Pest and Disease management

vegetablesWA

Perth Region NRM

CARING FOR OUR COUNTRY

Department of Agriculture and Food

Contents

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Pest and disease management

1. Introduction

Yield and quality are central to sustainable vegetable production. If not properly managed, pests and diseases can dramatically reduce crop yield, quality and subsequent returns. We invest a lot of time, money and natural resources into growing vegetables. Good pest and disease management can protect this investment from avoidable losses.

Traditionally, pests and diseases were managed using a calendar-based chemical spray program. These were often crop and locality specific, developed through experience gained over a number of seasons.

Today, pests and diseases are managed using a more integrated approach. You may be familiar with terms such as integrated pest management (IPM) and integrated disease management (IDM). These approaches bring together the best mix of chemical and biological controls and cultural practices, to manage pests and diseases. They don't discard traditional chemical treatments and local knowledge, but integrate them into a sustainable system.

In this chapter we will:

- Provide direction to specific pest and disease management resources
- Identify some of the key vegetable pests and diseases on the Swan Coastal Plain
- Outline a range of integrated management strategies

This will help you develop a pest and disease management strategy using the Plan-Do-Check-Review cycle of continuous improvement.

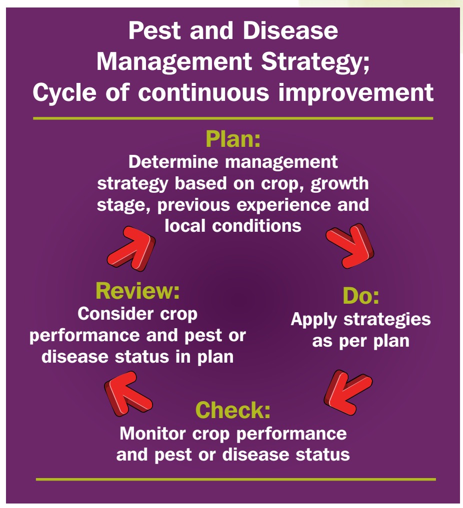


Figure 1. Cycle of continuous improvement

2. Resources to manage pests and diseases

Vegetable crops grown on the Swan Coastal Plain are affected by a range of pests and diseases. Some crops are more susceptible to damage from different pests than others. Different pest thresholds have been developed for different crops to reflect this variation.

There is a range of useful information to help growers make informed decisions about pest and disease management. A recent source is the IPM section on the AUSVEG website. National levy payers can access the IPM website by logging on to www.ausveg.com.au. Below is a list of specific vegetable resources from that site, many of which have been distributed to Western Australian growers through vegetablesWA. For more information contact vegetablesWA on 9481 0834.

BRASSICAS

Brassica grower's handbook (QDPI, 2004)
Brassica problem solver and beneficial identifier (QDPI, 2004)
Pests and beneficials in brassica crops (QDPI, 1997)
A guide to common pest and beneficial insects in brassica crops (DPI VIC, 1997)

BUNCHLINES

A guide to common diseases and disorders of bunching vegetables in Australia (Primary Industries Research VIC, 2003)

EGGPLANT

Growing eggplants in Queensland (QDPI, 1999)

LETTUCE

Integrated pest management in lettuce: information guide (DPI NSW, 2002)

Pests, beneficials, diseases and disorders in lettuce: field identification guide (NSW DPI, 2002)

Agrilink lettuce information kit (QDPI, 1997)

Integrated pest management for cole crops and lettuce (University of California IPM, 2008)

ONION

Agrilink onion information kit (QDPI, 1997)

Cream gold onion disorders and their control in Tasmania (DPI TAS, 1998)

POTATOES

Agrilink potato information kit (QDPI, 1998)

A field guide to insects and diseases of Australian potato crops (University of Melbourne, 2002)

Integrated pest management of potatoes in the western United States (University of California IPM, 1986)

STRAWBERRIES

Integrated Pest Management for Strawberries (University of California, 2008)

Which thrips is that? (NSW DPI, 2005)

SWEET CORN

Sweet corn grower's handbook (QDPI, 2005)

Sweet corn problem solver and beneficial identifier (QDPI, 2004)

Insect pest management in sweet corn CD (QDPI, 2001)

Sweet corn insect pests and their natural enemies (QDPI, 2000)

SWEET POTATOES

Agrilink sweet potato information kit (QDPI, 2000)

TOMATOES

Integrated pest management for tomatoes (University of California IPM, 1998)

Other key resources:

