Australian Government

Australian Centre for International Agricultural Research

Tomato, capsicum, chilli and eggplant

A field guide for the identification of insect pests, beneficials, diseases and disorders in Australia and Cambodia

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Sandra McDougall, Andrew Watson, Ben Stodart, Tony Napier,
Gerard Kelly, David Troldahl and Len Tesoriero

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Department of Primary Industries

AVRDC
The World Vegetable Center

2013

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Foreword

Vegetable consumption in Cambodia is currently one of the lowest in Asia. The Cambodian Government has a long-term plan to increase both vegetable production and consumption to improve the nutritional and health status of its people. In line with this plan, an Australian Centre for International Agricultural Research (ACIAR) program in Cambodia supports applied research and development that underpins agricultural diversification, particularly into non-rice field and horticultural crops.

ACIAR has funded research into developing new vegetable varieties; improved production practices such as fertiliser recommendations, raised beds, mulching and irrigation; improved supply-chain handling, storage and packaging; and increased capacity to identify and manage vegetable diseases. Further work was funded to take these research outcomes to a wider audience in Cambodia and Australia. In Australia, most of the Khmer-speaking vegetable growers grow tomato, capsicum, chilli and eggplant crops. In both Australia and Cambodia there was an absence of a suitable grower-friendly field guide to help growers identify key pest insects, likely natural enemies of these pest insects ('beneficials'), crop diseases or nutritional disorders.

This field guide will assist farmers, advisers to farmers and extension officers to manage their tomato, capsicum, chilli and eggplant crops through better recognition of the causes of crop damage. Key steps in an integrated pest management system are knowing what pest organisms are present in a crop, and understanding the basic biology of those pests, how they are spread and what factors may limit or control the populations. This guide provides information on key pests and diseases that are likely to be found in Cambodia and Australia, as well as basic information on minimising pest incursions and damage.

Dr Nick Austin

Chief Executive Officer, ACIAR

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Life cycle drawings are by Alan Westcott, Briony Cowper, Krystyna Honeywood and Sandra McDougall.

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How to use this guide

This field guide is designed to assist growers, workers, students, extension officers and farm advisers to identify insect or mite pests, beneficial organisms ('beneficials'), diseases and disorders in tomatoes, capsicums, chillies and eggplants. It is intended to be a tool for integrated pest management. The front section of the guide has a general introduction to pest management, and some useful summary agronomy tables. The rest of the guide is devoted to insect and mite pests, beneficials, diseases or disorders that may be found in these crops in either Australia or Cambodia.

The organisms are grouped into colour-coded sections:

- insect and mite pests (red)
- beneficials (green)
- bacterial diseases (blue)
- fungal and fungal-like diseases (purple)
- viral diseases (yellow)
- other diseases (orange)
- disorders (plum).

Each page has a text summary of useful information for identification or management of each pest, beneficial, disease or disorder, and accompanying colour photographs. The guide can be used by going directly to a known organism or disorder that is listed in the extended contents (pages 6–12) or, if the cause of the problem is unknown, the tables that show signs of plant damage (pages 26–29) can be used to narrow the search according to where on the plant the damage occurs (seedling, plant, root, stem, leaf, flower or fruit).

Note that the life cycle diagrams included in the sections on insect and mite pests and beneficial organisms are indicative of their life cycle, with only one nymph or larval stage shown, and the drawings are not diagnostically correct. The life cycle time intervals are provided as a guide only; they have been sourced from either laboratory studies or other field guides, and are typically derived from trials conducted at constant temperatures between 23 °C and 28 °C. Times given in the centre of the life cycle drawing are estimates of the time between egg laying and adult emergence. Life cycle duration is strongly influenced by both temperature and food quality, and may be longer or shorter than indicated.

If there is doubt as to the cause of a problem, samples should be sent to a diagnostic laboratory. Diseases are particularly difficult to identify from signs of plant damage only.

In the sections on insect and mite pests, and the various diseases, a table at the bottom of each text page indicates the plant part affected by the pest or disease. The disease sections also include a table of up to 20 management practices that can be used to manage the disease; the practices are listed on the inside back cover of the guide.

How to use the navigation sidebar

Coloured tab indicates main section.

Coloured text describes broad grouping of organisms.

Fruit icons indicate host susceptibility, and country icons indicate presence of organism in country:

- filled icon = known presence
- outlined icon = unknown or rare
- no icon = not present.

These icons are intended as quick visual references—further detail is contained in the text.

Beneficials are not usually crop specific, so crop icons are not used on the beneficial pages. All the families and genera illustrated in the beneficial organism pages are highly likely to be found in both countries, and so country icons are not used in this section.

Fruit and country icons are not included in the disorder sections of the guide because tomato, capsicum, chilli and eggplant crops in both Australia and Cambodia are affected by all the nutrient deficiencies, and the environmental and chemical disorders described.

Integrated pest management

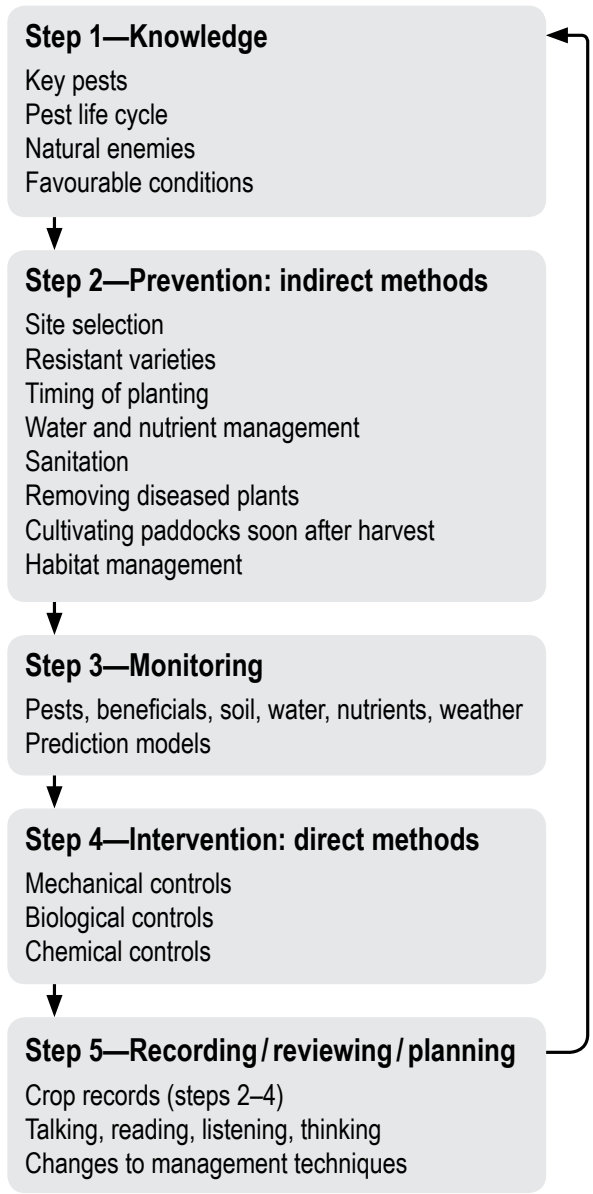
Pests include insects, mites, diseases, nematodes, weeds and vertebrate pests. Many different strategies and specific control options or tactics can be used in and around a farm to manage pest problems, but no single practice on its own can completely prevent pests causing losses to your crop and to your business.

Each option for pest management will tend to:

- have a different impact
- affect different pests
- have a different cost or benefit.

The key to cost-effective pest management is integrating the most suitable strategies from the best available options and establishing a solid prevention program—this is known as integrated pest management or IPM. The aim is not always to eradicate the problem because sometimes it is more profitable to tolerate a small number of pests than to spend more money on control options.

One way of thinking about IPM is as a continual improvement cycle: knowledge—prevention—monitoring—intervention—recording, reviewing and planning (see the adjacent figure). With each crop or season, more emphasis is placed on preventive strategies and gaining knowledge about what conditions are favourable or unfavourable for the pest to increase, and what factors will reduce the population. Knowing what your pests are is the first step, and this field guide will help you to identify insect and mite pests, beneficials, diseases and disorders you may find in your tomato, eggplant, capsicum and chilli crops. Where possible, seek expert confirmation as you are learning, and use available diagnostic services.



Integrated pest management cycle

Growing guide

Optimal growing conditions

The following table provides a guide to ensuring optimal growing conditions for healthy tomato, capsicum, chilli and eggplant plants.

Plant stage	Tomato	Capsicum and chilli	Eggplant
Optimum germination soil temperature	23–28 °C	20–25 °C	24–32 °C
Optimum growing temperature	20–30 °C	20–30 °C	20–30 °C
Limiting factors for sowing	Low temperatures and frosts for all crops		
Planting to maturity (depending on variety and area)	9–17 weeks	10–17 weeks	9–17 weeks
Seed to transplant	5 weeks	5–8 weeks	8–10 weeks
Vegetative to flowering	3–4 weeks	3–4 weeks	3–6 weeks
Flowering to harvest	6–8 weeks	9–14 weeks	4–5 weeks
Duration of harvest (depending on crop type and variety)	Up to 5 months	3–6 weeks, or longer for chillies	Up to 5 months
Soil pH	5.5–6.8	5.7–6.8	6.0–6.8
Salinity tolerance	Moderate (see the table under ‘Soil and water salinity tolerances’)		
Irrigation (average, depending on method of irrigation, variety and seasonal conditions)	4.5–8 ML/ha	3.5–5.5 ML/ha	3.5–5.5 ML/ha
Type of irrigation	Drip, furrow or sprinkler for all crops		
Row spacing (depending on variety)	1.5–1.8 m	Single or double rows on 1.5–2.0 m beds	1.5–2.0 m
Plant spacing (depending on variety)	0.4–0.8 m	0.3–0.6 m	0.5–0.8 m
Size of carton or case for market	10 kg cartons	11 kg cases (sweet capsicum)	6–8 kg cartons,12–20 fruit/ carton
Average yield (depending on variety)	5,000–8,000 cartons/ ha	1,600 cases/ha, 6 kg/ plant for hot chillies	5,000–8,000 cartons/ ha
Postharvest storage temperature	7–13 °C	7–13 °C	7–10 °C
Postharvest storage humidity (to slow water loss from fruit)	85–95%	85–95%	90–95% Eggplants do not store well (maximum 5–7 days in coolroom)

ha = hectare; kg = kilogram; m = metre; ML = megalitre

Soil and water salinity tolerances

Salinity levels of soil and water need to be tested to check if the crop can be grown in the soil. Salinity levels are measured as electrical conductivity of soil (EC_e) or water (EC_w) in deci-Siemens per metre (dS/m). The threshold of salinity is the maximum salinity at which the crop can be grown without a yield reduction. The 25% yield loss is the level at which yield is reduced by 25%.

	Soil salinity (EC_e [deci-Siemens per metre])		Water salinity (EC_w [deci-Siemens per metre])	
Crop	**Threshold**	**25% yield loss**	**Threshold**	**25% yield loss**
Tomato	2.5	5.0	1.7	3.4
Capsicum/chilli	1.5	3.3	1.0	2.2
Eggplant	1.1	3.0	1.0	2.0

Recommended base fertiliser rates

Fertiliser rates used should be based on soil test results. Nutrient levels should be measured by dry leaf test analysis or sap testing. Fertiliser applications can be formulated using these results. Potassium and other trace element foliar sprays can be applied throughout the growing season to avoid deficiencies.

	Recommended base application rate of nutrients that are low or high in the test results				
Soil test result	**Nitrogen (N) (kg/ha)**	**Phosphorus (P) (kg/ha)**	**Potassium (K) (kg/ha)**	**Calcium (Ca) as lime (t/ha)**	**Magnesium (Mg) as dolomite (t/ha)**
Low test result (deficient in nutrient)	240	110 tomato/ eggplant 100 capsicum/chilli	135 tomato/ eggplant 170 capsicum/chilli	5	4
High test result (above-average nutrient)	30	20 tomato/eggplant 30 capsicum/chilli	30	0–1.25	0

ha = hectare; kg = kilogram; t = tonne

Flowering-to-harvest fertiliser application guide

Time of application	Fertiliser	Rate (kg/ha)	Comments
Flowering to fruit set	Potassium nitrate (KNO_3)	12.5–25	Apply weekly
Flowering to fruit set	Calcium nitrate ($Ca(NO_3)_2$)	10–20	Apply weekly
Fruit set to harvest	Calcium nitrate ($Ca(NO_3)_2$)	12.5–25	Apply every 2 weeks
Fruit set to harvest	Potassium nitrate (KNO_3)	10–30	Apply on alternate weeks to calcium nitrate application Apply same week but separately to Liquifert P application
Fruit set to harvest	Liquifert P	10–20	Apply on alternate weeks to calcium nitrate application Apply same week but separately to potassium nitrate application

Pre-planting checklist

There are many issues to consider and activities to do before planting. It is also important to identify your market and suitable varieties for planting, choose your sowing date and consider the history of the planting area.

