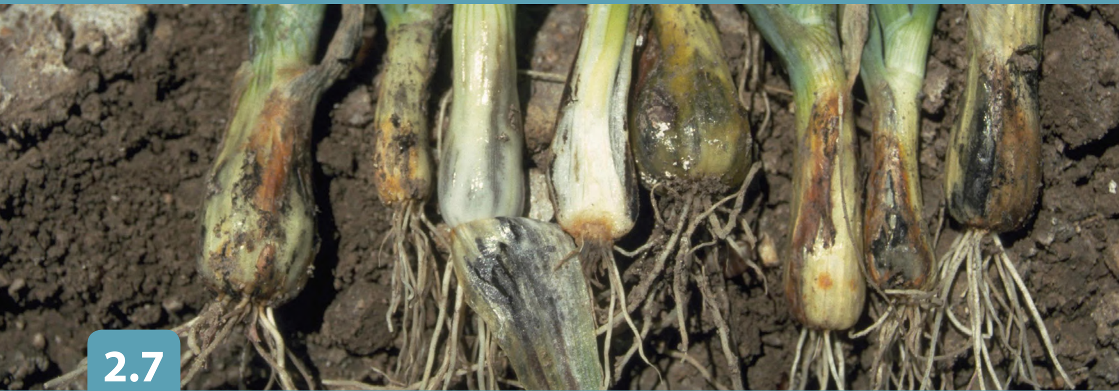
The optimum temperature for disease development is 25-28ºC. Storage of bulbs at 4ºC and 65-70% RH will minimize storage losses.

Resistant cultivars

The planting of resistant onion cultivars is an important control measure. Sources of field tolerance to basal rot have been identified and are available in commercial cultivars.

Biological control

Biological control has been shown to be effective against basal rot in overseas trials. Combined seed treatments with the fungal antagonist *Trichoderma viride* and the bacterial antagonist *Pseudomonas fluorescens* reduced basal rot incidence in the field.



2.7

Onion Smut

Urocystis cepulae Frost

Photos: Howard F. Schwartz, Colorado State University,
Image number: 5364050, Bugwood.org

Description

The first signs of the disease are the distortion and thickening of onion seedlings in the first and second leaf stage. Symptoms continue to appear in successive leaves, particularly if the infection is near the meristematic zone from which they form. Lesions appear as dark, thickened streaks on the outer surfaces of the leaves, leaf sheaths and young bulbs. The streaks are caused by masses of dark-brown to black spores (teliospores) that form in the tissues immediately under the epidermis. Mature lesions become silver in appearance as the epidermis thins. Subsequently the epidermis splits open and releases the spores into the soil. Many infected seedlings die within 3-5 weeks of germinating leaving gaps in rows. Some infected plants can grow on and express symptoms on the necks and enlarging bulbs.

Disease cycle

Infection occurs when teliospores germinate and mycelial threads penetrate, through the cuticle of the young cotyledon (first leaf). Plants are susceptible to infection 2-3 days after germination and remain so through the development of the first leaf, a period of 10-21 days.

The optimum temperature for smut spore germination and infection is between 16-22ºC, although temperatures between 10ºC and 25ºC are tolerated. No infection occurs in seedlings if the mean soil temperature is greater than 28°C. Soil moisture has no direct effect on spore germination or disease. Spores can remain dormant in the soil for up to 15 years in the absence of a crop. Maximum soil infestation occurs in the arable layers at the depth of 0-7 cm. Spores are readily carried from one area to another in soil on machinery, wheels of vehicles and bins. The disease is not normally carried in seed. Infection only occurs during and soon after germination and the disease does not spread from plant to plant in a growing crop.

Hosts

Onion and numerous *Allium spp.* Garlic appears to be immune.

Geographic Distribution

Americas, North, East and South Africa, West, South, and East Asia, Europe, Australia, and New Zealand. This fungus is present where temperatures are cool.

2.7 CONTROL STRATEGIES

Crop Monitoring:

The best way to manage the disease in New Zealand is on a preventative basis. Crops in suspect areas should be examined within the first 3-5 weeks of germination to check for any visible disease symptoms. Although control of the disease is not possible at that stage, knowledge of its presence in an area is vital to future management of the disease.

Non-pesticides strategies:

Choice of growing area

If possible, avoid areas known to be contaminated with smut. Ensure there is good surface drainage as smut spores can be carried by water.

Irrigation

Cool, damp conditions can slow plant growth, thus increasing the susceptible period of the seedling.

Nutrition

No research has been undertaken in New Zealand on this aspect of disease control. However, in Poland, research indicated that adding mineral fertiliser reduced the incidence of onion smut.

Sanitation

Preventing the movement of soil and crop debris is the single most important factors in minimising the spread of the disease. Spores can be spread any time soil is moved, not just during onion growing operations. Ensure that all tools used in an infested, or potentially infested site, are thoroughly cleaned. As spores can remain dormant for up to 15 years in the absence of a crop, good sanitation procedures should always be implemented. Mycelium produced when spores germinate in the absence of an onion crop can survive on organic matter in the soil.

Rotation

A three-year or longer rotation to crops such as cereals in areas with a low incidence of infection is recommended. Given the survival capacity of the spores, rotations of this duration are unlikely to reduce infection in heavily infested areas. Anecdotal evidence suggest that taking land out of onion production for up to 15 years and replanting only with carbendazim treated seed has been effective in overcoming the disease in some areas.

Pesticide control:

In New Zealand control of smut has predominantly been based on the benzimidazole fungicides benomyl and carbendazim. Due to the removal of benomyl, the industry is now reliant on carbendazim. The standard treatment is carbendazim (as MBC 50WP) applied at 125 g/kg or 250 g/kg onion seed. The lower rate of 12.5% is used as a precautionary measure in areas where the disease has been noted at a low incidence, or in areas where there is risk from contaminations from adjacent infested areas. Because carbendazim is relatively ineffective against other soil-borne fungi, it is always applied in combination with either captan or thiram to provide protection from common damping off fungi. Neither captan nor thiram alone will provide protection from smut.

Further info:

Experimental work in Canada suggests that fungicides of the triazole group have a role in the control of smut. However, some fungicides of this group are phytotoxic when applied to onion seed.

Onions NZ has published guidelines to manage the spread of onion smut. Contact Onions NZ for copies of these publications or visit www.onionsnz.com.

Onions NZ (2016) Onion Smut management code of practice. Developed by Market Access Solutionz Ltd for Onions NZ. 25p.

Onions NZ (2016) Onion Smut management guidelines. Developed for Onions NZ by Market Access Solutions Ltd. 4p.