- Australasian Biological Control website www.goodbugs.org.au/Chemicals.htm provides a useful list of pesticides and their effect on common beneficial insects, as well as what beneficials can be bought commercially
- CSIRO entomology website www.ento.csiro.au/education/index.html provides an excellent glossary, reproduced in Appendix 23: Pest Management - Glossary of Terms (CSIRO, 2008)
- DAFWA Bulletin 4705, Common seasonal pests: your guide to prevent the spread of animal and plant pests, diseases and weeds (DAFWA, 2007)
- DAFWA Bulletin 4582, Pests of vegetable brassica crops in Western Australia (DAFWA, 2006)
- DAFWA Farmnote 147, Diseases of vegetable brassicas (DAFWA, 2006)
- DAFWA Farmnote 28/2003, Virus diseases of vegetable brassica crops (DAFWA 2006)
- DAFWA Farmnote 166, Virus diseases of cucurbit crops (DAFWA, 2006)
- DAFWA Gardennote 34, Tomato pests in the home garden and their control (DAFWA, 2007)
- NSW DPI Primefact 154, Lettuce IPM (NSW DPI, 2006)
- Victoria DPI Agriculture Note, Growing Lettuce (VIC DPI, 2005)
- NSW DPI, Soil Biology Basics: Nematodes (NSW DPI, 2005)
- Queensland Department of Primary Industries website www2.dpi.qld.gov.au/horticulture/18247.html provides links to a range of information including crop and pest disease information

3. Common vegetable pests on the Swan Coastal Plain

While some conditions on the Swan Coastal Plain are unique, the management of vegetable pests generally employs the same principles used in other vegetable growing regions in Australia. This allows us to draw on experience developed in other regions to implement local management strategies.

3.1 Thrips

Thrips feed on leaves, flowers and fruit and some carry plant viruses. They are slender, tiny (1 to 2 mm long) and only just visible to the naked eye. You may be able to see thrips if you shake flowers or leaves onto white paper, or if they are caught on sticky traps (DAFWA 2007)**.**

Thrips pierce plant cells with their mouthparts and feed on plant juices. The collapse of plant cells can result in the formation of deformed flowers, leaves, fruit, stems and shoots. Thrips can attack ornamentals, vegetables, strawberries and fruit tree crops. Some species, such as western flower thrips (WFT), are also vectors for plant viruses such as tomato spotted wilt virus (TSWV). TSWV can reduce the yield of lettuce, tomato, capsicum and chilli.

Thrips can be hard to find as they hide in flowers, between touching fruit, or deep in the leaves of vegetables such as lettuce and broccoli. Thrips are present year–round, but are more active during spring and autumn. Weed hosts in and around the crop can also harbour thrips and TSWV. Weed hosts include amaranth, capeweed, pigweed, mallows, blue heliotrope, fat hen, nightshades, Scotch thistle and sow thistle.

Thrips that affect vegetable production on the Swan Coastal Plain include:

- Western flower thrips (WFT, Frankliniella occidentalis) cause feeding damage and are a vector for TSWV
- Tomato thrips *(Frankliniella schultzei)*, a vector for TSWV
- Onion thrips *(Thrips tabaci)*, a vector for TSWV
- Plague thrips *(Thrips imaginis)*, a native species that is not a vector for TSWV

WFT is the most damaging thrip and the most efficient vector of TSWV. TSWV is mainly of concern in tomatoes, capsicum and lettuce where it can cause up to 100% crop loss. DAFWA Farmnote 69/2004 Management of thrips and tomato spotted wilt virus (Broughton et al, 2004) is an excellent local reference. Also see Thrips and tospovirus: a management guide, produced by QDPI & F (Persley et al, 2008).

Control

There are currently few biological control options for thrips in Australia. For greenhouse growers, predatory mites such as *Neoseiulus cucumeris* or *Typhlodromips montdorensis* that feed on thrip larvae and Hypoaspis mites that feed on the pupae, are commercially available (see www.beneficialbugs.com.au or www.biologicalservices.com.au).

Some varieties of capsicums and tomatoes are resistant to TSWV, although strains that break the resistance can develop in areas of high TSWV pressure. Chemical control should be managed carefully as thrips, particularly WFT, can quickly develop resistance to chemicals. For WFT, the THREE SPRAY strategy must be followed, three consecutive sprays three to seven days apart with an insecticide from one chemical class, followed by three consecutive sprays with another insecticide from a different chemical class (see www.dpi.nsw.gov.au/agriculture/horticulture/pests-diseases-hort/multiple/thrips/wft-resistance). Ensure that you use insecticides that are registered for your crop and strictly observe the label or permit instructions.

3.2 Moths and butterflies

Moths and butterflies are grouped together in the order Lepidoptera, which means 'scaly wings'. The main difference between moths and butterflies is that moths do not fly during the day unless disturbed. Butterflies also have clubbed antennae and the habit of holding their wings vertically when at rest, whereas moths sit with their wings flat (CSIRO, 2008)**.**

Moths and butterflies undergo a complete life cycle that includes four stages: egg, caterpillar (larvae), pupae and adult. It is the caterpillar stage that is usually the most damaging.



■ **Diamondback moth** *(Plutella xylostella)* is a major caterpillar pest of brassica and crucifer (e.g. cabbage) crops in Australia. They cause damage by feeding on leaves, buds, flowers and seed-pods. The level of damage varies greatly depending on the plant growth stage, the numbers, size and density of grubs. Adult moths are 8 to 10 mm long and fold their wings over their body, forming a tent-like shape. Wings are light brown with three pale diamond shapes. Grubs hatch from eggs and are pale yellowish green. They wriggle violently and drop from the plant when disturbed. Mature grubs (10 to 12 mm long) pupate in white mesh cocoons attached to leaves or stems. Large flights of egg-laying moths can occur in spring and each female can lay up to 200 eggs. Numbers increase steadily from October to December, then diminish in the heat of summer and climb again when the weather cools in autumn (DAFWA, 2007).