		Check
Market	Order seed or seedlings	☐
Soil	Test soil	☐
Paddock history	Consider previous crops, weeds, diseases or pest problems. Consider crop rotation	☐
Irrigation	Install irrigation	☐
	Irrigate if necessary just before transplanting	☐
Weed control	Consider plastic mulch and/or herbicide, and pre-emergent spray for weeds	☐
Moisture monitoring	Install soil moisture monitoring (if using)	☐
Seed or transplant	Determine availability of seed or plants	☐
	Order transplants or seed early to ensure timely delivery	☐
	Check transplants for disease and pests on delivery	☐
Plant spacing	Decide on plant spacing, depending on crop and variety	☐
	Plan trellising or staking	☐
Ground preparation	Deep-rip soil to avoid hard pans and to help control some caterpillar pupae	☐
	Check for nematodes and spray with nematicide if necessary	☐
	Add lime to adjust pH approximately 8 weeks before sowing, if needed	☐
	Make sure any weeds are controlled and crop residues are well broken down to ensure nutrient availability	☐
	Put base application of fertiliser underground. This application needs to be 100% of the crop's phosphorus requirements (P) and approximately 60% of the crop's nitrogen (N) and potassium (K) requirements (see the table under 'Recommended base fertiliser rates')	☐
	Construct beds	☐
	If using plastic mulch, lay drip tape and mulch before sowing	☐

Planting-to-harvest checklist

The following table covers the key activities necessary to ensure healthy plants with good fruit yields.

		Check
Irrigation	Irrigate to ensure good plant growth and fruit set. Avoid overwatering if possible—use water-monitoring tools to assess moisture in the soil profile	☐
Diseases	Monitor for diseases throughout the growing season and try to treat before they become a major problem. Removing the plant may be the best option. Refer to the disease pages in this field guide	☐
Insects and mites	Monitor for insects and mites throughout the growing season; using pheromone traps, sticky traps and scouting will help. Apply an appropriate spray if pests are in sufficient numbers to cause damage. Refer to insect and mite pest and beneficial pages in this field guide	☐
Weeds	Keep weeds to a minimum in the crop, and control weeds around the crop and in fallow paddocks to remove alternative hosts for insect and mite pests and diseases	☐
Nutrients	Apply nutrients by side dressing of fertiliser or 'fertigation' through drip to maximise fruit set and fruit quality. Sap testing may help to identify nutrient deficiencies. Excess nitrogen fertiliser may delay maturity, reduce yield and make plants more susceptible to fungal diseases. Refer to the disorders pages in this field guide	☐
Trellising or staking	Train tomato plants on trellises or stakes and prune branches that will be damaged if left in between rows. Prune plants to maximise yield	☐
Harvest	Harvest with care to avoid damaging fruit. Remove or destroy non-marketable fruit	☐

Postharvest checklist

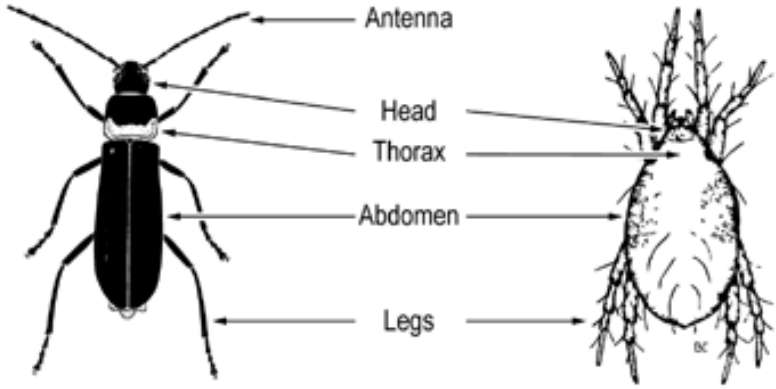
The following table covers the key activities necessary to minimise crop insect or mite pests, diseases or weed populations infesting neighbouring crops or subsequent plantings.

		Check
Weeds	Keep weeds to a minimum and control weeds around crop and in fallow paddocks to remove alternative hosts for pests and diseases. Do not allow weeds to seed. Keep records of weed problems within the crop and in the surrounding area	☐
Postharvest	As soon as possible after harvest, destroy the remaining crop. If the crop cannot be immediately incorporated into the soil or physically removed, spraying with a knockdown herbicide will stop any insect or mite pests or diseases building up on the living crop. Remove plastic mulch if fallowing, and incorporate the crop residue. Fallow the ground, or plant a break crop or cover crop to avoid erosion, reduce run-off and break disease and insect or mite pest cycles	☐

About insects and mites

Parts of an insect or mite

When identifying an insect, make sure you know which life stage you are looking at. In some insects, adults and juveniles look very different. Adult mites have eight legs and adult insects have six legs.



Insect and mite life cycles

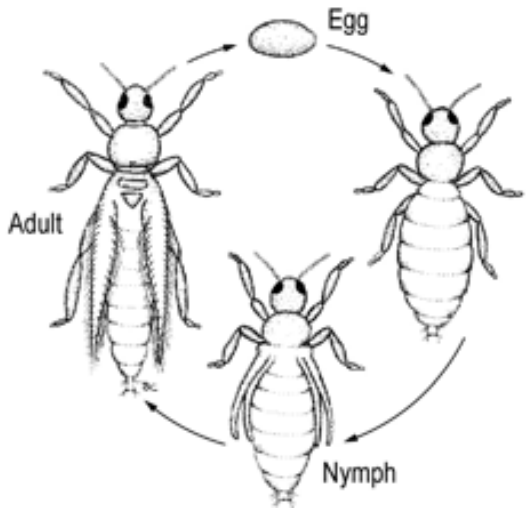
Insects and mites go through several different life stages. The pattern in which they do this falls into one of three categories: simple, incomplete or complete metamorphosis.

Simple life cycle

- Young and adult stages differ mainly in size.
- None of the stages have wings.
- Mites belong to this group.

Incomplete metamorphosis (gradual change)

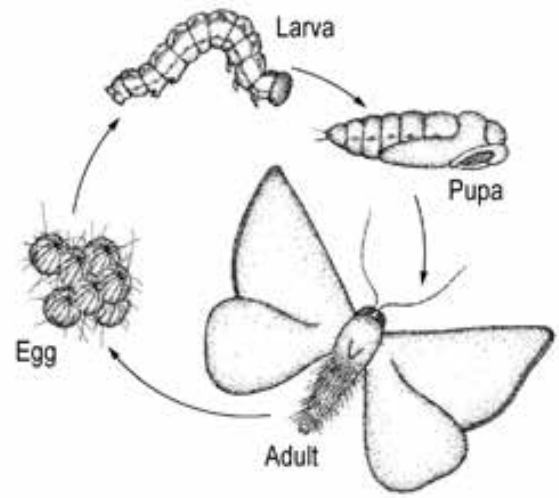
- Young look similar to adults, but without wings (juveniles are never winged).
- Young are usually called nymphs and undergo multiple moults as they grow.
- Adult stages are usually winged, but not always.
- There is no pupal stage.



- Aphids, thrips, bugs, earwigs, crickets and grasshoppers belong to this group.

Complete metamorphosis

- Young look completely different to adults.
- Young are called larvae, maggots, caterpillars, grubs or nymphs.
- Young are the primary feeding stage and undergo multiple moults as they grow.
- There is a pupal stage.
- Moths, whiteflies, beetles, wasps, lacewings and flies belong to this group.



Insect and mite damage

Insects and mites damage plants by chewing, leaving white speckling or white traces, blemishing fruit, windowing leaves, stunting growth from root feeding, cutting off seedling stems, reducing plant vigour by depositing honeydew, transmitting viral diseases or

contaminating the plant. Different groups of insects tend to cause different types of damage that relate to their size, mouthparts and where they feed on the plant.

Insects and mites with sucking mouthparts (such as aphids, thrips, spider mites, leafhoppers and whiteflies) pierce plant cells to suck plant juices and can leave characteristic speckling. Insects with chewing mouthparts bite holes that are indicative of the insect's size. Most leaf-feeding caterpillars are very small when they hatch and feed only on one side of a leaf, causing windowing; however, they quickly grow and leave ragged holes. Some insects (such as leafminers and leafrollers) leave white trace patterns in the leaves or webbing that folds leaves. Some hide or live in the soil and are not easily seen, but the plant may wilt or be stunted from their feeding.

Some general managment practices for controlling insects and mites are listed on page 232.

Beneficial organisms

Beneficial organisms ('beneficials') can help to manage insect and mite pests. The most important beneficials vary between crops and, to some extent, regions. Some beneficials eat a range of insect and mite pests and are called 'generalist predators'. Others feed only on a single group of insect or mite pests and are termed 'specialist predators'. Many groups of wasps and a few flies are 'parasitoids', which means their larvae eat and kill a single individual pest.

In field-grown crops, a range of beneficials will generally colonise the plants and help to manage insect and mite pests. In greenhouses, beneficials are less likely to be able to naturally colonise and they usually need to be introduced. Commercial insectaries rear some of the important beneficials for purchase and release. Targeted releases of beneficials in greenhouses have been very successful in managing a range of insect and mite pests.

Insect and mite beneficials will be killed if broad-spectrum insecticides are used. Note that the new-generation insecticides may affect some beneficials but not others. Where possible, identify the key beneficials in your system, and include them in your monitoring and in decisions about which agricultural chemicals to use.

Information on pesticide impact on beneficials has mainly been generated by commercial insectaries on the beneficial organisms they rear. Note that with some groups, such as Coccinellidae beetles, there is significant variation between species in their tolerance of pesticides.

A number of species can be purchased commercially in Australia (see listings under www.goodbugs.org.au) and are denoted by [CA] after their name in either the Insect and mite pests or Beneficial organisms sections of this field guide.

About plant diseases and disorders

A plant disease is any condition in a plant that interferes with normal functioning or development. Plant diseases can be divided into two categories: infectious (caused by pathogens) and non-infectious (commonly called disorders).

Infectious diseases can be transmitted from plant to plant and produce signs resulting from the interactions of the pathogen, host and environment. There are three main types of infectious plant diseases: bacterial, fungal and viral.

Non-infectious diseases (disorders) are caused by a range of non-living agents such as nutritional imbalances, environmental extremes, chemical toxicities, mechanical injuries and genetic problems. Disorders may produce signs that are similar to infectious diseases, and may also make plants more susceptible to infectious diseases.

Some general practices for controlling diseases are listed on the inside of the back cover.

Causative agents of plant diseases

Bacteria

Bacterial plant pathogens are single-celled organisms that can rapidly multiply under favourable conditions. They are usually carried in infected planting material, but can survive in soil and on the surface of plants, even in dry conditions, for long periods of time. Bacteria can infect plants through wounds and natural plant openings such as stomata.

Bacteria can be transmitted by:

- water (rain or irrigation water)
- seed
- vegetative propagation material
- insects
- human activities such as chipping, transplanting, harvesting, tractor passes and movement of soil.

Fungi

Fungi consist of threads (hyphae) that radiate out to find food. Fungi can survive in a wide range of habitats, including living and dead plants, and soils. They reproduce and spread by producing spores. Although individual spores cannot be seen with the naked eye, masses of spores are often seen on plants. Fungi can infect plants through natural openings (e.g. stomata), via mechanical pressure or through wounds.

Fungi can be transmitted by:

- water, wind and air
- soil
- seed
- insects and other animals
- human activities such as chipping, transplanting, tractor passes and movement of soil.

Viruses

Viruses can multiply only in living cells. They use the plant's normal processes to replicate themselves. Some viruses are systemic; others leave some plant tissue virus-free. There is no cure for infected plants, so control depends on prevention. Viruses are named after the first plant on which they were studied and the most obvious sign of the disease on that plant.

Viruses can be transmitted by:

- living vectors such as insects, mites, nematodes and fungi
- mechanical vectors such as equipment, or by leaf-to-leaf contact
- seed and pollen.

Phytoplasma

Phytoplasmas are very small, specialised plant parasitic bacteria that live in the phloem. They are transmitted by phloem-sucking insects such as leafhoppers. These pathogens cause a variety of signs from mild yellowing of leaves to plant death, and a range of growth-

form changes such as 'witches' broom' (an increased number of side shoots and longer internodes). There is no control for plants infected with phytoplasmas. Varietal resistance and vector control are the only management options.