2.8

Pink Root Rot

Phoma terrestris E.M. Hans., also known as:
Pyrenochaeta terrestris (Hansen) Gorenz, Walker & Larson

Photo (left): David B. Langston, University of Georgia,
Photo (right): Gerald Holmes, California Polytechnic State University at San Luis Obispo,
Image number: Left - UGA5077074, Right - 1571408, Bugwood.org

Description

As the name of this disease indicates, the most striking symptom of pink root is pink roots. Roots infected by the pink root fungus are initially pink in colour, and occasionally yellow to yellowish-brown. As the disease progresses, roots become semi-transparent and water-soaked, then shrivel and die, persisting as red-purple or dark brown remnants. As new roots grow, they also become infected, turn pink and eventually die. Although pink root can kill seedlings, the disease is most commonly seen in almost-mature plants, which usually do not die. If infection is severe, plants may develop leaf tip dieback – symptoms similar to drought or nutrient deficiency. Severely infected plants remain stunted, producing small poor quality, unmarketable bulbs. Infection is confined to roots and the bulb basal plate - living bulb tissue is not affected. Weak plants are more susceptible to pink root than vigorous plants.

Disease cycle

Pink root is strictly a soil-borne disease. *Phoma terrestris* survives in the soil as thick-walled resting spores (chlamydospores), fungal fruiting structures (pycnidia), spores (pycniospores), and as mycelium in colonised roots or infected plant debris. The fungus penetrates onion roots directly; wounds are not necessary for infection. The fungus is spread in water and by movement of infected soil. Pink root is more prevalent in hot growing conditions - temperatures of 24° to 28°C are optimum for pathogen growth and disease development, whereas little disease occurs below 16°C. The disease is greatly enhanced by stresses imposed on plants such as heat, cold, drought, flooding and nutrient toxicities/deficiencies. Onions infected with the pink root fungus have also shown a higher incidence of Fusarium basal rot.

Hosts

The pink root pathogen is only economically important on onion, but can cause disease in leeks and garlic. Some stains of the fungus are capable of infecting weakened roots of several vegetable crops including asparagus, carrot, cauliflower, cucumber, pea, potato, squash, sweet potato and tomato. Wheat and maize can also become infected. *Phoma terrestris* can be found in the rhizosphere surrounding the roots of many crop plants and weeds.

Geographic Distribution

Greece, Netherlands, Poland, Israel, Senegal, Argentina, Venezuela, USA, Australia and New Zealand.

2.8 CONTROL STRATEGIES

Non-pesticides strategies:

Pink root of onion, like most other soil-borne diseases, can be managed, but not eliminated, by using integrated crop production and protection methods. This aims to reduce pathogen levels, disease pressure and plant stress levels, thereby enabling vigorous plants to compete more successfully for nutrients and moisture. Disease management strategies for control of pink root include:

Crop rotation

Avoid repeated cropping of onions on the same soil. Ideally, use a long rotation to non-host crops (5 years or more). Long rotations will reduce but not eliminate the occurrence of the disease. Once soil becomes infected, the fungus remains for many years. Continuous production of onions in the same field results in increased losses to pink root.

Cultural practices

Plant high-quality onion seed in well-prepared, well-drained and fertile soil. Carefully manage fertilisers, irrigation and control of insects and other diseases to maintain healthy plants - this will help prevent plant stress and predisposition to infection. Apply pesticides, especially herbicides, according to label directions to minimize root stress/damage.

Soil fumigation

Pre-plant soil fumigation has been shown to be an effective, but expensive control measure for pink root of onion. Fumigation is not economically viable unless a high value seed crop is being grown.

Sanitation

Prevent contaminated soil and infected crop debris from being transported to clean fields. Clean soil from equipment with water before moving from infested to non-infested fields.

Resistant cultivars

New onion varieties are being developed with improved levels of resistance to pink root (check with your local seed merchant). However, some resistant varieties are resistant in some locations but may not be in others, depending on which strains of the fungus are present.

Pesticide Control:

There are no registered chemical control options for pink root rot in New Zealand *Allium* crops.

2.9

Southern Blight (Rolf's disease)

Corticium rolfsii (also known as Sclerotium rolfsii) (fungus)

Photo: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Image number: 1573639, Bugwood.org

Most commonly seen as a network of white fungal threads at the base of mature bulbs in the soil, or on the outer scales of bulbs and adjacent plant debris after wet weather during curing. Spherical, cream or brown sclerotia, approximately the size of a pinhead or slightly larger, are often found amongst the threads on the lifted bulbs and surrounding debris. In the standing crop it is sometimes associated with shredding of the outer scale leaves at their point of attachment to the base plate, leading to excessive loss of scale leaves during handling. If bags of onions carrying sclerotia are exposed to high temperature and humidity during transport to market, the fungus can grow over bulbs and surfaces of the bags causing market access problems.

Life cycle

S. rolfsii is typically a warm temperature fungus more common in tropical and subtropical areas. The fungus can grow saprophytically on almost any plant debris in the soil and survives adverse conditions as sclerotia. It is readily dispersed on infected plant material and contaminated soil. The fungus has a wide temperature range (8-40°C) with an optimum of 25-35°C. Although the organism is widely distributed, temperatures in New Zealand are frequently below optimum and it seldom causes major problems. Regular cropping of a favoured host can lead to high numbers of sclerotia in the soil. Significant losses from disease can occur in vegetable and ornamental crops from time to time.

Hosts

Onion and shallots. The fungus is found on over 500 species of plants including pasture and weeds. Commercial crops infected include carrot, potato, tomato, squash, cabbage debris, nerine and lily.

Geographic Distribution

The fungus has a worldwide distribution. It is common in the North Island of New Zealand but has not been found in the South Island.

2.9 CONTROL STRATEGIES

Non-pesticides strategies:

Cultural practices

- Because of its ability to survive for long periods as sclerotia in the soil, *S. rolfsii* is not effectively controlled by short term crop rotations.
- Good weed control will prevent multiplication of the pathogen on weeds and eliminate the moist areas under mats of weeds that could favour its growth.
- Mechanical topping and hand topping removes slow drying leaf material that promotes growth of the fungus in contact with bulbs during curing.
- Turning or raking after rain will assist drying and suppress fungal development where onions are being cured with their tops on.
- Avoid leaving onions in the field for extended periods after curing.
- Deep ploughing will bury sclerotia and minimise disease in the following crop.

Pesticide control:

Fungicides of the triazole group routinely used for the control of white rot are also effective in suppressing *S. rolfsii*. In early planted crops, where the white rot control programme may finish by October or November an additional late application of fungicide may be beneficial in areas with a history of the disease.

Further info:

Broadhurst PG. 1995. *Seasonal activity, host range and distribution of Sclerotium rolfsii in New Zealand*. Presented at Proceedings of the Forty Eighth New Zealand Plant Protection Conference, Angus Inn, Hastings, New Zealand, August 8-10, 1995. 1995, 351 353; 8 ref.

Sumner DR. 1995. Southern Blight. I*n Compendium of Onion and Garlic Diseases,* ed. HF Schwartz, Mohan, S. K., pp. 13-4. Minnesota: American Phytopathological Society, APS Publishing.