■ **Heliothis** *(Helicoverpa punctigera/armigera)* damage a wide range of crops and are a particularly important pest of sweet corn, lettuce and brassicas. In sweet corn, caterpillars chew leaves and tunnel down the silk channel of the cob to chew the kernels. Damage increases as the caterpillar grows in size. The presence of caterpillars and associated droppings can render the cob unmarketable. Damage may be removed by topping and tailing the cobs and marketing in pre-packs. Heliothis are most active from October to April.

■ **Cutworm caterpillars** *(several species)* eat into a plant's stem, sometimes making the plant fall over. They have a very wide host range and can damage almost all vegetable crops; young seedlings are especially vulnerable. The caterpillars are brown or black, herring-boned, hairless, and about 40 mm long. They can be found in the soil surrounding the plant and curl up nose to tail when disturbed. The caterpillar pupates in the soil and emerges as a medium-sized, grey-bodied moth with dark wings. Cutworm may be active throughout most of the year but it's the autumn, and more especially the spring generations, that do the most damage.

■ **Cabbage white butterfly** *(Pieris rapae)* also chews holes in leaves. The mature caterpillar has a pale yellow line on its back and a line of yellow spots on each side. It normally sits on the upper surfaces of leaves in broad daylight. Plants attacked include cabbage, broccoli, Brussels sprouts, Chinese cabbage, celery, beetroot, rocket and watercress. The adult female moth is distinctive, with white wings and a black spot on each forewing.

■ **Cluster caterpillar** *(Spodoptera littura)* chews holes in leaves. Older caterpillars also attack flowers and pods. Young caterpillars are smooth-skinned with a pattern of red, yellow, and green lines. When disturbed, the caterpillar curls into a tight spiral with the head protected in the centre. They attack a range of crops including lettuce, leek and tomatoes.

Other moths attack vegetable crops including armyworm (various species), and potato moth *(Phthorimaea operculella)*.

Control

There is a range of biological control options for caterpillars in Australia. Naturally occurring beneficials include insect predators such as assassin bugs, tachinid flies, paper wasps, lacewings and ladybirds. Parasites include Trichogramma wasps which parasitise moth eggs and other wasps such as Apanteles and Cotesia spp. which parasitise the caterpillar. Trichogramma is available commercially for release against Heliothis eggs in sweet corn.

Bacillus thuringiensis (Bt) and nuclear polyhedrosis virus (NPV) are highly effective and selective biological controls. Bt is a bacterial stomach poison for all caterpillars, that is sprayed onto foliage like other insecticides. NPV is a virus that is registered in Australia for use on Heliothis. It attacks the cell structure of the caterpillar, forming 'crystals' that kill the caterpillar after a few days. Both Bt and NPV are applied to foliage where they are eaten by actively feeding caterpillars that die three to five days later. Bt and NPV are safe to use with beneficial insects, bees and mammals.

Chemical control options should be managed carefully to reduce the development of resistance and harm to beneficials. See the Australasian Biological Control website www.goodbugs.org.au/Chemicals.htm for a useful list of pesticides and their effects on common beneficial insects. Resistance to synthetic pyrethroid insecticides has been detected in populations of diamondback moth in all Australian states. Helicoverpa armigera has developed resistance to organochlorines, synthetic pyrethroids and carbamates. Ensure that you use insecticides that are registered for your crop and strictly observe the label or permit directions. Crops should be inspected two to four days after spraying to ensure the spray has killed enough caterpillars to prevent economic loss.

3.3 Aphids

Aphids are small, soft-bodied insects that grow up to 1 to 4 mm long. They are sap suckers and form colonies on the new shoots of a wide range of crops. Species range from yellow to green to black. Colonies include mostly wingless and some winged individuals (DAFWA, 2007)**.**

Most vegetable crops are attacked by aphids. Aphids can stunt and distort the growth of plants and cause wilting and bud drop, resulting in poor flowering and fruit set. Aphids can also spread plant viruses. Aphid numbers are generally highest in spring when conditions are favourable.

Aphids that affect vegetable production on the Swan Coastal Plain include:

- Currant lettuce aphid (CLA, *Nasonovia ribis-nigri)*
- Green peach aphid (GPA, *Myzus persicae)*
- Potato aphid *(Macrosiphum euphorbiae)*
- Corn aphid *(Rhopalosiphum maidis)*
- Cabbage aphid *(Brevicoryne brassicae)*

Aphids have a wide host range and may be found on all vegetable crops with the exception of CLA. CLA is only found on lettuce, chicory, endive and radicchio and is primarily a contamination pest, colonising lettuce hearts and rosettes, making them unsaleable. NSW DPI Primefact 155 Currant lettuce aphid (McDougall and Creek, 2007) is an excellent Australian reference. This outlines a range of management options to reduce the economic impact of CLA.