Nematodes

Nematodes are microscopic round worms. Plant parasitic nematodes are found in three genera; the most widespread and economically significant are the root-knot nematodes (*Meloidogyne* spp.). The root-knot nematodes are obligate parasites of roots of many thousands of different plant species, and form distinctive root galls. There are more than 60 *Meloidogyne* species, and many have several races. Infected plants can show a decline in yield and fruit quality, and a greater susceptibility to other stresses.

Disorders

Conditions that promote disorders in plants include:

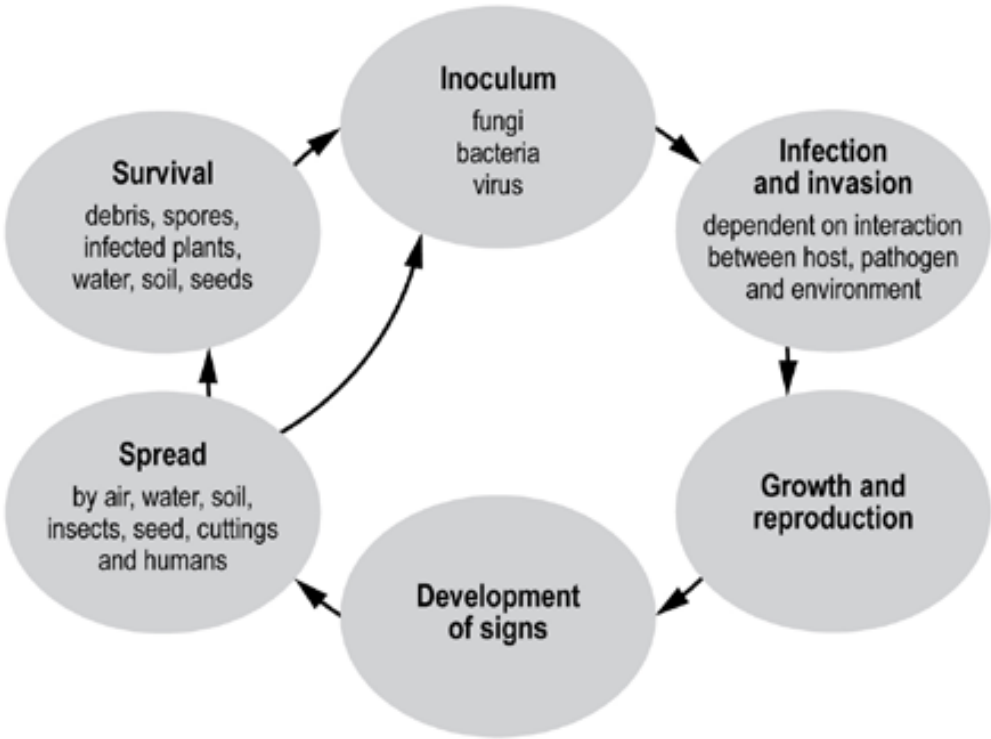
- unfavourable temperatures
- unfavourable soil moisture
- unfavourable atmospheric moisture
- unfavourable soil structure
- incorrect soil pH
- nutrient deficiencies and toxicities
- harmful substances
- mechanical injuries
- genetic abnormalities.

Disorders cannot be transmitted. Disorders caused by nutrient deficiencies or toxicities can appear similar and may be confusing. To determine the exact cause, tests on leaf dry matter, sap or soil are recommended.

Diagnosing diseases and disorders

To diagnose diseases and disorders:

- Look at the whole plant.
- Check for damage to roots, foliage and flowers.
- Note the distribution of signs within the plant—for example, is only the new growth affected, or only one stem?
- Note the pattern of affected plants within the crop.
- Note the changes to plants over time—the signs produced by plant diseases often vary with weather conditions or age of plants.



General disease life cycle

Signs of plant damage

The tables in this section use the following abbreviations:

INSECTS	
Acari	Aca
Aculops lycopersici	*Al*
Polyphagotarsonemus latus	*Pl*
Tetranychus urticae	*Tu*
Tetranychus ludeni	*Tl*
Thysanoptera	Thy
Hemiptera	
Aleyrodids	Ale
Aphids	Aph
Cicadellids	Cic
Nezara viridula	*Nv*
Nysius vinitor	*Nyv*
Pseudococcids	Pse
Lepidoptera	Lep
Agrotis spp.	*Aspp*
Leucinodes orbonalis	*Lo*
Ostrinia furnacalis	*Of*
Phthorimaea operculella	*Po*
Sceliodes cordalis	*Sc*
Spoladea recurvalis	*Sr*
Diptera	
Asphondylia capsici	*Ac*
Bradysia spp.	*Bspp*
Liriomyza huidobrensis	*Lh*
Liriomyza sativae	*Ls*
Tephritids	Tep
Coleoptera	Col
Curculionids	Cur
Elaterids	Ela
Monolepta signata	*Ms*
Scarabs	Sca
Tenebrionids	Ten
Orthoptera	Ort
Gryllotalpa spp.	*Gspp*

BACTERIAL DISEASES	
Clavibacter michiganensis subsp. *michiganensis*	*Cmm*
Pseudomonas corrugata	*Pc*
Pectobacterium carotovorum subsp. *carotovorum*	*Pcc*
Pseudomonas syringae pv. *tomato*	*Pst*
Ralstonia solanacearum	*Rs*
Xanthomonas spp.	*Xspp*
FUNGAL DISEASES	
Alternaria solani	*As*
Botrytis cinerea	*Bc*
Cercospora capsici	*Cc*
Choanephora cucurbitarum	*Chc*
Damping off	DO
Fulvia fulva	*Ff*
Fusarium oxysporum f. sp. *lycopersici*	*Fol*
Fruit rots	FR
Leveillula taurica	*Lt*
Oidium lycopersici	*Ol*
Oidium neolycopersici	*On*
Phoma destructiva	*Pd*
Phytophthora infestans	*Pi*
Phomopsis vexans	*Pv*
Rhizoctonia solani	*Rhs*
Stemphylium spp.	*Sspp*
Septoria lycopersici	*Sl*
Sclerotinia minor	*Sm*
Sclerotinia rolfsii	*Sr*
Sclerotinia sclerotiorum	*Ss*
Verticillium dahliae	*Vd*

VIRUS DISEASES	
Alfalfa mosaic virus	AMV
Begomoviruses	Beg
Capsicum chlorosis virus	CaCV
Cucumber mosaic virus	CMV
Potato leafroll virus	PLRV
Potyviruses	Pot
Tobamoviruses	Tob
Tomato bushy stunt virus	TBSV
Tomato spotted wilt virus	TSWV
Tomato torrado virus	TTV
OTHER DISEASES	
Phytoplasma	Phy
Nematodes	Nem
DISORDERS	
Calcium deficiency	Ca–
Iron deficiency	Fe–
Magnesium deficiency	Mg–
Manganese deficiency	Mn–
Molybdenum deficiency	Mo–
Nitrogen deficiency	N–
Phosphorus deficiency	P–
Potassium deficiency	K–
Zinc deficiency	Zn–
Chloride toxicity	Cl+
Catface	Cf
Misshapen fruit	MsF
Sunburn	Sb
Herbicide damage	HerbD

Seedlings

Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Cuts	*Aspp,* Sca					
Darkening at stem base			DO, *Pi*			
Death	*Bspp*	*Cmm*	DO, *Pi*, *Pv*	TSWV		P–
Small, irregular spots	Aca		*Pv*			
Wilting	Thy, Aph, Cic, Ale, Ela, Ten, Sca	*Cmm*	DO		Nem	

Plants

Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Browning and death of leaf shoots	*Lo, Sc*					Ca–
Browning and death of plant				TTV		
Death of all but youngest leaves	*Tu*		*Sl*	Pot		
Pale and weak growing tips	*Po*					N–
Stunting	Ale, *Nv, Po,* Cur	*Cmm*	*Rhs*	AMV, Beg, CaCV, Pot, TBSV, Tob, PLRV		Mo– P–, Zn–, Cl+, HerbD
Upright/stiffness					Phy	
Wilting	Aca, *Nyv, Sc, Lo, Bspp*, Sca, Cur, Ela, Ten, *Gspp*	*Pcc*, *Rs*, *Pc*	*Chc*, *Fol*, *Sr*, *Ss, Sm*, *Vd*		Nem	Cl+

Roots

Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Browning	*Bspp*		*Rhs*, DO			
Nodules					Nem	
Weak root system	Sca, Ela, Ten					P–

Stems

Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Bark peeling			*Chc*			
Boring	*Of, Lo, Sc*					
Concentric rings			*Cc*, *As*			
Cracked and sunken cankers			*Pv*			
Girdling, rotting at base	Cur		*Rhs*, *Sr*			
Hollowness		*Cmm*, *Pc*				
Lesions	*Lo*	*Cmm*, *Xspp*, *Pc*	*Bc, Cc, Ss, Sm*			
Scabbing		*Pcc*				
Streaking				Pot, TSWV		

Leaves

Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Concentric ring spots			*Cc*, *As*			
Darkened veins		*Pcc*		Pot		Cl+
Dark spots and lesions		*Pst*	*Bc, Sspp*, *Pi*, *Pv*, *Pd*	PLRV		P–
Irregular holes/chewing	Lep, Col, Ort					
Leaf distortion, abnormal growth	Aph, Ale, *Pl*			All	Phy	Zn–, HerbD
Mines (silver lines in leaf)	*Lh, Ls*, *Po*					
Purpling or bronzing	Aca		*Ff*	TSWV, TBSV		P–, N–
Round holes/shot holes	*Ms*		*Cc*	TTV		
Scorched emerging leaves						Ca–
Silvering (speckles)	Aca, Thy, Ale, Pse					
Silvery hairs on surface	*Tu,* Pse, Ale		*Chc*			
Skeletonised leaves	Lep, Sca*,* Cur					
Small spots	Aca, Cic		*Ss, Sm*			
Sooty mould	Aph, Pse, Ale					
Webbed leaves	*Sr*					
White powdery growth	Pse, Ale		*Lt, Ol, On*			
Wilting lower leaves	*Al, Tl, Tu*		*Fol, Sspp, Vd*			Mg–, Fe–, Mo–, Cl+
Wilting shoots	*Lo, Pl, Po*			TSWV		
Yellowing at leaf margins						K–, P–, Cl+
Yellowing, chlorosis, mottling	Pse	*Pcc*		All		Fe–, Mg–, Mn–, Mo–, N–, Zn–, HerbD

Flowers

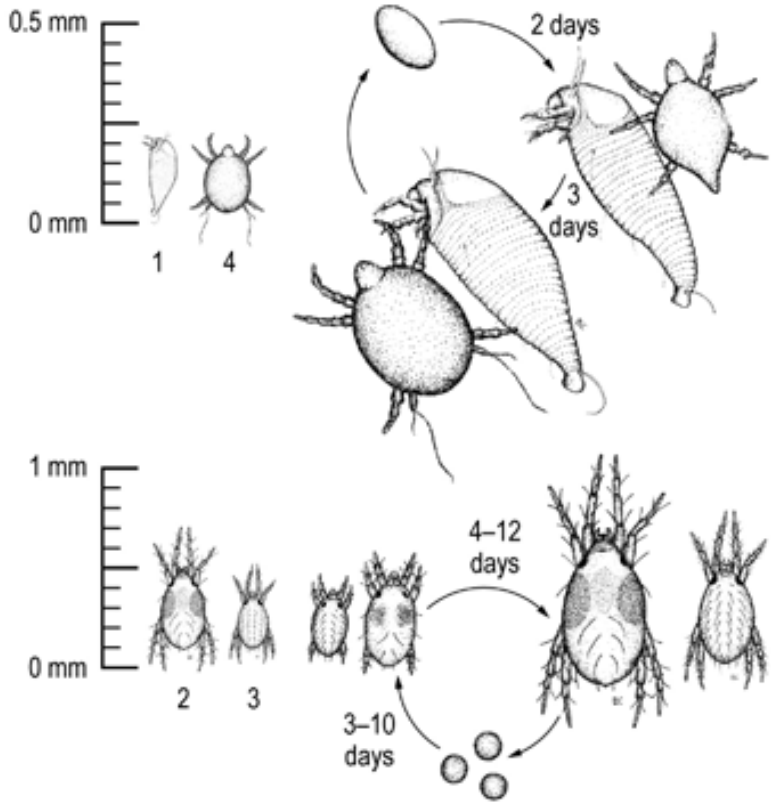
Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Distorted or overgrown			*Chc*		Phy	K–
Dropped or aborted	Thy, Pse	*Xspp*	*Ff*	Beg, Pot		P–, Zn–

Fruit

Sign	Insect	Bacteria	Fungus	Virus	Phytoplasma/ nematodes	Disorders
Concentric ring spots			*As*	CMV		
Distorted or small and malformed	Thy, *Ac*			AMV, CaCV, PLRV, Pot, TBSV, Tob, TSWV	Phy	Zn–
Holes	Lep					
Malformation or scarring at blossom end						Ca–, Cf, MsF
Raised spots		*Cmm*, *Pst*, *Xspp*				
Rot	Lep, Tep	*Pcc*	FR, *Ss, Sm*, *As*			
Slender and pinched at blossom end						N–
Sunken spots		*Pcc*	*As*	AMV		Ca–, Sb
Uneven ripening	Ale			CMV, TBSV, Tob, TSWV		K–, Cf
Water-soaked lesions	*Nv*	*Pcc*	*Pi*			

Insect and mite pests

Mites—Acari



Tomato russet mite *Aculops lycopersici* (*Al*)[1], bean spider mite *Tetranychus ludeni* (*Tl*)[2], two-spotted (spider) mite *T. urticae* (*Tu*)[3], broad mite *Polyphagotarsonemus latus* (*Pl*)[4]

Importance: *Al* is a major and frequent pest while *Tl* and *Tu* are occasional pests. *Pl* is mainly a pest of capsicum.