2.10

Stemphylium Leaf blight

Stemphylium vesicarium (Wallr.) E.G. Simmons, (1969)

Photo: Gerald Holmes, California Polytechnic State University at San Luis Obispo, Image number: Left - 1570866, Right - 1572312, Bugwood.org

Description

Stemphylium leaf blight (SLB) disease can prematurely defoliate onion plants which can compromise bulb quality and make the crop more susceptible to secondary diseases that affect bulb quality (i.e. storage rots caused by bacterial pathogens). SLB affects all foliar parts of the onion crop, and severely infected crops develop small to no bulbs.

Historically, SLB has been a minor disease of onion crops in New Zealand but in recent seasons (2017-18) SLB has caused significant yield losses particularly in the Pukekohe region.

In onion and garlic, infection usually remains restricted to the leaves and inflorescences, and does not extend to the bulb scales. Although SLB can be seen when the onion crop is at the 3-4 leaf stage, the disease most commonly occurs at plant maturity and when leaves begin to senesce. Typical SLB lesions are more commonly found on the side of leaves facing the prevailing wind.

Above: Stemphylium leaf blight (SLB) lesion

Photo: Peter Wright, Plant and Food Research.

Above: Pukekohe onion field with high incidence and severity of Stemphylium leaf blight

Photo: Mike Blake

The initial symptoms on onion leaves are small yellow to tan, water-soaked spots. These small spots develop into elongated light brown to tan leaf lesions which turn dark olive brown when the pathogen begins to produce dense masses of spores. Leaves may become completely blighted as the lesions coalesce. As the disease progresses, infected leaves undergo rapid necrosis from the tip down which can lead to desiccation of leaves and early dying of the crop. Sometimes, small, black, pin-like, raised fungal fruiting bodies called perithecia may appear in the blighted areas of the leaves and scape.

The symptoms of SLB can be confused with purple blotch. SLB and purple blotch lesions may occur on the same plant, and spores of each may develop on the same lesion.

Disease cycle

The main primary source of SLB-pathogen inoculum is infected plant residues on the soil on which *S. vesicarium* asexual conidia are formed. The disease cycle of SLB is characterised by sexual and asexual phases, and pseudothecia may develop on the blighted leaves. The SLB fungi are also introduced into onion fields by windblown spores from nearby plants.

Infection of onion leaves by *S. vesicarium* spores occurs mainly through (1) stomatal openings, (2) via wounds caused by other diseases, insect pest feeding or physical damage such as hail and herbicide damage, and (3) direct infection of dead or dying leaves. Without leaf tissue damage, the incidence and severity of SLB is reduced. *S. vesicarium* can be a secondary invader of downy mildew, botrytis leaf blight and purple blotch lesions and can ultimately 'take over' becoming a very aggressive leaf defoliator. Onion plants subjected to heat stress are more susceptible to SLB.

Older onion leaves and mature plants are more susceptible to infection than young leaves. When onions reach maturity their foliage naturally dies back as the plant transfers nutrients from the leaves to the bulb, making infection by *S. vesicarium* more likely since it readily colonises necrotic leaf tissue under favourable environmental conditions. Onion plants that died prematurely, 'standing up', often have many more bulb rots at harvest.

SLB infection and disease development is favoured by temperatures between 18-25°C, humid conditions and long periods (>8h) of leaf wetness. Sporulation usually occurs at the site of initial lesions and is observed 6-14 days after the development of initial lesions.

Hosts

Not only does *S. vesicarium* cause disease in onion, but it can attack the leaves of many other crops including garlic, asparagus, pear, lucerne, mango and soybean. All of these crops develop typical leaf blight symptoms, including light brown lesions that turn dark brown when the pathogen sporulates, leaf blighting and death. Alternative crops can also serve as reservoirs of inoculum in the absence of onion crops.

Geographic Distribution

Stemphylium leaf blight (SLB) of onion occurs in most onion growing regions of the world.

2.10 CONTROL STRATEGIES

There is no single tactic will manage SLB, integrating several control practices can help onion growers to maintain crop quality while minimizing economic losses due to the disease. Control of SLB of onion has been attempted in various ways including a number of cultural control strategies.

Non-pesticides strategies:

Maintaining a healthy crop

Since the pathogen is likely to enter leaves that have been physically damaged or infected by other diseases, it is important to maintain healthy plant stands and control other common foliar diseases of onions such as downy mildew and botrytis leaf blight. Avoid injuring bulbs during production. Do not over-fertilise the onion crop with nitrogen because excessive N applications can increase SLB severity.

Crop rotation

Because the SLB pathogen can survive in soil for long periods on decomposing plant material, crop rotation with non-hosts plays an important role in reducing the inoculum levels in onion fields. A 3- to 4-year rotation to reduce the amount of inoculum present and to reduce SLB disease incidence is recommended.

Treated seed

Fungicide seed treatments (e.g. carbendazim, thiram, procymidone) are not effective in eradicating the SLB pathogen from onion seed. Hot water soaking seed at 50°C for 20 min reduced *S. vesicarium* in seed but germination was also reduced.

Reducing leaf wetness duration

Methods to reduce leaf wetness duration to reduce the incidence and severity of SLB include (1) increasing plant spacing in seedbeds to facilitate air movement and rapid drying of the foliage, (2) aligning rows of plants to follow the direction of the prevailing wind, and (3) irrigating crops during the late morning or early afternoon to allow leaf surfaces to dry rapidly.

Cultural practices

Cultural methods for management of fungal diseases such as SLB aim to reduce the pathogen numbers and to create conditions that are unfavourable for infection. Burying plant residues at the end of the onion growing season by deep tillage reduces SLB by facilitating decomposition and increasing the action of pathogen antagonists.

Removing culls and volunteer plants from the field since these can be a source for both pathogens and insects that cause wounding on onion plants.

If SLB-infected onions are dying standing up when they should be toppling, they should be pulled. It may take longer for the necks of these onions to dry, and they also have a higher risk of rotting in storage than healthy onions.

Biological control

Although biological control agents such as *Bacillus subtilis, Saccharomyces cerevisiae, Pseudomonas fluorescens* and *Trichoderma* species reduced the severity of SLB in onion under controlled conditions, these products do not provide effective management of SLB when used as the sole management strategy under field conditions.

Resistant cultivars

Although genetic resistance is a fundamental and effective weapon for disease control in many crops, currently there are no commercially available onion cultivars that are resistant to SLB.

Pesticide control:

The most effective way to manage SLB on onion is regular applications of preventative fungicides, but few fungicides have been reported to be effective in the management of this disease.

In New Zealand, no fungicide is currently registered for control of SLB of onion. Fungicides registered in New Zealand for leaf spot of asparagus caused by *S. vesicarium* are:

1. Chlorothalonil (not currently registered in New Zealand for onion diseases)
2. Copper (also registered in New Zealand for onion downy mildew and bacterial blight)
3. Difenoconazole (not currently registered in New Zealand for onion diseases)
4. Iprodione (not currently registered in New Zealand for onion diseases)
5. Procymidone (also registered in New Zealand for onion white rot).

Because *S. vesicarium* readily invades onion leaves via dead or damaged tissues, controlling other foliar diseases such as purple blotch, downy mildew and Botrytis, and insect pests such as thrips is critical when managing SLB of onion. Fungicides effective against purple blotch are also effective against SLB, but fungicides that control downy mildew do not always control SLB (e.g. Mancozeb).