Control

There is a range of biological control options for aphids in Australia. Beneficials include naturally occurring insect predators such as lacewings, ladybirds and hoverfly larvae. Parasitic wasps such as Aphidius species occur naturally and are also available commercially. The adult female stings the aphid and lays its eggs directly inside the body, causing it to swell and turn bronze. Chemical control options should be managed carefully to reduce the development of resistance and harm to beneficials (see Chemicals and Natural Enemies for a list of insecticides and their effect on beneficials www.goodbugs.org.au/Chemicals.htm). Ensure that you use insecticides that are registered for your crop and strictly observe the label or permit instructions.

3.4 Bugs

Hemipterans are the only insects correctly identified as bugs and include aphids. Members of the order Hemiptera are characterised by sucking mouthparts that originate from the tips of their heads. They use their needle-like mouthparts to pierce the plant, sucking up plant juices. Their life cycle stages include the egg, adult-like nymphs, and winged adults.

■ Rutherglen bug *(Nysius vinitor)*

This native species is considered to be a contaminant pest. Adults are found in a range of crops including lettuce, but do not usually reproduce on the crop. Rutherglen bugs are brown, approximately 2 mm long and move onto crops in large numbers from surrounding vegetation in summer.

Eggs are deposited on the soil, grasses and the flower heads of weeds. These eggs hatch into nymphs that grow through five moults until they become adults. The length of the life cycle from egg to adult is about four weeks. Winter is passed as an adult and breeding commences in early spring. Large numbers are normally present in November and December.

Rutherglen bugs are sap suckers and damage to susceptible plants is similar to that caused by aphids. Crops such as lettuce are not usually damaged by these bugs, but they can cause problems by contamination at harvest. Their presence may render the lettuce unacceptable.

■ Green vegetable bug *(Nezara viridula)*

These are bright green in colour and adults are 15 mm long. Nymphs are smaller, black and white or black and red. Green vegetable bug attacks beans, tomatoes, potatoes, sweet corn and ornamentals and is most active in hot weather. Bugs feed on flower buds and seed pods resulting in premature flower drop, seed damage and distorted development. In tomatoes, damage on green fruit appears as dark pinpricks, surrounded by a light discoloured area that turns yellow or remains light green on ripe fruit. Fissures below the surface turn corky. Green vegetable bugs are rarely a problem for vegetable growers.

3.5 Beetles

Beetles are a diverse group of insects characterised by adults with hardened wings and grub-like larvae that are sometimes mistaken for caterpillars. Some beetle larvae live underground (e.g. wireworm, African black beetle). Their life cycle includes the egg, larval, pupal and adult stages.

■ **African black beetle** *(Heteronychus arator)*. Adults are glossy black and about 15 mm long. Eggs are laid in spring and early summer and hatch into larvae known as 'white grubs' or 'curl grubs'. When fully developed these grubs are about 25 mm long. The beetles attack many plants, usually at ground level or just beneath the soil surface. They damage seedlings and young plants more than mature plants. The beetles attack a range of vegetable crops, but can be a particular problem in potatoes.

■ **Vegetable beetle** *(Gonocephalum elderi)* or false wireworm. Adult vegetable beetles are 8 mm long, oval and flattened. They are usually a dull grey, but sometimes appear brown or almost black. They often have soil or sand stuck to their backs. The larvae are brown and worm-like, but have a hard and shiny skin, with three pairs of legs at the front.

■ **Vegetable weevil** *(Listroderes difficilis)*. The adult is about 10 mm long and a dull greyish-brown; the larva is 15 mm long when fully grown and pale green with a slug-like shape. Both the larvae and adult attack vegetables, particularly potatoes, tomatoes and root crops such as carrots. They often infest weeds such as capeweed and marshmallow. The insects are usually nocturnal feeders.

Beetle damage to vegetable crops is regarded as rare. There are no biological control options currently available for their control. If chemicals are required, ensure that you use insecticides that are registered for your crop and strictly observe the label or permit recommendations. You may need more than one treatment.

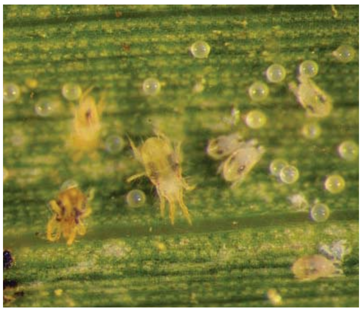
3.6 Mites

Mites are very small, often less than 1 mm. They are not insects, but are related to spiders. Like spiders and ticks, mites have eight legs, although the nymphs only have six (DAFWA, 2007)**.**

Mites that affect vegetable production on the Swan Coastal Plain include:

- Two-spotted mite (TSM, *Tetranychus urticae)*
- Tomato russet mite *(Aculops lycopersici)*

Mites damage leaves and fruit by sucking out the cell contents. This can cause stippling (fine speckling) and/or distortion of leaves. Heavily stippled leaves may wither at the edges, turn brown and fall off. In addition, tomato russet mite causes the stem to discolour, resulting in a rusty-brown or smoky colour. The stem may also develop cracks. Injured fruit turns bronze and can crack longitudinally. If not controlled, tomato russet mite can kill plants.