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Beans, carrots, cucurbits, lettuce, potatoes, sweet corn

Similar to: Other mites. Damage to leaves looks similar to frost damage or other sucking insect feeding.

Description:

Egg: Minute, round to globular eggs, clear white to cloudy yellow.

Immature: Similar to adult in shape and colour but smaller.

Adult: *Al* and *Pl* are white to yellow and about 0.2 mm long. *Al* is wedge shaped and *Pl* is oval. *Tu* and *Tl* are both larger at 0.5 mm. *Tu* looks yellowish green with two pronounced dark spots, one on either side of the body. *Tl* is uniformly dark red.

Damage: *Pl* injects a toxin as it feeds that increases the damage caused. Unlike for *Al*, *Tl* and *Tu*, the damage is usually seen first on young growth, causing distortion as well as bronzing. The initial indication of infestation of *Al*, *Tl* and *Tu* is silvering of the lower leaves, which become bronze coloured before dropping off. Damage moves up the plant. Tomato stems lose their surface hairs and become shiny, smooth and brown. Fruit may be more susceptible to sunscald due to loss of foliage. *Tu* can cover plants in webbing and leave white spots where it feeds.

Vector: Not a disease vector

Commonly found: On the underside of leaves and stems; *Pl* also in growing points.

Beneficials: *Tl*, *Tu* and *Pl* are fed upon by a range of other predatory mites including persimilis (*Phytoseiulus persimilis*)[CA], cucumeris (*Neoseiulus cucumeris*)[CA], monties (*Transeius montdorensis*)[CA] and western predatory mite (*Galendromus occidentalis*).[CA]

Management:

- Use windbreaks and minimise dust-creating activities—infestations are favoured by dusty conditions (e.g. adjacent to dirt roads or tracks in fields).
- Reduce humidity by using adequate plant spacing, orientating plantings to the prevailing wind and maintain appropriate watering practices—*Pl* prefers warm (25 °C) and humid (80–90% relative humidity) conditions.

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

Aculops lycopersici adult

Aculops lycopersici on stem

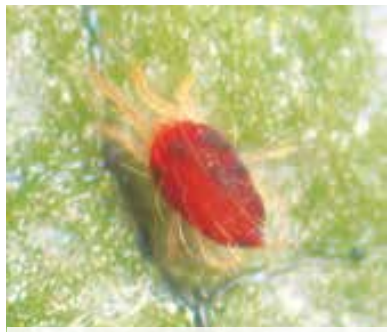
Advanced *Aculops lycopersici* infestation—older leaves die

Aculops lycopersici leaf damage

Aculops lycopersici stem damage

Aculops lycopersici fruit damage

Aculops lycopersici fruit damage

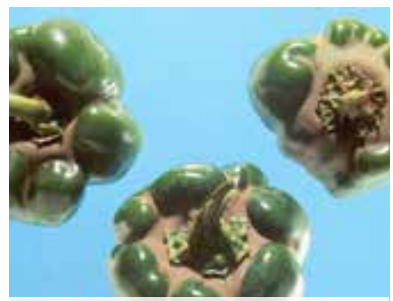


Tetranychus ludeni adult

Tetranychus urticae adults

Tetranychus urticae leaf damage (S. Ramasamy)

Tetranychus urticae webbing (S. Ramasamy)

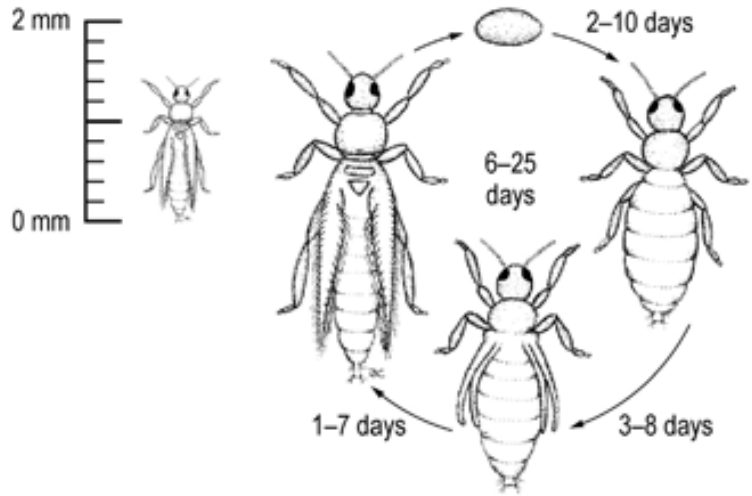


Polyphagotarsonemus latus fruit damage

- Visually monitor seedlings and crops at least weekly for signs of damage.
- Work in unaffected areas first, and wash hands and contaminated clothing regularly.
- Minimise use of broad-spectrum insecticides to encourage natural colonisation by predatory mites, which can reduce pest mite populations.
- Use miticides if pest pressure becomes too high; however, mites can be difficult to control by chemical means because of resistance, and pest mite populations rapidly increase or are 'induced' after applications of pyrethroids that kill predatory mites in the crop.

Thrips—Thysanoptera

Western flower thrips *Frankliniella occidentalis* (*Fo*), tomato thrips *F. schultzei* (*Fs*), chilli thrips *Scirtothrips dorsalis* (*Sd*), plague thrips *Thrips imaginis* (*Ti*), melon thrips *T. palmi* (*Tp*), onion thrips *T. tabaci* (*Tt*)



Importance: Minor but frequent

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: *Fs*, *Fo* and *Sd* have a very wide range of crop and weed hosts. *Tp* is also found on potatoes, cucurbits and beans. *Tt* is primarily found on alliums.

Similar to: Other thrips

Description:

Egg: Eggs are laid into actively growing leaf tissue, developing flower buds and fruit.

Immature: The wingless larvae are white or yellowish with an elongate body about 0.5–1 mm long.

Adult: Thrips are tiny, torpedo-shaped insects about 1–1.5 mm long. They have two pairs of wings that have fine hairs around the margins. Thrips vary in colour and size depending on the species.

Damage: Feeding damage appears as silvering and flecking on the leaves of seedlings. Heavily infested plants are characterised by a silvered or bronzed appearance of the leaves, stunted leaves and terminal shoots, and scarred and deformed fruit.

Vector: *Fs*, *Fo*, *Tp*, *Sd* and *Tt* are vectors for tomato spotted wilt virus. *Tp* and *Fs* are vectors for capsicum chlorosis virus in capsicum and tomato (currently found in tropical and subtropical regions).

Commonly found: On all above-ground plant parts

Beneficials: Predatory thrips, predatory mites

Management:

- Manage weeds in and around crop to reduce alternative thrips breeding areas.
- Use thrips exclusion screening in seedling nurseries or for protective cropping structures.
- Monitor thrips numbers with yellow or blue sticky traps, or by tapping flowers over white paper or a tray.
- Note that high predator numbers should control pest thrips.
- Use insecticides if necessary but care should be taken as the overuse of insecticides has increased the problem in the past, probably by killing predators.
- Note that *Fo* is highly resistant to most insecticides.
- Remove plants that show virus signs and destroy crops after harvest to reduce virus transmission within the crop or to neighbouring crops.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ■ Flower ■ Fruit

■ Australia ■ Cambodia (*Tp*, *Tt*)

Frankliniella occidentalis adult

Frankliniella occidentalis nymph

Frankliniella occidentalis damage

Frankliniella schultzei adult

Scirtothrips dorsalis adult

Thrips imaginis adult

Thrips palmi adult

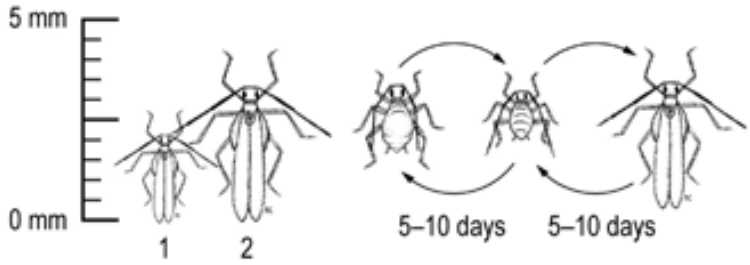
Thrips palmi damage

Thrips palmi damage

Thrips tabaci adult

Aphids (Aph)

Cotton aphid *Aphis gossypii* (*Ag*)[1], foxglove aphid *Aulacorthum solani* (*Aus*)[2], tomato/potato aphid *Macrosiphum euphorbiae* (*Me*)[2], green peach aphid *Myzus persicae* (*Mp*)[2]



Importance: *Me* is the most commonly found aphid in solanaceous crops and is normally only a minor pest, although frequent.

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Lettuce, potatoes, sweet corn and a range of weeds

Similar to: Other aphid species

Description:

Egg: Aphids usually produce live young but can lay eggs on rare occasions.

Immature: Immature aphids resemble the adult.

Adult: Aphids are soft-bodied insects with six legs. *Ag* is the smallest at about 2 mm long, while the other species are about 3 mm long. Aphids can be either winged or wingless. Wings are held roof-like over the abdomen at rest. Colour varies between species and between winged and wingless types. *Mp* and *Ag* are usually light-to-dark green, *Me* is greenish with a pinkish tinge and *Aus* is yellowy green to almost brown.

Damage: Large populations in a seedling crop can cause leaves to curl and leaves or growing tips to die prematurely. In older crops, yield may be reduced. Aphids leave a sticky substance called honeydew on the leaves and growing tips that can promote the growth of sooty mould and reduce plant vigour. Aphids can also transmit damaging plant viruses when they feed.

Vector: Aphids are vectors for a range of viruses in fruiting solanaceous crops, including alfalfa mosaic, chilli veinal mottle, cucumber mosaic (also known as fern leaf), tobacco etch and tomato yellow top viruses, and potato virus Y.

Commonly found: Aphids usually feed on the underside of leaves but may attack the soft growing tips.