Further info:

Tyson, J. L., Wright, P. and Fullerton, B. 2018. Stemphylium leaf blight of onion. A Plant & Food research report prepared for Onions NZ. March 2018. PFR SPTS No. 16075. Plant & Food Research Ltd. pp. 7.

Aphids

Hemiptera: Aphididae

Photo: Lesley Ingram,
Image number: 5402104, Bugwood.org

There are **three species of aphid** that are associated with Allium crops:

- **Shallot Aphid** *(Myzus ascalonicus Doncaster)*
- **Onion aphid** *Neotoxoptera formosana (Takahashi)*
- **Marigold aphid** *Neotoxoptera oliveri (Essig), marigold aphid*

Shallot Aphid *(Myzus ascalonicus)*

Photos (left to right): 1 - insecte.org, 2 - aphid.aphidnet.org, 3 & 4 - influentialpoints.com

Description

Wingless adults are 1-2 mm long; brownish-green; antennal tubercles well-developed and slightly convergent; antennae as long as body; distal part of siphunculi slightly swollen. Winged aphids, male and female also occur in New Zealand.

Biology and Damage

Parthenogenetic (no mating required) females can breed all year. Winged aphids occur in spring and autumn, mainly in October, November and April, May. Feeding can cause distortion of plants.
Often occurs in large numbers on bulbs in store at the end of the storage period. Can vector some viruses.

Hosts

Onion, garlic, shallot, leek, chives, strawberry and potato.

Geographic Distribution

Known from Europe, North America and Australasia.

Onion aphid *(Neotoxoptera formosana)*

Photo: Lesley Ingram,
Image number: 5402104, Bugwood.org

Description

Wingless females are oval, small to medium sized, purplish-red to almost black, have black antennae, and the cornicles are dark but paler than the body of the insect. Winged adults are dark red to black with the veins in the wings having a heavy black-border. Juveniles are dark grey.

Biology and Damage

This aphid only feeds on *Allium* species. Colonies can establish on leaves or bulbs, however they are rarely seen on onions which are subjected to insecticide applications (for thrips). Onion aphids are common on chives. Can vector some viruses.

Hosts

Onion, garlic, shallot, leek and chives.

Geographic Distribution

Present in Europe, America, Asia, Australasia and Papua New Guinea.

Marigold Aphid *(Neotoxoptera oliveri)*

This species similar to *N. formosana*. See left page for information on appearance and biology. Host plants include *Allium* species. The biology of *N. formosana* and *N. olivera* has been compared on three *Allium* species. On garlic and chives, *N. formosana* grew and reproduced faster than *N. olivera*, but on onions *N. olivera* grows and reproduces faster than *N. formosana*.
Known from Europe, South Africa and Australasia.

3.1 CONTROL STRATEGIES

Crop Monitoring:

The different *Allium* species may vary in their susceptibility to each aphid species. Susceptibility will also be affected by the way the crop is grown and methods adopted to control other pests. Crops that are not vulnerable to onion thrips and therefore receive little or no insecticide may need monitoring for aphids, e.g. chives and shallots.

Bulbs kept for propagation should be checked for aphids before planting out.

Pesticide control:

Most insecticides used for thrips control will also control aphids, however, if aphids are the primary target, select an insecticide that has a label claim for aphid control. Ensure that there is good coverage of all plant leaves. Inspect the crop a week after application and if some aphids are left make a second application of the same product. If subsequent aphid infestations need treating, use an insecticide from a different chemical class.

Non-pesticide strategies:

For crops susceptible to aphids, ensure that all bulbs from previous crops are disposed of in a way that prevents aphids breeding on them. Remove any self-sets from the crop field before and after planting. Also remove self-sets from adjacent fields.

3.2

Greasy cutworm

Agrotis ipsilon aneituma Walker (Lepidoptera: Noctuidae)

Photo: Merle Shepard, Gerald R.Carner, and P.A.C Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia
Image number: 5368057, Bugwood.org

Description

Adult moths, about 20 mm long, have grey-black mottled wings with brown markings. Small white eggs are laid on plants or plant debris. Young larvae are brown to greyish while large larvae are dark grey with two yellowish stripes. Large larvae have a shiny greasy appearance. Brown pupae are formed in a cell in the soil.

Biology and Damage

Adults hide in vegetation during the day, fly at night and may be seen flying to lights. A typical female lays between 600-800 eggs. Young larvae feed on foliage. Larger larvae hide in the soil, emerging at night to cut seedlings and small plants at ground level and drag vegetation into their burrows to feed on. Moths fly all year. However, larger crop damaging cutworm larvae do not normally develop until early October onwards.

Cutworm infestations in *Allium* crops are sporadic, depending upon the abundance of moths in late winter and early spring. The presence of weeds and crop debris in fields during moth flights may increase risk of attack.

Hosts

Cutworm larvae feed on a wide variety of plants.

3.2 CONTROL STRATEGIES

Crop Monitoring:

While monitoring crops for disease and pests, look for cut seedlings and small plants from late September onwards.

When cut plants are found dig in soil to try and locate larvae to determine size. Survey the crop to determine the area affected.

Pesticide control:

In crops such as maize and sweet corn, insecticides are used at sowing or post emergence when crop damage is seen. For many *Allium* crops insecticide treatment at planting is likely to be too early. Insecticide sprays should be applied in early evening when larvae are active.

Non-pesticide strategies:

Crop infestations are sporadic and probably associated with crop debris and presence of weeds in late winter and early spring.

Ensure that the seed bed is well prepared and that all residues from the previous crop have fully decomposed before sowing seed.
Keep crop site weed free before and after sowing.

3.3

Leaf mining fly

Scaptomyza flava (Diptera: Drosophilidae)

Photos: Howard F. Schwartz, Colorado State University,
Image number: Left - 5498722, Right - 5362732, Bugwood.org

Description

Adult flies are slender, about 2 mm long, and grey or yellowish grey. The larvae are white maggots that are found in the white mines on leaves.

Biology and Damage

The flies are active all year, most numerous in spring and early summer. Females puncture leaves with their ovipositor, feed on the cell contents and lay eggs in some of the punctures. Larvae tunnel through the plant leaf creating a distinctive white mine. It starts as a long narrow mine that widens into a large blotch.

Leaf mining fly does not appear to cause economic damage to *Allium* crops in New Zealand.

Hosts

Leaf mining fly has many hosts. The main host plants are in the Brassicaceae family, but mines can be found in old leaves of onion plants not treated with insecticide.

Note: overseas there are several species of leaf miners that cause economic damage to *Allium* crops. If you see serpentine leaf mines without a blotch, contact MAF Biosecurity immediately.

3.3 CONTROL STRATEGIES

Non-pesticide strategies:

None required.

Pesticide control:

Insecticides used to control other pests (e.g. thrips) will control this fly.