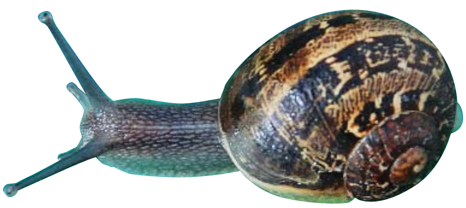
Mites are present all year round, but are likely to be more active during warmer, dry months. A small number of mites is not a cause for concern, but high populations can be damaging. Two-spotted mite feeds on a wide range of plants and is an important pest of glasshouse crops, including cucumbers, tomatoes, capsicums, and beans. It can also be a serious pest of outdoor crops including beans, strawberries, sweet corn and peas. TSM occurs on many common weed species such as clovers, plantains, black nightshade, mallows, Amaranthus, and Convolvius, and on a variety of shelter plants including willows, poplars, walnut and elm. TSM secretes very fine, silk-like webbing which is usually obvious over the dying leaves. As the leaves dry out and fall, the mites move away to feed on growing shoots.

Control

Biological controls for TSM include the predatory mites *Typhlodromus occidentalis* and *Phytoseiulus persimilis* which are commercially available (see the Australasian Biological Control website for a list of available mite pests and their predators, www.goodbugs.org.au/natenemieslist.htm). Spraying with insecticides may cause an outbreak of mites, as natural enemies that keep mites under control are killed. To treat mites, use miticides or horticultural oils that are registered for your crop, and strictly observe the label or permit instructions.

3.7 Snails and slugs

These are closely related and are classified as molluscs, moving by gliding along on a muscular 'foot'. This muscle constantly secretes mucus, which later dries to form the silvery 'slime trail' that signals the presence of either pest. Slugs and snails are hermaphrodites, so all have the potential to lay eggs. Although Australia has native snails and slugs, all the pest species are introduced, mainly from the Mediterranean region (Davis et al, 2006 b)**.**



- **Common garden snail** *(Helix aspersa)* is brown with alternating dark and light brown bands. The fully-grown shell is 25 mm or more in diameter and the body is dark grey.

■ **White snail** *(Theba pisana)* is white, often with fine brown concentric lines of varying intensity, and may be from 12 to 20 mm in diameter. The body is white. In late spring, white snails climb up plants, posts, fences and other vertical surfaces to get away from the heat.

■ **Green snail** *(Helix aperta)* appeared some years ago in areas near Perth. The shell is about 15 to 25 mm in diameter, and a uniform greenish-brown to brown. The body is white. In spring, green snails burrow underground 25 to 150 mm and spend the dry summer months in an inactive state.

■ **Slugs** lack the external spiral shell and range in size from less than 10 mm long to over 50 mm. Slugs are not usually visible during the day.

Snails and slugs eat both living plants and dead or decaying vegetation, chewing irregular holes with smooth edges in leaves and flowers. Some plants that can be seriously damaged include basil, beans, cabbage, lettuce and strawberries. The seedling stage is the most vulnerable. Look for the slime trail to confirm that damage was caused by a snail or slug, and not another pest. Ideal conditions for snails and slugs, and hence when they cause the greatest damage, are damp, mild (15 to 25°C) and calm periods.

Control

Effective control of snails and slugs involves a combination of cultural and chemical methods. Snails prefer moisture and shelter. Abundant vegetation cover provides ideal moisture levels and shelter where snails and slugs thrive. This is why they can be a problem on the edge of a crop with a weedy fenceline. Good hygiene, weed control and removal of refuges can reduce snail and slug numbers over time and will improve the value of baiting.

Timing is the most critical aspect of control when using baits. Trying to control snails and slugs when they are a problem, usually in spring, is the least effective method. The best time to bait is in autumn, late March to April, before the break of the season, or as soon after as possible. This kills adult snails and slugs before they get a chance to lay their eggs. Snails and slugs are also hungry after spending the summer period inactive and there is little alternative feed to compete with the baits. Rain is also infrequent, so the field life of baits is extended (Davis et al, 2006 a).

Baits contain either metaldehyde or methiocarb. Some slug species may be naturally tolerant to methiocarb, so metaldehyde baits should be used, especially in crop situations. Place baits near sprinklers, close to walls and other areas where snails and slugs congregate. Bait in the same areas because snails and slugs tend to return to food source sites. Copper-containing products such as Four-S act as a repellent rather than a bait and can be used to protect plants.

WARNING: Baits containing metaldehyde and methiocarb are toxic to dogs and other animals. Use them with discretion. For further information on snail and slug control see DAFWA Gardennote 12 *Control of pest snails and slugs* (Davis et al, 2006 a).

4. Beneficials

The tables below show beneficial organisms that are available for specific pests. Greenhouse growers have a wider range of options because beneficials are not subjected to high temperature and humidity extremes as they are in the field. For a list of commercial suppliers of bio-control agents and the products they sell, visit the Australasian Biological Control website www.goodbugs.org.au/suppliers.htm.