Beneficials: Aphids have many predators, including Coccinellidae beetles[CA], Neuroptera[CA], syrphids, nabids[CA] and parasitic wasps.[CA]

Management:

- Note that beneficial insects can usually keep populations under control unless they are sprayed out with broad-spectrum insecticides.
- Note that in moist conditions, insect-attacking fungi can quickly reduce aphid populations.
- Use insecticides if aphids are causing significant damage or if there is a high incidence of aphid-vectored virus present. Where possible, choose selective chemistries (e.g. primicarb or pymetrozine) to minimise harm to predators of aphids and other pests.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

Aphis gossypii wingless adult

Aphis gossypii winged adult

Aphis gossypii colony on chilli

Aphis gossypii colony being tended (protected) by ants

Aulacorthum solani winged adult

Aulacorthum solani wingless adults and nymphs

Macrosiphum euphorbiae nymph

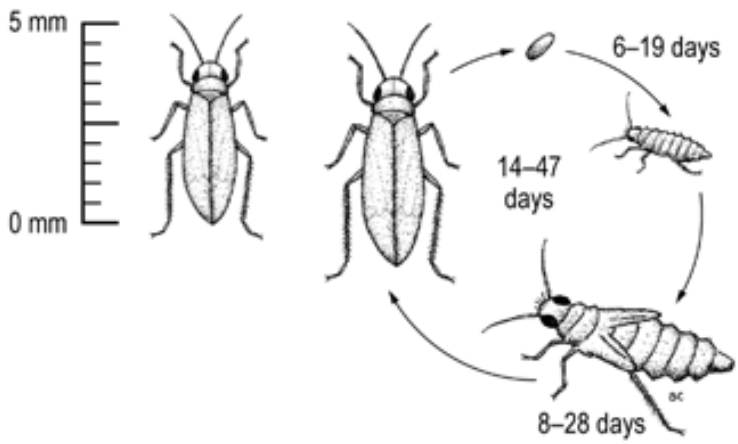
Macrosiphum euphorbiae winged adult

Myzus persicae wingless adults and nymphs

Myzus persicae (note parasitised aphid with parasite exit hole)

Leafhoppers—Cicadellidae (Cic)

Cotton leafhopper *Amrasca devastans* = *A. biguttula* (*Adb*), vegetable leafhopper *Austroasca viridigrisea* (*Av*), common brown leafhopper *Orosius orientalis* = *O. argentatus* (*Oo*)



Importance: Minor and infrequent

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: *Oo* has a very wide host range; *Av* attacks most leafy vegetables, carrots, beans and potatoes.

Similar to: Whitefly adults (superficially)

Description:

Egg: Pale, elongate, laid into leaf tissue.

Immature: Pale, white to green, head rounded or pointed. Similar to adult.

Adult: Very active. Wedge shaped, varies in colour with species, can be white to brown, green or yellow. Hind legs adapted for jumping. Holds wings roof-like over abdomen.

Damage: All stages suck sap. Damage appears similar to that caused by thrips and mites. Feed on underside of leaf, causing leaf distortion and stunting of new growth. Black spots of excrement are often left behind. Heavily infested plants can become stunted and grey. Fruit may be attacked, resulting in faint whitish spots.

Vector: *Oo* can be a vector for big bud phytoplasma disease in tomatoes.

Commonly found: Over plant foliage. When disturbed, adults either fly or hop away. Nymphs can neither fly nor hop but will still quickly move around to the other side of the twig or leaf by walking sideways.

Beneficials: Not known to have many effective natural enemies.

Management:

- Not commonly a problem. Use insecticides if pest numbers become high or phytoplasma disease is present, but this may cause population flares in mites, thrips or whiteflies.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ■ Fruit

■ Australia (*Oo Av*) ■ Cambodia (*Adb*)

Amrasca devastans adult

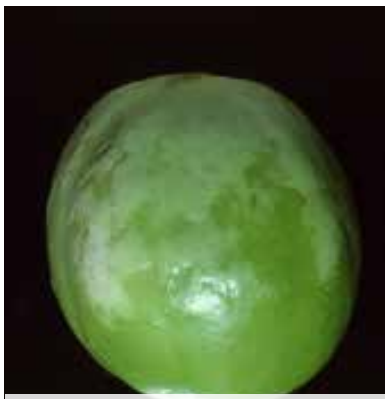
Austroasca viridigrisea adult

Austroasca viridigrisea adult

Austroasca nymph

Orosius orientalis adult

Orosius nymphs and adult



Orosius-vectored phytoplasma disease signs on tomato fruit

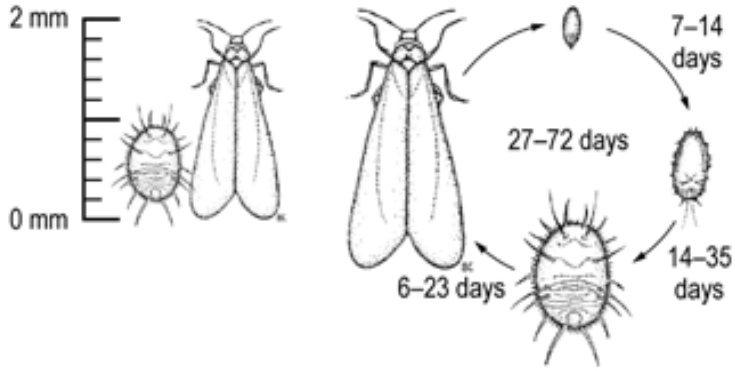
Tomato leaf damage

Leaf damage

Eggplant leaf damage
(S. Ramasamy)

Whiteflies—Aleyrodidae (Ald)

Spiraling whitefly *Aleurodicus dispersus*, silverleaf whitefly *Bemisia tabaci* (*Bta*), greenhouse whitefly *Trialeurodes vaporariorum*



Importance: Minor and infrequent. *Bta* has greater importance as a virus vector.

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Beans, cucurbits and a range of weeds

Similar to: None

Description:

Egg: Small and yellowish green, changing to brown as they approach hatching. Laid on the underside of leaves.

Immature: Greenish-white, oval-shaped nymphs. Yellow pupa with a fringe of hairs.

Adult: Approximately 1–1.5 mm long and appear moth-like with white wings.

Damage: Suck sap from the plants. Heavy infestations can result in poor growth, leaf yellowing and loss of plant vigour. Honeydew is produced that encourages sooty mould growth, which further reduces plant vigour.

Vector: *Bta* is a vector of tomato yellow leaf curl virus on tomato and capsicum.

Commonly found: Adults and nymphs are usually found feeding on the underside of leaves.

Beneficials: Parasitoid wasps (e.g. *Encarsia formosa*[CA] and *Eretmocerus hayati*[CA]), predatory mites and thrips, and green lacewings[CA]

Management:

- If whitefly are a major pest, the area must not contain whitefly host crops or weeds for at least 2 months each year, otherwise populations become too high to manage effectively.
- Use whitefly exclusion screening in seedling nurseries or for protective cropping structures.
- Monitor whitefly numbers with yellow or blue sticky traps, or visually on undersides of leaves.
- Control whiteflies by releasing commercially reared beneficials such as *Encarsia formosa* within protective cropping structures.
- Note that high predator numbers can control pest whitefly.
- Use insecticides if necessary but care should be taken as the overuse of insecticides has increased the problem in the past, probably by killing predators.
- Note that some *Bta* populations are highly resistant to insecticides.
- Remove plants that show virus signs and destroy crops after harvest to reduce virus transmission within the crop or to neighbouring crops.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ■ Fruit

Aleurodicus dispersus adults

Aleurodicus eggs left in a distinctive spiral (S. Ramasamy)

Aleurodicus third-instar nymphs

Bemisia tabaci adults

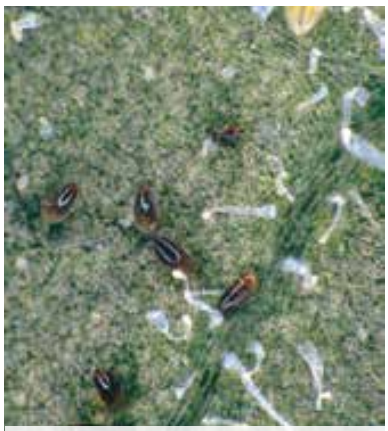
Bemisia adult and pupa

Bemisia eggs

Bemisia 'redeye' nymph (P. De Barro)

Bemisia feeding causes uneven ripening (P. De Barro)

Trialeurodes vaporariorum adult



Trialeurodes eggs

Trialeurodes colony (note fungi feeding on insects)

Mealybugs—Pseudococcidae (Pse)

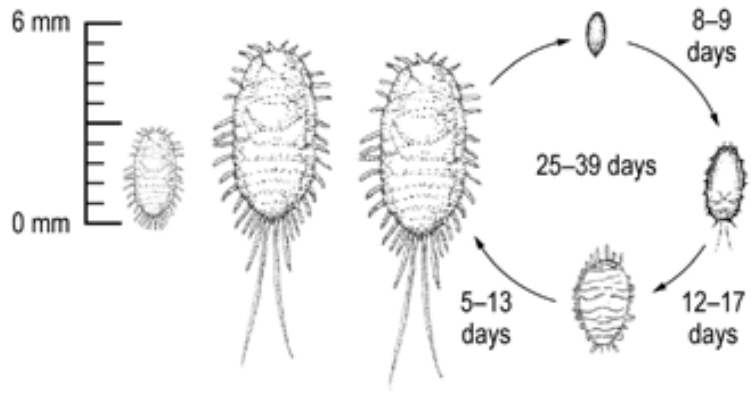
Papaya mealybug *Paracoccus marginatus*, cotton mealybug *Phenacoccus solenopsis*, other species

Importance: Rare (Australia), minor (Cambodia)

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide host range for different species

Similar to: Other mealybugs



Description:

Egg: Eggs are held in an ovisac by females.

Immature: First-instar nymphs are called 'crawlers' and move away from their mother to find a new spot to settle on their host plant. Once settled, they insert their long piercing and sucking mouthparts into the plant to feed. Mealybugs have 4–5 instars.

Adult: Adult females are oval, about 3–6 mm long and covered in a white waxy coating, often with wax filaments on the margins. Males are small, aphid-like and do not feed; they are short lived and rarely seen.

Damage: Infested plants become stunted. On tomatoes, mealybugs cause deformation and distortion of the terminal growth, twisting and curling of stems and leaves, and leaf wrinkling and puckering. In severe outbreaks, infested sites yellow and die (including the loss of flower buds, flowers and immature fruit). Black sooty mould grows on the large amounts of honeydew that the mealybugs produce. The honeydew can also attract ants, which may defend the mealybugs from attack by predators and parasitoid wasps.

Vector: Not a disease vector

Commonly found: Colonies can be found on shoots, stems and leaves, and sometimes on flower buds and petioles.

Beneficials: Larvae and adults of Coccinellidae beetles[CA], Neuroptera larvae[CA] and parasitic wasps

Management:

- Destroy infested plants by burning or burying to prevent infestations spreading.
- Spray water with a high-pressure hose to help kill the crawlers and dislodge the adults.
- Use of systemic insecticides is effective but not usually needed.

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ■ Fruit

Adult on tomatoes

Nymph

Nymph

Phenacoccus solenopsis nymph (I. Walker)

Paracoccus marginatus colony on eggplant (S. Ramasamy)

Green vegetable bug

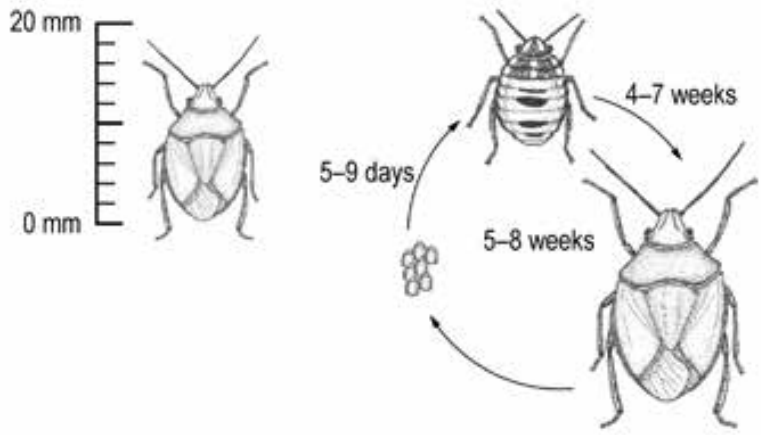
Nezara viridula (*Nv*)

Importance: Minor and infrequent

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Beans, brassicas, lettuce, potatoes

Similar to: Other stink bugs



Description:

Egg: Pale yellow to reddish brown, about 1 mm long and laid upright in tight clusters with 40–80 eggs in each egg raft.

Immature: Nymphs resemble the adult and there are five moults between egg and adults. The first-stage nymph is about 1.5 mm long and each successive nymph increases in size. Nymphs have red, green, black and orange markings; the fifth-stage nymph is mostly green.

Adult: Adults are uniformly bright green and approximately 12–15 mm long with a shield-shaped body. Overwintering adults can become brownish purple during hibernation.

Damage: The sap-sucking nature of this pest causes water-soaked lesions to develop and some malformation in growth around the affected area. High numbers of bugs reduce plant vigour.

Vector: Not a disease vector

Commonly found: Over the plant canopy

Beneficials: *Trissolcus basalis* (wasp), *Trichopoda giacomellii* (fly)

Management:

- Use insecticides if pest pressure becomes too high; however, this may cause population flares in other pests including mites, thrips or whiteflies, and kill the natural enemies of *Nv*.