3.4

Lucerne flea (Clover flea)

Sminthurus viridis (L.) (Collembola: Sminthuridae)

Photo (left): *Sminthurus viridis* by Lucarelli / CC-BY-SA-3.0
Photo (right): Joseph Berger,
Image number: Right - 5515510, Bugwood.org

Description

Small, 1-2 mm, globular springtails that jump readily when disturbed. Commonly known in New Zealand as Springtails. Other species of globular springtails occur in New Zealand fields. Most are harmless. Two summer active species, *Bourletiella arvalis* and *B. hortensis* are known to damage some crops. The first species is orange brown and the latter is purple black.

Biology and Damage

Active after autumn rains with peak populations in spring. Infestations are likely to be worse after warm winters. More problematic in the Waikato region and in fields out of pasture. Feeding damage may make plants more susceptible to disease.

Hosts

Primarily on clovers and other legumes but can also be found on older leaves of onion seedlings.

3.4 CONTROL STRATEGIES

Crop monitoring:

While monitoring crops for disease and pests, look for damage to older leaves on seedlings and for small jumping insects. Define area of crop infested.

Non-pesticide strategies:

Crop infestations are likely in late winter and early spring.

- Keep crop site weed free before and after sowing.

Pesticide control:

There are insecticide label claims for lucerne flea control for pasture that can be modified for use on onion seedlings. Treat at the first signs of infestation.

Onion Fly

Delia platura (Diptera: Anthomyiidae)

Photos (left/right bottom): Whitney Cranshaw, Colorado State University,
Photo (top right): Coutin R. / OPIE
Image number: Left - UGA5210032, Right Bottom - UGA5210043, Bugwood.org

Note: This is not the onion fly (*Delia antiqua*) that causes severe problems in Asia, Europe and USA. That species is not present in New Zealand. Overseas the New Zealand onion fly is called bean seed fly and seed corn maggot.

Description

Adult flies are slender, about 4 mm long, and grey-black. Larvae are small and yellowish-white.

Biology and Damage

Females lay eggs in spring and early summer on recently disturbed, open soil, especially where there are residues of vegetable matter or where organic fertiliser has been applied. The small yellowish-white larvae can live on plant debris, but will also burrow into germinating seeds and seedlings. Pupation occurs in the soil. The length of the lifecycle depends on temperature, but in warm areas can be completed in 4-5 weeks.

Hosts

The fly larvae can damage a wide variety of plants, especially those with slow germinating seeds such as beans and maize.

3.5 CONTROL STRATEGIES

Non-pesticide strategies:

The New Zealand onion fly is associated with decaying plants and animal dung.

- Ensure that the seed bed is well prepared and that all residues from the previous crop have fully decomposed before sowing seed.
- Do not apply organic fertiliser.
- Keep crop site weed free before and after sowing.

Pesticide control:

Overseas, insecticide treated seed is used on some crops.

3.5

Onion Thrips

Thrips tabaci Lindeman (Thysanoptera: Thripidae)

Photo (left top/bottom): Whitney Cranshaw, Colorado State University,
Photo (right): Alton N. Sparks, Jr., University of Georgia,
Image number: Left Top - 5364131, Left Bottom - 5364128, Right - UGA1327083, Bugwood.org

Description

Thrips are tiny, elongated, thin insects. Two species may be found on *Allium* plants; onion thrips and the predatory thrips, A*eolothrips fasciatus (L.)*. The predatory thrips is readily distinguished from onion thrips by its black and white wings.

Onion thrips adults are small, up to 2 mm long and winged. Adult females in summer are pale brown, while the winter generations are dark brown. Adult males are smaller and paler than females. The two larval stages are a similar shape to the adults, but do not have wings and are white to pale yellow. The pupae are also white to pale yellow and can be recognised by the presence of wing buds.

Damage

Onion thrips feed by puncturing the surface cells of both the green leaves and fleshy scales of bulbs, sucking out the cell contents and killing the cells. When they feed they deposit black faecal droplets.

Feeding damage on leaves appears as yellow or yellow-white speckles that in severe infestations cover most of the leaf.

Thrips tend to be where two leaves are close together or on the underside of bends or hollows in *Allium* leaves. On older leaves damage often has a silvery appearance.

Feeding damage to bulbs occurs where thrips have access to the fleshy scale, i.e. where the skin has broken by the root base, splits in the dry skin and where thrips have had access through the neck, under the skin around the neck and between scales. In these areas black faecal droplets may be visible and the surface of the fleshy scale is shrunken and less shiny.

Onion Thrips



Photos: Thrips damage to foliage and an onion bulb

Onion thrips vector tospoviruses, such as tomato spotted wilt virus and iris yellow spot virus. These viruses are only acquired by thrips larvae feeding on infected plants and are subsequently transmitted by the adults feeding on uninfected plants. Iris yellow spot has not yet been detected in New Zealand. See Appendix: "Unwanted in New Zealand; diseases and pests of *Alliums*" for more information.

Biology

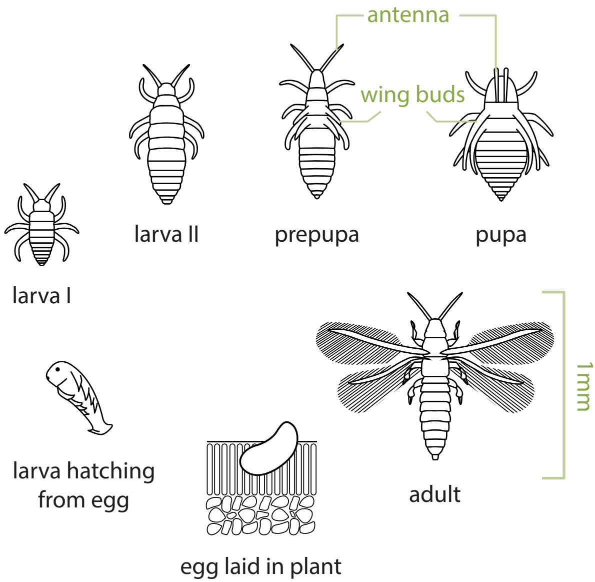
Female thrips lay eggs into soft plant tissue. They hatch into larvae. The two larval stages are followed by two non-feeding stages, the prepupa and pupa. The prepupa and pupa usually hide in the soil and adults then emerge from the soil and move to onion leaves to feed and reproduce. Larval thrips feed mostly on the young leaves and are mainly found in the gaps between leaves. Adult thrips and older larvae may also be found on older leaves, especially when populations are high.

Onion thrips breed continuously with all stages present all year. The rate of development depends upon temperature, as the weather becomes hotter the generation time becomes shorter (see Table I). In winter they can breed on weeds and on 'self-set' or 'volunteer' onion plants. Thrips can also survive in onion bulbs in stores or bulbs dumped outside. In storage all life stages can be found on onion bulbs.

Adult thrips can fly and migrate into crops most of the year. In the South Auckland region from mid June to early September, onion thrips do not normally fly.

High numbers of thrips can develop on the leaves of unsprayed onion plants. However, there is no clear relationship between the level of infestation on leaves and subsequent infestation in bulbs.