Field

Pest	Biocontrol agent
Aphids	Green lacewings, *Mallada signata*
	Brown lacewings, *Micromus tasmaniae**
	Parasitoid, *Aphidius colemani*
	Lady beetle, *Hippodamia variegata**
Heliothis	*Trichogramma pretiosum*
Two-spotted mite	*Phytoseiulus persimilis*
Whitefly (greenhouse)	Green lacewings, *Mallada signata*
	Whitefly parasitoids, *Encarsia formosa*

Greenhouse

Pest	Biocontrol agent
Aphids	Green lacewings, *Mallada signata*
	Brown lacewings, *Micromus tasmaniae**
	Parasitoid, *Aphidius colemani*
Heliothis	*Trichogramma pretiosum*
Fungus gnats	Hypoaspis predatory mites
	Parasitic nematodes
Two-spotted mites	*Phytoseiulus persimilis*
Thrips	Hypoaspis predatory mites
	Montdorensis predatory mites
	Cucumeris predatory mites
Greenhouse whitefly	Green lacewings, *Mallada signata*
	Whitefly parasitoids, *Encarsia formosa*

* Insects with this symbol are under development and not yet commercially available

5. Vegetable diseases on the Swan Coastal Plain

Vegetable diseases affect yield and quality and are of concern throughout the supply chain, from growers to consumers.

The number of crops and diseases is vast. In this publication we highlight the importance of some key diseases and guide you towards crop- and disease-specific resources.

Consult crop specific references in Section 2, Resources to manage pests and diseases for crop-specific disease information.

5.1 Virus diseases

There are many viruses that affect vegetable crops. Symptoms vary depending on the plant host, age, variety, weather conditions and nutritional status. Viruses often have a number of alternative hosts including vegetables, ornamentals, weeds and native plants and are usually spread from plant to plant by insect (e.g. aphids, thrips) or fungal vectors.

- **Tomato spotted wilt virus** (TSWV) is spread by thrips (see Section 3.1) and frequently infects capsicum, celery, lettuce, potato and tomato where it can cause total crop loss. Symptoms include ring spots, line patterns and mottling of leaves and fruit. In lettuce, plant death also occurs. Many weeds including nightshade and sowthistle and ornamentals such as asters are hosts of this virus. Brassicas and cucurbits are not affected. See DAFWA Farmnote 69/2004 *Management of thrips and tomato spotted wilt virus* (Broughton et al, 2004).

■ **Lettuce big-vein disease** causes lettuce to develop enlarged veins; infected plants are often stunted with small hearts. The virus is spread by a fungus that lives in the soil and infects lettuce roots. Fungal spores move in water and can survive in the soil for long periods.

■ **Carrot virus Y** causes severe root symptoms in carrots including shortened roots, knobbliness and severe distortion, particularly if plants are infected at an early growth stage. The virus is spread by aphids (Latham et al, 2003).

■ **Celery mosaic virus** causes plants to be stunted with severe vein clearing on leaves, leaf up-curling and chlorosis. Plants are often unmarketable when infected early. The virus is spread by aphids and also infects coriander, parsley and parsnip (Latham and Jones, 2001).

■ **Cucumber mosaic virus** is spread by aphids and has a very large host range including capsicum, celery and tomato, as well as many weeds. Cucumber mosaic virus causes a range of symptoms including stunting and leaf mottling and distortion. Fruit are often small and distorted.

A number of virus diseases can infect cucurbit crops, including cucumber mosaic virus, papaya ring spot virus, squash mosaic virus, watermelon mosaic virus and zucchini yellow mosaic virus. These can cause significant yield loss and fruit quality defects. Zucchini yellow mosaic virus causes severe leaf mottle and blistering to pumpkin and zucchini plants, and fruit are often severely distorted with lumps (Coutts, 2006).

Control

To control virus diseases you must control the vectors and reduce potential sources of infection. This means that pest management, on-farm hygiene and biosecurity are critical.

Generic control measures for viral diseases include:

- Promptly destroying or removing old crops to help eliminate virus reservoirs
- Avoiding sequential plantings side by side of susceptible crops
- Using healthy planting material
- Sowing virus-resistant varieties when available
- Planting non-host barriers between plantings to reduce the movement of vectors
- Removing and destroying plants with virus symptoms
- Removing all weeds to minimise virus and vector sources
- Rotational use of different insecticides effective against vectors
- Breaking the disease cycle by not growing susceptible crops for three months

5.2 Fungal diseases

Collectively, fungi and fungal-like organisms cause more plant diseases than any other group of plant pest with over 8,000 species shown to cause disease (Ellis et al, 2008).

- **Damping-off** is a term often given to the sudden death of seedlings. This is usually associated with the fungi Pythium, Rhizoctonia, Phytopthora, Fusarium or Aphanomyces. Damping-off generally occurs under cold, wet conditions. While there is a range of fungicides registered to control damping-off, an integrated approach is required. The incidence is significantly reduced by planting under good conditions when practical, careful irrigation management, and the use of appropriate fungicides when required.