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ■ Fruit

Adult

Freshly laid egg raft (H. Brier)

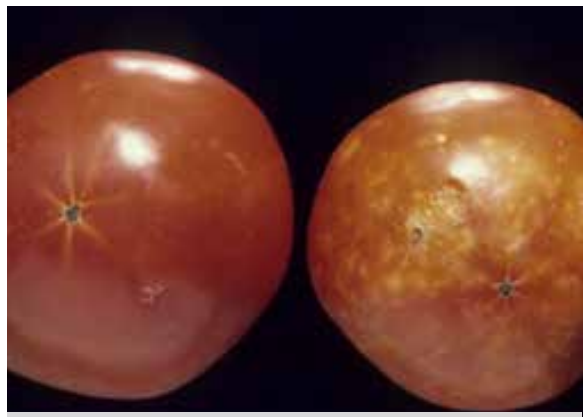
Hatching nymphs (J. Wessels)

First-instar nymphs

Third-instar nymph

Fourth-instar nymph

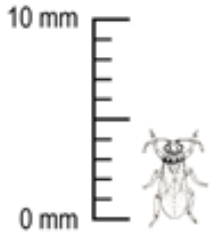
Fifth-instar nymph

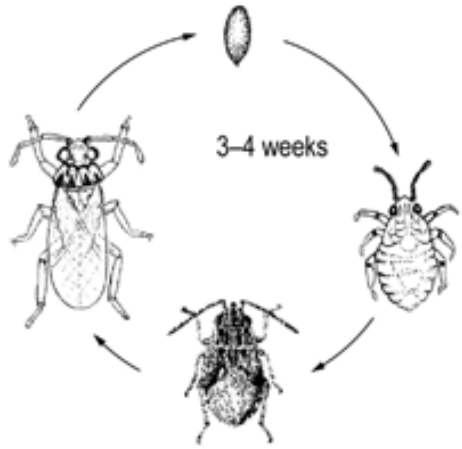


Feeding fruit damage

Rutherglen bug

Nysius vinitor (*Nyv*)





Importance: Minor and infrequent; worse in dry conditions.

Crops: Tomato, capsicum, chilli eggplant

Other hosts: Brassicas, cucurbits, lettuce, potatoes, wide range of field crops and weeds

Similar to: Green mirids and other small predatory bugs

Description:

Egg: 1 mm long and cream in colour. Laid in clusters of six on flower heads of weeds or ground trash.

Immature: Resembles adult. The short, stout nymphs are amber coloured when they hatch but soon turn darker.

Adult: Narrow bodied, grey–brown with black eyes. The wings are silvery, forming a cross-like pattern on their back.

Damage: Large numbers sucking the leaves can cause plants to wither.

Vector: Not a disease vector

Commonly found: As weeds dry off, *Nyv* can migrate into solanaceous crops. They can be seen running over all the above-ground parts of the plant.

Beneficials: Not many known natural enemies. *Telenomus* wasp parasitises eggs.

Management:

- Use insecticides if pest pressure becomes too high; however, this may cause population flares in mites, thrips or whiteflies.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ■ Flower ☐ Fruit

Adult

Eggs

Nymph

Potato moth

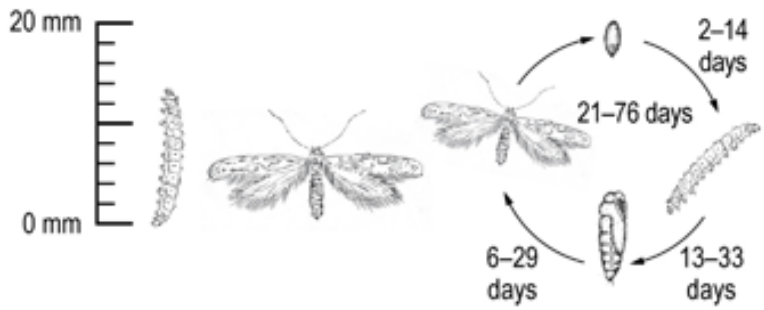
Phthorimaea operculella (*Po*)

Importance: Minor and occasional

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Solanaceous weeds

Similar to: Other Gelechiidae caterpillars



Description:

Egg: Small, oval, milky white, laid singly on foliage.

Immature: Green, brownish or pink.

Adult: Small, greyish-brown moth. Tips of forewings and all edges of hindwings fringed with long hairs.

Damage: Larvae bore into tips of stems and tunnel down, causing tip death and seriously affecting growth. Larvae can bore into fruit at the stalk ends or where fruits touch each other. On older plants, larvae produce blotch mines in the leaves.

Vector: Not a disease vector

Commonly found: Eggs are laid on the underside of leaves, and larvae quickly bore into leaves and stems.

Beneficials: *Orgilus lepidus* can effectively manage potato moth if not killed by insecticides. General predators also feed on eggs and larvae.

Management:

- Use light traps to monitor moth activity.
- Visually monitor leaves for eggs, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs or larvae.

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Adult (D. Crawford)

Adult

Larva

Larva and pupa (Shepard, Carner and Ooi)

Stem damage

Leaf damage

Fruit damage

Armyworm

Beet or onion armyworm *Spodoptera exigua* (*Se*), cluster caterpillar *S. litura* (*Sl*)

Importance: *Sl* is minor in Australia; *Se* is regular and potentially major.

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Brassicas, lettuce, alliums and many broadleaved field crops

Similar to: Other noctuid caterpillars and moths

Description:

Egg: Laid in clusters and covered with buff-coloured body scales.

Immature: Young larvae are pale green and turn grey to dark brown as they get older. *Sl* has two rows of black triangles and a conspicuous yellow line along either side of the body. *Se* is smooth and green with pale-yellow stripes along the body. Larvae may have dark markings on the third segment and darken all over as they mature.

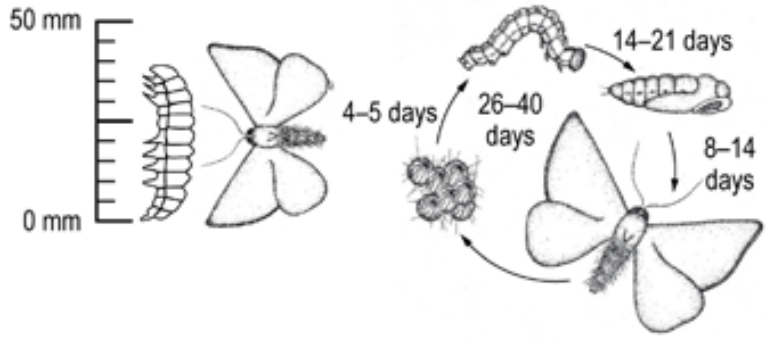
Adult: Dark forewings with characteristic species-specific, whitish, irregular markings and marginal lines. Hindwings are pearly white.

Damage: Young larvae feed in groups, skeletonising the leaves. Older larvae are solitary and eat flowers, leaves and growing points of plants.

Vector: Not a disease vector

Commonly found: On leaves. *Sl* young larvae cluster together on the underside of leaves.

Beneficials: *Trichogramma*[CA] and *Telenomus* wasps parasitise eggs, tachinid flies parasitise larvae, and generalist predators feed on eggs and larvae.



Management:

- Monitor moth activity using light and pheromone traps.
- Visually monitor leaves for egg masses, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs or larvae.

■ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ■ Flower ■ Fruit

Spodoptera exigua larvae

Spodoptera exigua larva (note tachinid parasitoid eggs)

Spodoptera exigua pupa

Spodoptera exigua entry hole in chilli

Spodoptera litura moth (W. Leedham)

Spodoptera litura eggs

Spodoptera litura newly hatched larvae

Spodoptera litura larva (W. Leedham)

Spodoptera litura moth

Cotton semi-looper

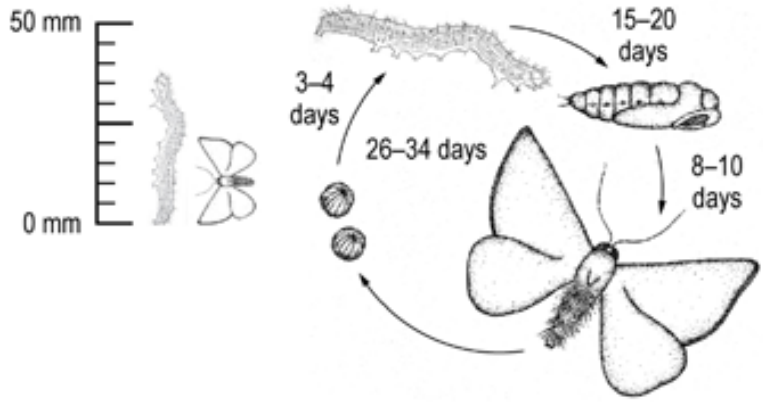
Anomis flava

Importance: Minor

Crops: Tomato

Other hosts: Okra, cotton, cowpea, green gram, sweet potato, melon

Similar to: Other looper or semi-looper caterpillars



Description:

Egg: Eggs are pale bluish green and are usually laid singly on the under surface of leaves.

Immature: Larvae are green, up to 40 mm long and may have white stripes running along the body. Pupae are found in rolled up leaves.

Adult: Moths are 20 mm long and have reddish-brown forewings with a darker grey–brown area at the rear of the wing.

Damage: Larvae are leaf feeders, but can occasionally feed on young fruiting bodies. Young larvae skeletonise leaves; older larvae eat irregular holes in leaves.

Vector: Not a disease vector

Commonly found: On leaves at any crop stage

Beneficials: Eggs are commonly parasitised by *Trichogramma*[CA] wasps. Larvae and pupae are infrequently parasitised by braconid and chalcidid wasps, respectively.

Management:

- Rarely necessary to control, but *Bacillus thuringiensis* (Bt) products are very effective.

☐ Seedling ■ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

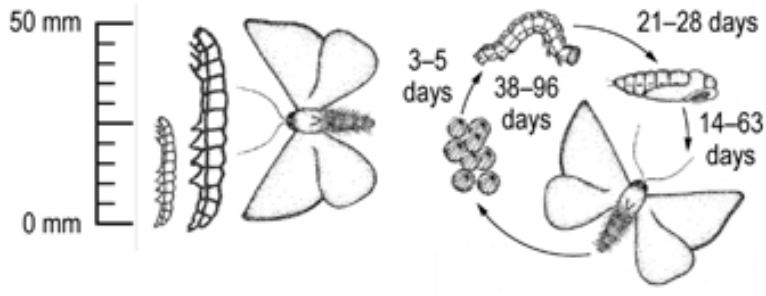
Adult (W. Leedham)

Larva (W. Leedham)

Pupa (W. Leedham)

Cutworm (*Aspp*)

Bogong moth or common cutworm *Agrotis infusa,* black or greasy cutworm *A. ipsilon*, variable cutworm *A. porphyricollis*



Importance: Minor and frequent; field-grown crops only

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Carrots, brassicas, cucurbits, lettuce, alliums, sweet corn and a range of field crops

Similar to: Other noctuid caterpillars

Description:

Egg: Laid in clusters close to the soil on crop leaves or weeds

Immature: Caterpillars can range from 25 mm to 50 mm long. Cutworms can vary in colour but are usually a dark greyish brown. Larvae curl into a distinct 'C' shape when disturbed.

Adult: Moths are stout bodied with dark-coloured forewings. Forewings are patterned with a row of three light spots contrasting with the dark background. Hindwings are pale.

Damage: Older caterpillars cut seedlings off at ground level, causing the plant to fall over and die.

Vector: Not a disease vector

Commonly found: Cutworms usually feed in the evening or at night, and hide by day in the soil. Larvae may be found at the base of fallen plants.

Beneficials: Eggs can be parasitised by *Trichogramma*[CA] and *Telenomus* spp. Predatory beetle larvae feed on larvae when in soil.

Management:

- Avoid infestations with long fallows before planting.
- Visually monitor new seedlings for egg masses and feeding damage.
- If seedlings are attacked, dig in nearby soil to find larvae.
- If insecticides are required, spray at night when the larvae are more active. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs or larvae.

■ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

■ Australia ■ Cambodia (*Aip*)

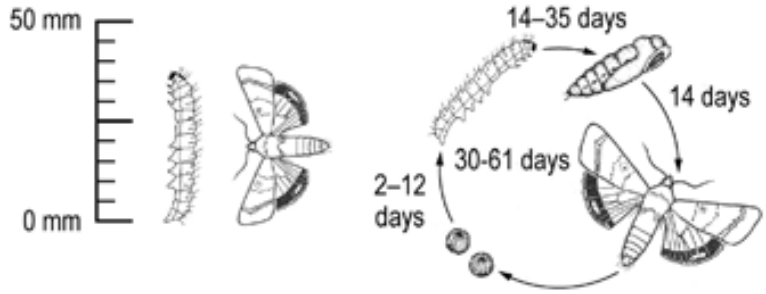
Adult

Eggs

Larva

Heliothis

Corn earworm or tomato budworm *Helicoverpa armigera* (*Ha*) and native budworm *H. punctigera*



Importance: Major and frequent

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Beans, lettuce, sweet corn, range of field crops and weeds

Similar to: Other noctuid caterpillars

Description:

Egg: White domes with ribs about 1 mm in diameter. As the embryo develops, the egg changes colour to yellow then orange and brown just before hatching.