In New Zealand there are strains of onion thrips that are female only, i.e. unmated adult females lay eggs that produce female offspring.



There are also other strains that are bisexual, i.e. that produce male and females that mate when they reach adulthood. Each strain is likely to have different host plant preferences and different spectrum of susceptibility to insecticides. Thrips strains also vary in their ability to vector viruses.

Table 1:

Estimated number of days of each life stage of onion thrips on onions.

Temperature (°C)	Egg	Larva	Pupa	Egg to adult
12	17.6	19.1	13.8	51.1
18	8.7	8.5	6.6	23.3
21	6.0	6.2	4.7	16.8
25	4.9	4.5	3.7	13.0
30	3.4	3.8	3.0	10.3

There are also other strains that are bisexual, i.e. that produce male and females that mate when they reach adulthood. Each strain is likely to have different host plant preferences and different spectrum of susceptibility to insecticides. Thrips strains also vary in their ability to vector viruses.

Hosts

Onion thrips has a very wide host range and causes economic damage to many *Allium* species and to lettuce, cabbage and other vegetable and ornamental plants. It also lives on a variety of weeds.

Geographic Distribution

Worldwide and in all horticultural and agricultural areas of New Zealand.

3.5 CONTROL STRATEGIES

Monitor crops for onion thrips from September onwards.
See appendix – Thrips Control Strategy

Non-pesticide strategies:

Minimising infestations

- Do not dump onions or other *Alliums* outside near fields to be planted with onions or other *Alliums*.
- Remove all self set *Alliums* from new crops and fields adjacent to new crops as soon as possible. Dispose of these plants well away from crops.

Time of planting

- Plant crops so that seedlings emerge between mid June and late August to minimise the risk of overwintering infestations and delay infestation until mid September onwards when spring flights start to invade.
- Early sown crops with seedling emergence before June are at risk of an autumn/early winter infestation that can breed in a warm winter.

Crop location

Avoid planting main and late crops near early crops because thrips will move from the senescing early crop to the nearby actively growing crops.

Biological control

Parasites, pathogens and predators of onion thrips are known, but none appear to give adequate control of onion thrips in *Allium* crops.
The main parasite, *Ceranius menes* (Walker) is a tiny parasitic wasp. Several predators are regularly found in unsprayed crops including the predatory thrips *Aeolothrips fasciatus* (L.), hover fly larvae and spiders. Two species of fungal pathogens, *Beauvaria bassiana* and *Verticillium lecanii*, are available in commercial formulations. However the efficacy of these products for thrips control in crops is not known. Currently biological control is not a practical option.

Fertilization

High nitrogenous fertiliser increases the susceptibility of onion bulbs to onion thrips feeding and damage.

Skin quality

Thrips can only infest bulbs if they have access to fleshy scale tissue through cracked skin at the base of the bulb, split skins and though the neck. Therefore, growing onion bulbs with intact skins and tight necks reduces the incidence of onion thrips on bulbs.

Some red skin varieties and hybrids have shown greater susceptibility to thrips infestations. Recent studies have shown that the use of foliar applied calcium sprays has little effect on improving onion skin quality.

Harvesting and handling

- Harvest and handle bulbs to minimise breaks in the dry skins. Onions lifted when 100% dry tend to have more skin defects and more thrips.
- Hand-clipped onions tend to have more thrips in storage.
- Segregate heavily infested lines of bulbs from thrips free bulbs.
- Keep onions as cool as possible, this slows the rate of development, feeding and breeding in bulbs. Aim for <20°C.

Pesticide control:

Insecticide application

- Apply insecticides only when the action threshold has been exceeded. The current action threshold is 1 thrips (any stage) per 10 plants.
- Apply insecticides as a cluster of 3 applications of the same active chemical. Only the feeding stages (adults and larvae) are vulnerable to most insecticides. The latter spray applications within a cluster target those thrips previously hidden from sprays as eggs beneath the surface of the leaf or pupae in the ground.
- The recommended time between sprays within a cluster is based on the estimated number of days to complete each hidden life stage (eggs and pupae) and varies depending on region, time of season and whether it is a hot of cool season. Table 2 shows recommended time period between sprays within a cluster for each month.

Table 2:

Recommended number of days between sprays within a cluster in Pukekohe, Hawke's Bay and Canterbury.

Month	Pukekohe	Hawke's Bay	Canterbury
October	13-16	13-18	15-23
November	10-14	11-16	14-20
December	6-9	6-9	7-11
January	6-8	6-8	7-9
February	5-7	6-9	7-10
March	6-8	7-10	8-12

Selection of insecticides

- Use an insecticide from a different chemical class for each cluster of sprays.
- Observe the withholding periods.
- Avoid using synthetic pyrethroids for thrips control; only one application is likely to provide any reduction of thrips numbers.

Spray coverage

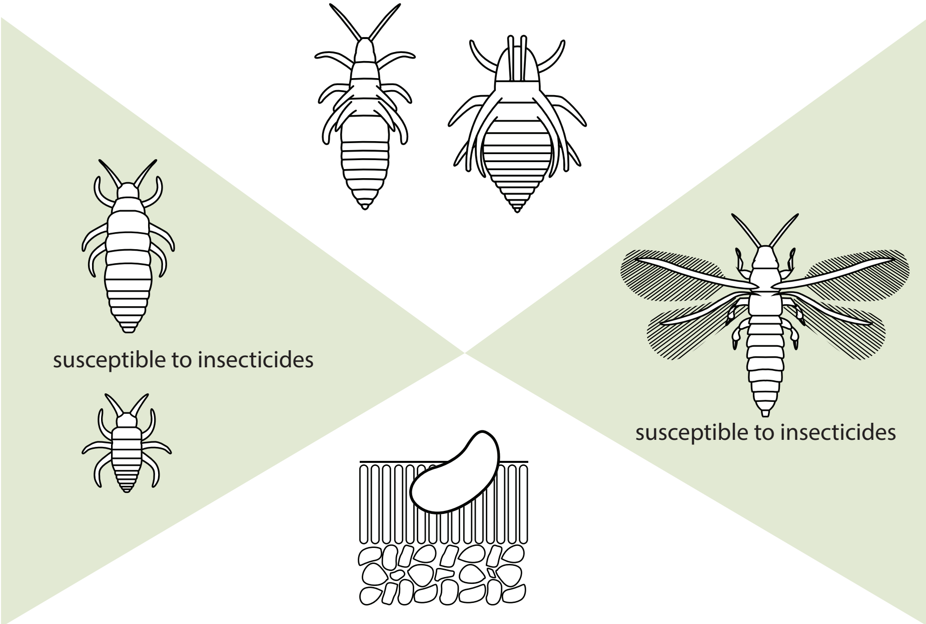
Thrips larvae and adults are usually living in the tiny spaces between leaves, especially around the youngest leaf.

- Adjust the spray equipment to give complete coverage of all plant leaves enabling spray solution to run down the space between leaves.
- Use wetters/spreaders or oils where these are recommended to enhance insecticide contact with thrips.