- **Downy mildew** is a collective term for disease that affects a wide variety of plants, with different species infecting different plant groups (McDougall et al, 2002). For example, downy mildew is caused by *Bremia lactucae* in lettuce, *Peronospora destructor* in spring onions and *Peronospora parasitica* in brassicas. In some instances, control can include using resistant varieties, but ensure that the right control measures are implemented for the right crop and conditions.

- **Alternaria** species also affect a range of crops. The most notable are leaf spot/target spot in brassicas and leaf blight in carrots.

■ **Clubroot** is caused by the pathogen *Plasmodiophora brassicae* and infects plants of the brassica family. Affected plants produce large distorted (galled) roots and wilting is often the first symptom noticed. Severely infected plants will be stunted, produce poor quality crops and may die before harvest. Ideal conditions for clubroot infection are: acid soils, high soil moisture, warm temperatures (20 to 25°C) and the presence of a susceptible brassica host (Lancaster, 2000 a).

■ **White blister** or white rust is a fungal disease caused by Albugo candida which affects many brassica crops and weeds. Currently 17 different races of the disease have been identified throughout the world. In Western Australia, race 9 causes symptoms on cauliflower and broccoli. Symptoms are white 'blisters', which in the early stages of infection are seen on the underside of leaves. As the symptoms progress, circular areas of leaf discolouration (light green to yellow) appear on the upper leaf surface, corresponding to white blisters on the underside. The blisters contain white powdery spores which are spread by wind. Systemic infections of white blister cause abnormal growth, distortion of plants or the formation of galls (Lancaster, 2003 b).

■ **Cavity spot** disease of carrots is caused by the soil-borne fungus Pythium sulcatum in WA. Cavity spots are small elliptical lesions (usually less than 10 mm across) often surrounded by a yellow halo. Infection can take place anywhere along the carrot root and lesions start as pinhead-size spots. In most cases visible symptoms develop in the month before harvest maturity and develop rapidly if conditions are favourable (Davison and McKay, 2007).

Other common fungal diseases include Sclerotinia, septoria, grey mould and powdery mildew. It is important that fungal diseases are properly identified and that appropriate management is applied (see Section 6, Sampling for horticultural disease diagnosis).

5.3 Bacterial diseases

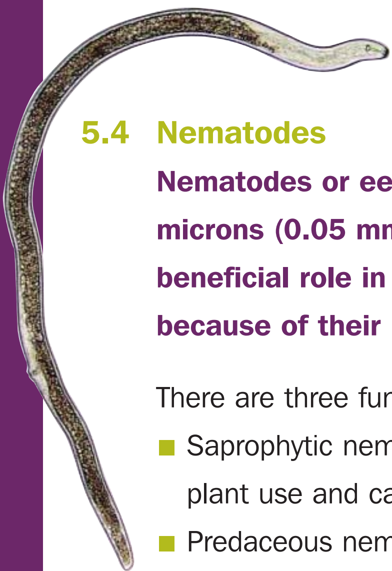
Bacterial diseases of vegetables often cause spotting of leaves, stems or fruits. Bacteria do not generally infect healthy plant tissue; they need a wound or an area of dead or dying tissue to start an infection.

■ **Black rot disease** (*Xanthomonas campestris*) is often seen as a light brown to yellow V-shaped lesion on the leaf, typically starting at the leaf margins. When the leaf veins are cut in half, the veins will be black. Black rot is caused by the bacteria entering the plant through natural leaf openings or from damage caused by insects, other pathogens or mechanical damage (Lancaster, 2006 a).

■ **Soft rot disease** (*Erwinia and Pseudomonas spp.*) is common to most plants and causes a soft mushy breakdown. The decay is often foul-smelling but there is no mould associated with the rot. Infection is through damaged areas often resulting from fertiliser burn or hail injury in the field, but can be associated with harvest damage (Lancaster, 2006 a).

■ **Bacterial leaf spot** (*Psuedomonas syringae*) affects a range of crops including beets, leeks and spring onions. The bacterium can be seed-borne and survive on plants and crop debris (Kita et al, 2003).

It is important that bacterial diseases are properly identified and that appropriate management is applied (see Section 6, Sampling for horticultural disease diagnosis).



5.4 Nematodes

Nematodes or eel worms are small, non-segmented worms. They are only 50 microns (0.05 mm) in diameter and about 1 mm long or less. Most species have a beneficial role in the soil, but we tend to know more about the pest species because of their impact on vegetable production (Jenkins, 2005)**.**

There are three functional groups of nematodes:

- Saprophytic nematodes break down organic matter in the soil, release nutrients for plant use and can improve soil structure, water-holding capacity and drainage
- Predaceous nematodes feed on soil microbes including other nematodes
- Parasitic nematodes are important to vegetable growers because they feed on roots and reduce productivity.