Immature: Newly emerged larvae are 1.5 mm long, hairy, and cream in colour with a dark-brown head. Older larvae can be green, pink, buff or brown. Larvae have distinct lateral (side) stripes and visible hairs.

Adult: Moth colour can vary. Forewings are buff to reddish brown with darker markings. Hindwings are pale grey with a dark band along the lower edge.

Damage: Heliothis larvae can chew on foliage or fruit. They can defoliate and kill plants at the seedling stage. The larvae can chew holes in fruit, causing blemishes and creating entry holes for disease and rots.

Vector: Not a disease vector

Commonly found: Over the plant canopy. When feeding, they like to be protected and tend to be found in hidden areas of the foliage and burrowed into the fruit.

Beneficials: Eggs are parasitised by *Trichogramma*[CA] and *Telenomus* spp. Larvae are parasitised by a range of wasps (*Microplitis* spp., *Cotesia* spp.). Both eggs and larvae are fed upon by a range of generalist predators including predatory bugs, wasps, beetles and spiders.

Management:

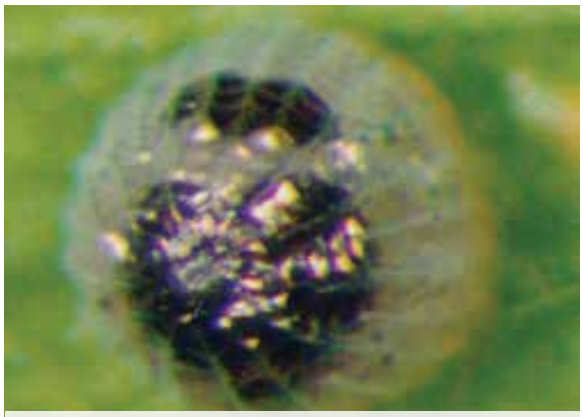
- Monitor moth activity using light and pheromone traps.
- Visually monitor leaves for eggs, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) or the *Helicoverpa*-specific nuclear polyhedrosis virus (NPV) to minimise harm to lepidopteran and other pest predators.
- Note that *Ha* has developed resistance to pyrethroid and carbamate insecticides.
- In small plantings, physically remove eggs and larvae.
- Cultivate soil to a depth of 10 cm or perform 'pupae busting' after harvest to help reduce carryover between crops.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ■ Flower ■ Fruit

■ Australia ■ Cambodia (*Ha*)

Adult

Egg

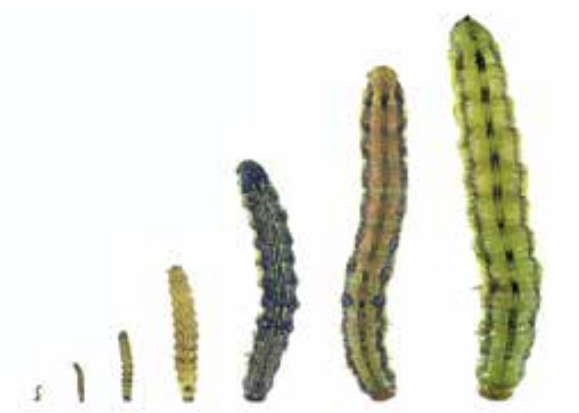


Egg about to hatch; ‘black head stage’ (B. Scholz)

Egg hatching (B. Scholz)

Larva

Pupae—*H. armigera* (top), *H. punctigera* (below)



Larval instars—note colour variation

Loopers

Chrysodeixis acuta, *C. chalcites*, *C. eriosoma*

Importance: Minor and occasional

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Beans, cotton, crucifers, lettuce, silverbeet

Similar to: Other noctuid caterpillars

Description:

Egg: Small, round and pale, usually laid singly or in a small cluster on underside of leaf.

Immature: Larvae are pale green and grow to a length of 40 mm. They are smooth and slender, and move in a looping motion.

Adult: Dark-brown forewings with characteristic silver–white markings.

Damage: Larvae can skeletonise leaves or chew holes. Large infestations can defoliate plants.

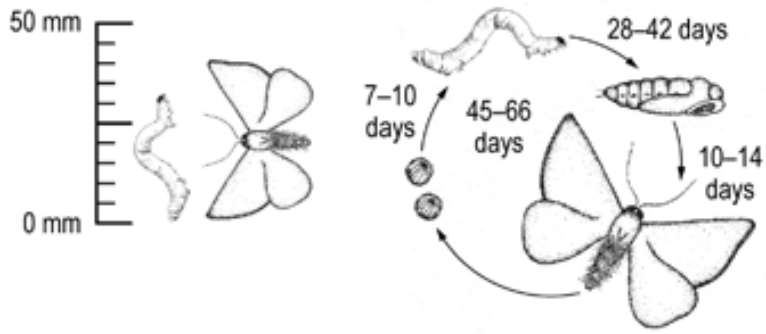
Vector: Not a disease vector

Commonly found: On the underside of leaves, and can be difficult to see. Look for elongate, dark-brown droppings on lower leaves or on the ground near plants.

Beneficials: *Trichogramma*[CA] and *Telenomus* wasps parasitise eggs, tachinid flies parasitise larvae, and generalist predators feed on eggs and larvae.

Management:

- Monitor moth activity using light traps.
- Visually monitor leaves for eggs, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs and larvae.



☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

Adult

Larva

Pupa

Asian corn borer

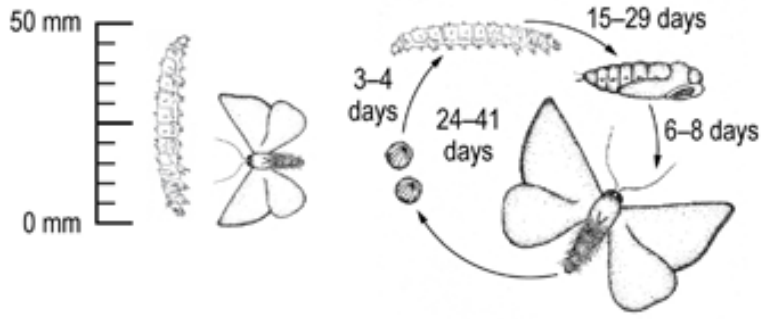
Ostrinia furnacalis (*Of*)

Importance: Minor in Australia

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Maize, sorghum, millet and other grasses

Similar to: Other pyralid caterpillars



Description:

Egg: Oval; light yellow or cream, turning black before hatching. Eggs are deposited in overlapping clusters on the upper leaf and hatch in 3–5 days.

Immature: Young larvae are pink or yellowish grey. Mature larvae are up to 50 mm long, and white with wart-like black spots on each body segment. Pupae are found wherever the last feeding occurred.

Adult: Adults are brownish or straw coloured, with a wingspan of approximately 30 mm. In a lifetime, a female can deposit up to 1,500 eggs and fly 1.5 km.

Damage: Stem boring leads to yield loss, provides entry points for secondary rots and may result in the crop lying on the ground (lodging).

Vector: Not a disease vector

Commonly found: Leaves, stems, fruit

Beneficials: *Trichogramma*[CA] wasps, larval parasitoids, Neuroptera[CA], earwigs and *Orius*[CA] pirate bugs

Management:

- Monitor moth activity using light and pheromone traps.
- Visually monitor leaves for egg masses, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applicaitons for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs and larvae.

☐ Seedling ☐ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Adult (W. Leedham)

Larva (W. Leedham)

Larva in growing tips

Pupa (W. Leedham)

Beet webworm

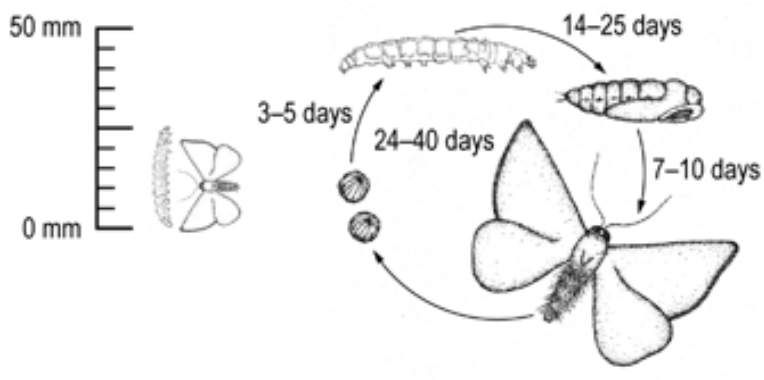
Spoladea recurvalis (*Sr*)

Importance: Minor

Crops: Eggplant

Other hosts: Beetroot, silverbeet and a range of weeds

Similar to: Other pyralid caterpillars



Description:

Egg: Bluish, scale-like and laid singly or in pairs on the lower leaf surface.

Immature: Young larvae are creamy white in colour but develop to grey–green with a distinct dark line down the middle of the back. The full-grown caterpillar is about 25 mm long, spindle shaped and usually stretched out, so that the two prolegs on the last abdominal segment are distinctly visible. When larvae are mature, they drop to the ground and spin tubular cocoons about 12 mm long in the soil at the base of the plant; they pupate just below the surface.

Adult: The adult moth is dark brown and about 19 mm across with outstretched wings. The forewings have two oblique white bands. The hindwings are divided by a single broad, oblique, white band. They are triangular in shape when resting.

Damage: Usually feed on leaves but may eat flowers and fruit. Early instar larvae feed on the lower surface of leaves; later instars skeletonise whole leaves and web plant parts together, feeding inside the web.

Vector: Not a disease vector

Commonly found: On leaves at any crop stage

Beneficials: *Trichogramma*[CA] wasps, larval parasitoids, Neuroptera[CA], earwigs and *Orius*[CA] pirate bugs

Management:

- Remove alternative wild hosts from around crop to reduce the likelihood of crop damage, particularly for autumn crops.
- Maintain weed-free cultivation before planting.
- Visually monitor leaves for eggs, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs and larvae.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ■ Flower ■ Fruit

Adult (W. Leedham)

Larva (W. Leedham)

Larva (S. Ramasamy)

Eggfruit caterpillar

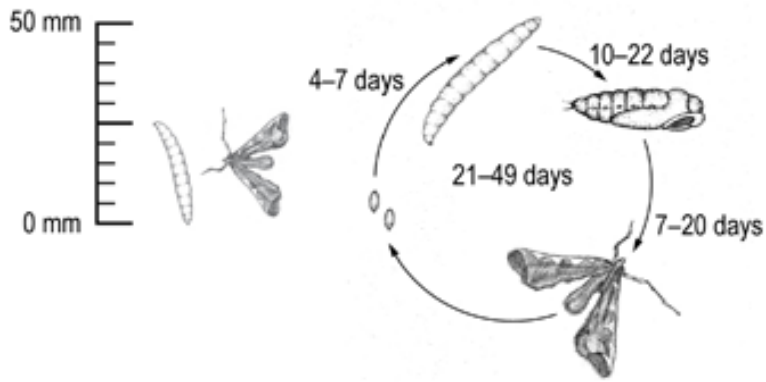
Sceliodes cordalis (*Sc*)

Importance: Major for eggplant

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Thornapples and native species of *Solanum* (nightshades)

Similar to: Other pyralid caterpillars



Description:

Egg: Creamy white, oval and dome shaped. One or two eggs are laid on the calyx of each fruit. A single moth is capable of laying 100 eggs in one night.

Immature: Newly hatched larvae have a colourless body with a brown head. As the larvae mature, they turn pink and have a smooth, glistening appearance. Fully grown caterpillars can reach 25 mm long.

Adult: The adult moth has a wingspan of about 25 mm. Wings are yellowish brown with transverse markings. The forewings have golden tips with black edges.

Damage: Most larvae bore into the fruit, causing it to break down and rot. Some larvae bore into the stem, causing the plant to wilt.

Vector: Not a disease vector

Commonly found: Moths are active at night. Eggs are usually laid on the calyx and larvae bore into the fruit at the stem end.

Beneficials: Eggs and larvae are fed upon by a range of generalist predators including predatory bugs, wasps, beetles and spiders.