Resistance to insecticides

Some strains of onion thrips are resistant to synthetic pyrethroid insecticides and to two organophosphate insecticides, diazinon and dichlorvos. No resistance has been found to other organophosphate insecticides. The insecticide resistance is persistent, though due to mixing of strains in the field the effects are diluted until the resistant strain is selected by use of the chemical.

Onion thrips are prone to develop resistance to other insecticides if they are used inappropriately and especially if over used.



Only larvae (left) and adults (right) are susceptible to insecticides.

Further info:

New Zealand Plant Protection Society web site for updates on resistance management strategies: www.nzpps.org.nz.

4.1

Iris Yellow Spot Virus

Photos: Howard F. Schwartz, Colorado State University,
Image number: Left - 5362050, Right - 5365621, Bugwood.org

Other Names Used: Lisianthus leaf necrosis

Damage and Symptoms

Iris yellow spot virus (IYSV) appears transmitted only by onion thrips (Thrips tabaci). The host range includes: *Iris*, onion, garlic, leek, chive, lisianthus, *Hippeastrum*, tomato and pepper. Weeds such as redroot and purslane, may also act as a host. Disease symptoms include straw-coloured, dry, tan, spindle- or diamond-shaped lesions on the leaves and scapes (stalks) of onion plants. Some lesions have distinct green centres with yellow or tan borders; other lesions appear as concentric rings of alternating green and yellow/tan tissue. Seed stalks may bend over at the lesion with withering of leaves and flower bearing stalks (straw bleaching). These symptoms can be confused with herbicide damage. Infected plants may be scattered throughout a field, or generalised throughout an entire field. Lesions may also appear on bulbs. The disease can cause complete loss of onion seed crops because flower heads do not develop.

Diagnosis is possible by ELISA or RT-PCR.

Nematodes

Photo: Howard F. Schwartz, Colorado State University,
Image number: 5362283, Bugwood.org

Introduction

Disorders of *Alliums* caused by nematodes are either very dramatic or insidious. Nematodes are microscopic worm-like animals some of which can damage plants including *Alliums*. The stem/bulb nematode can kill plants, but other species weaken plants allowing more serious secondary bacterial or fungal infections. Nematode disorders of onions are often not recognised as such and are often misdiagnosed as being caused by other biotic (fungus, bacteria) or abiotic (nutrient deficiency, residual herbicide, hard soil etc.) factors.

The most serious nematode disorder of *Alliums* is caused by the stem/bulb nematode (*Ditylenchus dipsaci*). In New Zealand other nematode disorders are caused by the root-knot nematode (*Meloidogyne sp.*), the needle nematode (*Longidorus elongatus*), the lesion nematode (*Pratylenchus sp.*) and stubby root nematode (*Paratrichodora allius*).

5.1

Stem and Bulb Nematode

Ditylenchus dipsaci (Kuhn) (Nematoda: Tylenchidae)

Photos: Ed Kurtz,
Image number: Left - 1635369, Right - 0162062, Bugwood.org

Description

Stem nematodes are colourless and slender. They cannot be seen without magnification. The adult body is 2.2 mm long, filiform and tapering at each end, with internal organs visible through the cuticle. At the mouth end they have a sharp stylet for piercing plant cells.

Biology and Damage

Stem/bulb nematodes live as parasites within plant tissue. Males, females and four larval stages may be present. After mating females can lay up to 500 eggs and live up to 2 months. Desiccated fourth stage larvae can survive for several years in the absence of growing host plants either in the soil or attached to plant tissue such as seeds or bulbs.

Symptoms in New Zealand onion plants include erratic stands, looping and bending of leaves below the soil surface, spikkel formation (swelling) and extensive splitting of cotyledons and leaves. Leaves are short and thickened and frequently exhibit brownish or yellowish spots and bloat (stem swelling). Infested seedlings become twisted, enlarged, and deformed and subsequently die in severely infested crops.

As the season progresses, onion foliage collapses, and a softening of the bulb begins at the neck and gradually proceeds downward. Scales become soft and light grey, making them more susceptible to soft rot, and this is accompanied by an offensive odour. Plants may decay at the base and contain secondary invaders.

Hosts

The species has an extensive list of host plants. There are more than 20 races of stem/bulb nematodes, each with a different selection of preferred host plants. The main race infesting onions and other *Alliums* also affects a wide range of crops including shasta peas, parsley celery, lettuce, hairy nightshade and salsify. Mixtures of more than one race may occur in the same field.

Geographic Distribution

Stem/bulb nematode occurs though out New Zealand in all countries where *Allium* crops are grown.

5.1 CONTROL STRATEGIES

Crop Monitoring:

While monitoring crops for disease and pests, look for plants showing symptoms of stem & bulb nematode and plants showing poor vigor. Some of the latter should be sent for examination for nematodes. Regularly monitor areas of concern. Define area of crop infested.

Non-pesticide strategies:

Preventing spread

The nematodes can only move themselves a few centimetres. Most dispersal is from movement of soil and infected plant material including seed. They may be spread by soil on machinery, washed by rain and flood water and by wind.

Crop rotation

Rotate *Allium* crops with at least 4 years of non-host crops between plantings. Eliminate volunteer onions and other host weeds in order to suppress populations.

Pesticide control:

No pesticide has a label claim for control of nematodes of *Allium* crops.

5.2

Root-knot Nematode

Meloidogyne sp. (Nematoda: Tylenchidae)

Photos: Jonathan D. Eisenback, Virginia Polytechnic Institute and State University, Image number: Left - 5440559, Right - 5441448, Bugwood.org

Description

Root-knot nematodes are minute, worm-like animals that are very common in soil. Juveniles are active, thread-like worms about 0.5 mm long and too small to be seen with the naked eye. They occasionally develop into males, but usually become spherical-shaped females.

Biology and Damage

Females lay 100 to 1000 eggs into a gelatinous matrix, which holds them together. After one moult in the egg, second stage juveniles hatch and move to a root tip. These juveniles penetrate the root just behind the root cap. Once inside it migrates to the cortex, becomes sedentary and initiates the formation of gall tissue. The nematode does not infest seed, but may be present in bulbs.

Symptoms are typical for all host plants, round to spindle-shaped swellings (galls) on roots. Galls are often smaller (1-2 mm in diameter) on onion than many other plants. Infected secondary root systems are usually shorter and have fewer roots and root hairs than normal. Additional symptoms are erratic plant stand, plant stunting and yellowing, loss of vigour of the root system.

Generally, root-knot is more severe in sandy-textured soils than clay soils. The nematode is more mobile in soils with larger, aerated pore spaces. It has not been a common problem on *Alliums* in New Zealand.

Hosts

The species attacking *Alliums* also attacks a wide range of plants including brassicas, lettuce and potatoes.

Geographic Distribution

Root-knot nematodes that infest *Alliums* occur throughout the world.

5.2 CONTROL STRATEGIES

Crop Monitoring:

While monitoring crops for disease and pests, check the roots of plants showing ill thrift. Any plants with root galls should be sent for expert examination.