- **Root knot nematodes** *(Meloidogyne spp.)* can be the most damaging on the Swan Coastal Plain. These nematodes have a very wide host range, affecting more than 2,000 plant species worldwide. Root knot nematodes enter the roots as larvae, causing the plant roots to form galls or knots. These galls or knots block the transport of water and nutrients through the plant. Underground organs such as potato tubers and carrot taproots may also be damaged and become unmarketable. Nematode larvae mature in the roots where they mate. Female adults remain in the roots and lay eggs into an egg sac that exudes into the soil. The eggs hatch and the young larvae go on to infect more roots (Knoxfield, 2003; Hoffmann and Vanstone, 2006).

■ **Beet cyst nematode** *(Heterodera schachtii)* can cause considerable yield loss to cruciferous vegetable crops (cabbage, Chinese cabbage, cauliflower, Brussels sprouts, broccoli, turnip, radish and swede), as well as to beets (red and silver), rhubarb and spinach, by severely damaging the root systems, especially during the summer months (Vanstone, 2006).

■ **Potato cyst nematode** (PCN) is a quarantine concern to Western Australia, having the potential to cause significant damage through crop losses and the loss of export markets. PCN was identified in WA in 1986 and successfully eradicated; the nematode has not been detected in WA since eradication. The main crops affected by PCN are potato, eggplant and tomato (Eyres et al, 2005; Hoffman and Vanstone, 2006).

Control

Successful management of parasitic nematodes requires an integrated approach. Healthy plants are more tolerant to nematodes and a healthy soil promotes beneficial fungi, bacteria and non-parasitic nematodes. Crop rotation, improvements in soil organic matter, correct plant nutrition and correct irrigation are all part of an integrated approach to nematode management.

Only use those nematicides that are registered for your crop and strictly observe the label or permit directions.

6. Horticultural Diagnostic Service

The Department of Agriculture and Food provides a commercial horticultural disease diagnostic service through the AGWEST Plant Laboratories in South Perth. Following is an outline of guidelines to ensure you send the most appropriate plant or soil samples for accurate and timely disease diagnosis.

- **Take fresh samples**, keep them cool and out of direct sunlight
- **Label sample bags** clearly with a permanent marker
- **Submit affected** and **unaffected** plants packaged and labelled separately (e.g. inside, outside and boundary of affected areas)
- For plants up to 1 m high, submit at least three whole plants, complete with soil, or 20 seedlings
- For plants over 1 m high, separate into top and bottom components before submitting.
- **Send** samples as per specific instructions (Appendix 24)
- **Avoid** sending samples on a Thursday or Friday; it's better to refrigerate until despatch the following week
- **Label the parcel** 'URGENT PLANT SAMPLES - KEEP COOL'
- **Complete the Horticultural Plant Disease Diagnosis Submission Form.** Available on AGFAX 1902 990 506, Document No 20366. www.agric.wa.gov.au/agwest/plantlabs
- **Complete a separate form** for each **species**

There are also specific instructions for submitting:

- **WHOLE PLANT OR ROOT SAMPLES**
- **LEAF SAMPLES**
- **SOIL SAMPLES FOR DETECTION OF NEMATODES**
- **SOIL SAMPLES FOR DETECTION OF PHYTOPHTHORA**

The complete guidelines are included in Appendix 24: Sampling for horticultural disease diagnosis.

7. Chemical and resistance management

Pesticides are a major technological tool used successfully throughout the world. An adverse consequence of persistent application has been the emergence of resistant populations. Pesticide resistance is a global phenomenon that has occurred with fungicides, bactericides, insecticides, rodenticides, nematicides and herbicides (Powles and Holtum, 1991)**.**

Resistant populations occur when the same chemical, same family of pesticides or pesticides with a similar mechanism of activity are used repeatedly at the same location. When a few naturally resistant organisms remain after a treatment, they contribute to the development of a larger population of resistant organisms. Eventually the population that develops may contain mainly resistant organisms and will not be controlled with the recommended rates of the pesticide.

To help minimise the development of pest resistance, all fungicides, insecticides and herbicides sold in Australia are grouped according to their **mode of action**, indicated by a letter number code on the product label. The mode of action label allows the user to identify pesticides that work by similar means and which share a common resistance risk (CropLife Australia Limited, 2008).

The CropLife Australia website (www.croplifeaustralia.org.au) has mode of action tables for fungicides, insecticides and herbicides, and resistance management strategies based on these to prevent or delay resistance developing. The website also contains some regional or crop-based resistance management strategies.

The selection of pests for resistance to a pesticide may be slowed by limiting the exposure of a pest population to pesticides with a particular mode of action. This can be achieved by limiting the total number of applications of pesticides from any one mode of action group and by alternating pesticides from chemical groups with different modes of action.

Effective chemical resistance management requires:

- A good understanding of the pests' life cycle to target the best control methods
- Alternations or sequences of different modes of action
- Application of chemicals at recommended rates with calibrated equipment
- Good spray coverage to ensure the best possible chance of contact and subsequent control of the pest
- Incorporation of cultural techniques for controlling the pest to reduce selection pressure from the insecticides

Any resistance management strategies should incorporate all available methods of control for the pest concerned.

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