Non-pesticide strategies:

Preventing spread

The nematodes can only move themselves a few centimetres. Most dispersal is from movement of soil and infected plant material. They may be spread by soil on machinery, and washed by rain and flood water, and wind.

Crop rotation and soil treatment

Crop rotation to non-host crops or a long fallow period effectively reduces nematode populations.

Pesticide control:

No pesticide has a label claim for control of nematodes of Allium crops.

5.3

Needle Nematode

Longidorus elongatus (de Man, 1876) Micoletzky, 1922.
(Nematoda: Longidoridae)

Photo: Jonathan D. Eisenback, Virginia Polytechnic Institute and State University, Image number: 5442340, Bugwood.org

Description

The female nematode is relatively large, 6 mm long.

Biology and Damage

All life stages can be found in the soil at any one time.
The nematode reproduces optimally in soil with a high (80% +) sand content, temperatures about 20°C and moderate moisture levels. It has not been a common problem on *Alliums* in New Zealand.

Field symptoms usually consist of severe stunting, a tendency to wilt prematurely, leaf chlorosis and sometimes death. There is usually a well defined boundary between diseased areas and healthy plants. Root injury symptoms vary with the age of plants, but generally consist of greatly reduced root systems with short stubby roots exhibiting dark shrunken lesions along the root and the tips.

Hosts

The nematode has a very wide host range, including vegetables, fruit and arable crops and grass.

Geographic Distribution

Needle nematode is widespread in Europe and present in North America and some parts of Asia. In New Zealand it has mostly been found in the Wellington and Nelson areas.

5.3 CONTROL STRATEGIES

Crop Monitoring:

While monitoring crops for disease and pests, check the roots of plants showing ill thrift. Any plants with poor root systems should be sent for expert examination.

Non-pesticide strategies:

Preventing spread

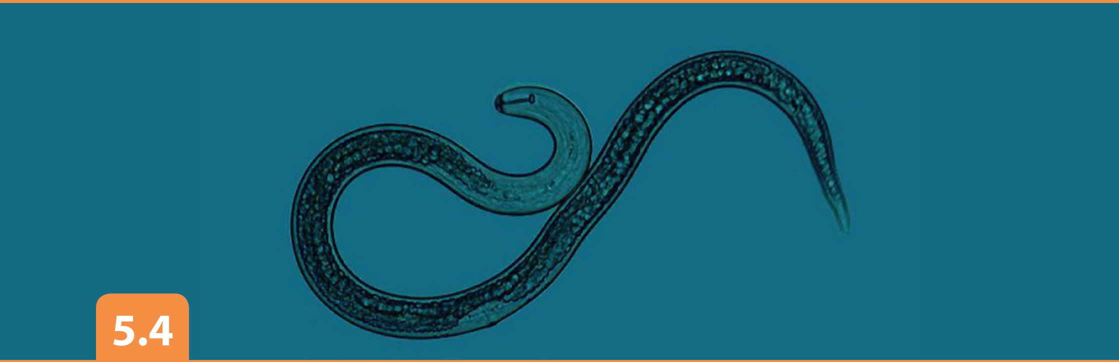
The nematodes can only move themselves a few centimetres. Most dispersal is from movement of soil and infected plant material. They may be spread by soil on machinery, and washed by rain and flood water, and wind.

Soil treatment

The nematode is sensitive to sudden changes in soil conditions. Populations may be reduced by keeping fields weed-free and fallow for three or more months.

Pesticide control:

No pesticide has a label claim for control of nematodes of *Allium* crops.



5.4

Lesion Nematode

Pratylenchus penetrans (Cobb, 1917) Filipjev & Schuurmans Stekhoven, 1941 (Nematoda: Pratylenchidae)

Photo: Jonathan D. Eisenback, Virginia Polytechnic Institute and State University, Image number: 5440647, Bugwood.org

Description

Adult males and females are very similar, thread-like and less than 1mm long.

Biology and Damage

The nematode is an internal parasite of plants. All stages may be found in host plants or in the surrounding soil. The nematode enters developing roots or other soil-born structures through the epidermis and moves cell by cell through the cortex. When the plant senesces at the end of the growing season, many nematodes remain in the dehydrating tissue, where they remain protected from extreme desiccation until next growing season.

Nematode breeding is favoured by high temperatures (20-30°C), coarse sandy soils and moderate soil moisture. It may also be present in organic soils.

Field symptoms consist of plant stunting and root systems without fine roots and the development of lesions on roots. Lesions may be round or irregularly elongate and are initially small and pale coloured, but turning darker with time.

Hosts

The nematode has a very wide host range, including vegetables, fruit and arable crops and grass.

Geographic Distribution

Worldwide.

5.4 CONTROL STRATEGIES

Crop Monitoring:

While monitoring crops for disease and pests, check the roots of plants showing ill thrift. Any plants with poor root systems should be sent for expert examination.

Non-pesticide strategies:

Preventing spread

The nematodes can only move themselves a few centimetres. Most dispersal is from movement of soil and infected plant material. They may be spread by soil on machinery, and washed by rain and flood water, and wind.

Soil treatment

Crop rotations and non-chemical soil treatments are not known to be effective.

Pesticide control:

No pesticide has a label claim for control of nematodes of *Allium* crops.

5.5

Stubby root nematode

Paratrichodorus species (Nematoda: Trichodoridae)

P. allius and P. minor.

Photo: Howard F. Schwartz, Colorado State University,
Image number: 5362283, Bugwood.org

Description

Stubby-root nematodes are very small and can be seen only with the aid of a microscope. They are unique among plant-parasitic nematodes because they have an onchiostyle, a curved, solid stylet or spear that is used in feeding. All other plant-parasitic nematodes have straight, hollow stylets. Males are rare as they are not needed for reproduction.

Biology and Damage

The nematodes feed externally on roots, usually just behind the root tip leading to short stunted roots, and an overall reduction in root development. Parasitized roots may have short knob-like branches, or very short laterals, each with a prolific growth of branch rootlets.

The nematode prefers well-drained sandy or sandy clay loam soils. They are unable to survive in dry soils. They may go down below the root zone in soil. The nematodes of this genus may be present on host without the plant showing symptoms and are vectors of Tobacco rattle virus.

Hosts

The nematodes have a very wide host range, including vegetable and cereal crops and many weeds. Overseas, *P. allius*, can damage onions in storage.

Geographic Distribution

P. minor is worldwide. *P. allius* is known from USA, Kenya, Hong Kong, Italy (possibly), Israel.

5.5 CONTROL STRATEGIES

Crop Monitoring:

While monitoring crops for disease and pests, check the roots of plants showing ill thrift. Any plants with stubby root systems should be sent for expert examination.

Non-pesticide strategies:

Preventing spread

The nematodes can only move themselves a few centimetres. Most dispersal is from movement of soil and infected plant material. They may be spread by soil on machinery, and washed by rain and flood water, and wind.

Fallow

Six or more weeks of fallow between crops helps prevent an increase in the population of *P. minor.*

Pesticide control:

No pesticide has a label claim for control of nematodes of *Allium* crops.