Management:

- Monitor moth activity using light and pheromone traps.
- Visually monitor fruit for eggs, larvae, beneficial activity and feeding damage.
- Use foliar insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs and larvae.

☐ Seedling ☐ Plant ☐ Root ■ Stem ☐ Leaf ☐ Flower ■ Fruit

Adult (I. Kay)

Adult

Eggs

Larvae (I. Kay)

Exit hole (I. Kay)

Damage

Eggplant fruit and shoot borer

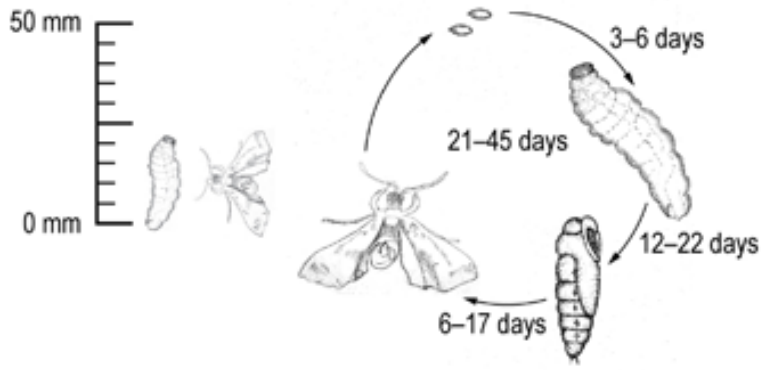
Leucinodes orbonalis (*Lo*)

Importance: Major on eggplant

Crops: Tomato, eggplant

Other hosts: Solanaceous weeds

Similar to: Other pyralid caterpillars



Description:

Egg: Eggs are creamy white when laid and turn red before hatching. They are flattened ovals in shape and 0.5 mm in diameter. Eggs are laid on the lower surface of young leaves, green stems, flower buds or calyces of fruits.

Immature: Young caterpillars bore into tender shoots near the growing point, into flower buds, or into fruit. Older larvae prefer fruit over the other plant parts. A full-grown larva is 18–23 mm long. Pupation occurs in tough silken cocoons among fallen leaves on the soil surface near the base of eggplant plants.

Adult: Young adults are generally found on the lower leaf surfaces after emerging. Moths have a 20–22 mm wingspan. The white wings have a pinkish or bluish tinge and are edged with small hairs; forewings have a number of black, pale and light-brown spots. The bodies are white with pale brown or black spots on the back of the thorax and abdomen.

Damage: Soon after hatching, larvae bore into the nearest tender shoot, flower or fruit, and plug the entrance hole with excreta. Larval feeding results in wilting of the young shoots and is a common sign of this pest. The damaged shoots, flowers and fruit wither and drop off, reducing plant growth and crop yield.

Vector: Not a disease vector

Commonly found: On leaves, flowers and fruit

Beneficials: Sixteen parasitoids, three predators and three species of entomopathogen. Only the ichneumonid wasp parasitoid *Trathala flavoorbitalis* has shown high levels of parasitism.

Management:

- Use resistant varieties of plants.
- Monitor moth activity using light and pheromone traps.
- Visually monitor stems, leaves, flower buds and fruit for eggs, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs and larvae.
- Promptly eliminate eggplant stubble from old plantings to prevent movement or carryover of *Lo* to new crops, or from season to season.

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ■ Fruit

Adult (S. Ramasamy)

Egg (S. Ramasamy)

Larva (S. Ramasamy)

Larva (S. Ramasamy)

Pupae (S. Ramasamy)

Damage (S. Ramasamy)

Damage (S. Ramasamy)

Damage (S. Ramasamy)

Death's head hawkmoth

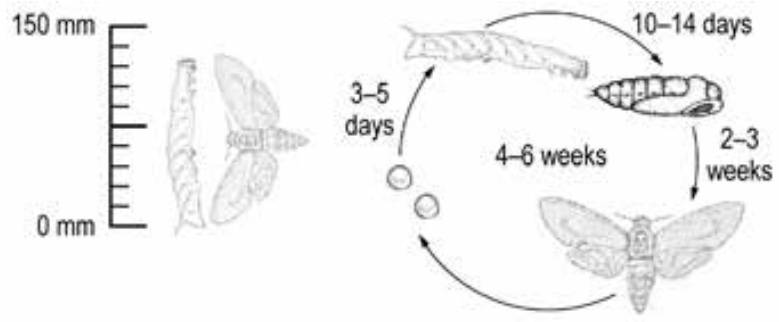
Acherontia styx

Importance: Not known

Crops: Tomato, eggplant

Other hosts: Cucurbits, beans

Similar to: Other sphingid caterpillars



Description:

Egg: Oval; 1.5–1.2 mm long; glossy, pale green changing to yellowish green just before hatching. Laid singly on leaves and usually hatch 3–5 days later.

Immature: Newly hatched larvae are 5 mm long, yellowish green with a long, black, fork-tipped horn. In the second instar, white lateral stripes and numerous small white spots (tubercles) appear. Fully grown larvae are 90–120 mm long, and can be green, yellow or brown, with lateral stripes and spots, and a distinct posterior horn. Pupae are smooth, glossy and light brown. Generally found in top 10 cm of soil.

Adult: Large and heavily built, with relatively large, dark forewing with two medial bands on the underside. Wingspan of 90–120 mm. Hindwings are yellow with black submarginal lines. Dorsal surface of thorax has a skull-like marking. Antennae are stout, with an even thickness and a fine terminal hook.

Damage: Larvae feed on young leaves and shoots, potentially defoliating whole crops.

Vector: Not a disease vector

Commonly found: On shoots

Beneficials: Two tachinid fly species parasitise the larvae: *Drino* (*Zygobothria*) *atropivora* and *D. ciliata*. *Trichogramma* spp. are known to parasitise the eggs.

Management:

- Monitor moth activity using light traps.
- Visually monitor leaves for eggs, larvae, beneficial activity and feeding damage.
- Use foliar and systemic insecticides if necessary to control severe infestations, and time applications for egg hatch and first-instar larvae. Where possible, choose selective chemistries such as *Bacillus thuringiensis* (Bt) to minimise harm to lepidopteran and other pest predators.
- In small plantings, physically remove eggs and larvae.
- Cultivate soil to a depth of 10 cm or perform 'pupae busting' after harvest to help reduce carryover of population between crops.

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

Adult (W. Leedham)

Eggs—newly laid egg is white, black egg is parasitised

Egg—mid development (note yellow colour)

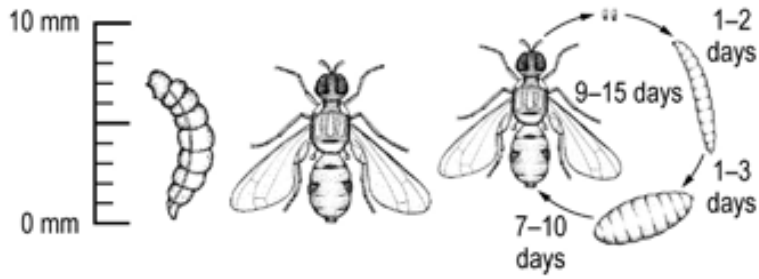
Larva (W. Leedham)

Larva (W. Leedham)

Pupa (W. Leedham)

Fruit fly—Tephritidae (Tep)

Melon fruit fly *Bactrocera cucurbitae* (*Bac*), oriental fruit fly *B. dorsalis* (*Bd*), solanum fruit fly *B. latifrons* (*Bl*), Queensland fruit fly *B. tryoni* (*Bat*)



Importance: Major and frequent

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Species dependent, wide range of fruiting plants

Similar to: A brightly coloured housefly

Description:

Egg: White, banana shaped, laid in batches of 6–12 underneath the skin of fruit.

Immature: White-to-creamy maggots with tapering ends and no legs or head, 6–8 mm long.

Adult: 6–8 mm long fly with red–brown to yellow markings along the side of the body. Tephritids can overwinter as adults in sheltered areas.

Damage: Egg-laying sites in maturing and ripe fruit and subsequent larval feeding on fruit tissue encourages fruit-rotting organisms.

Vector: Not a disease vector

Commonly found: Often seen walking on underside of leaf or on surface of fruit.

Beneficials: Braconid wasps parasitise eggs; ants and ground beetles feed on larvae.

Management:

- Monitor fruit fly populations with pheromone (male) and protein bait (female) traps.
- Use baited insecticide sprays on trunks or surrounding vegetation to reduce high populations.
- Remove unharvested mature fruit and destroy crops as soon after harvest as possible.
- Manage fruit fly in other nearby hosts.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ☐ Leaf ☐ Flower ■ Fruit

■ **Australia** (*Bat, Bac*) ■ **Cambodia** (*Bac, Bd, Bl*)

Bactrocera cucurbitae (Shepard, Carner and Ooi)

Bactrocera tryoni

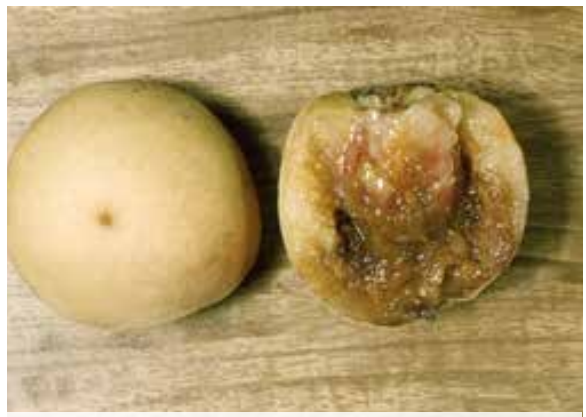
Bactrocera tryoni (J. Bentley)

Bactrocera tryoni eggs

Bactrocera tryoni larvae

Bactrocera tryoni pupae

Bactrocera tryoni damage to capsicum



Bactrocera tryoni damage to peach

Fungus gnats—Sciaridae

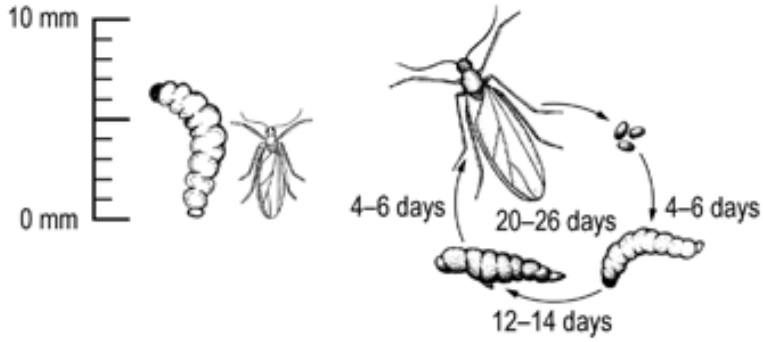
Bradysia spp. (*Bspp*)

Importance: Minor, more of a problem in glasshouses

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Most greenhouse vegetables, decaying vegetation and fungi

Similar to: Other small flies, and mosquitoes



Description:

Egg: Very small, whitish, laid in cracks and crevices of soil surface.

Immature: White, semitransparent and maggot-like, with distinctive black head. Pupates in soil.

Adult: Small, slender, black or dark-brown fly with long dangling legs and long antennae. They are weak fliers, and have a Y-shaped vein at the tip of the wing.

Damage: Larvae feed on organic matter and roots, stripping root hairs, especially of seedlings and young plants. They tunnel into stems at and below the soil line, causing collapse of tissue. Larvae and adults can spread fungal diseases.

Vector: Larvae can ingest fungal spores such as *Pythium* and *Fusarium* and spread them in both the larval and adult stages. Adults can spread foliar diseases such as *Botrytis*.

Commonly found: Running over soil or substrate surface and leaves (adults) and close to roots (larvae).

Beneficials: Predatory mites[CA], entomopathogenic nematodes[CA], staphylinid beetles[CA], parasitic wasps

Management:

- Ensure good root zone drainage.
- Avoid wet areas in crop.
- Use only clean (sterilised) potting mix or substrate.
- In hydroponic systems, ensure irrigation lines are cleaned between plantings.
- Use *Bacillus thuringiensis* (Bt) strain israelensis or entomopathogenic nematode sprays on damaging populations, if necessary. In greenhouses, predatory mites or staphylinid beetle releases can help control populations.

■ Seedling ☐ Plant ■ Root ☐ Stem ☐ Leaf ☐ Flower ☐ Fruit

Adult

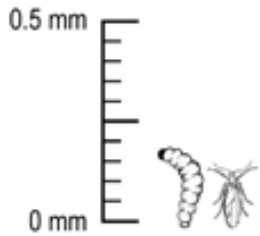
Adult

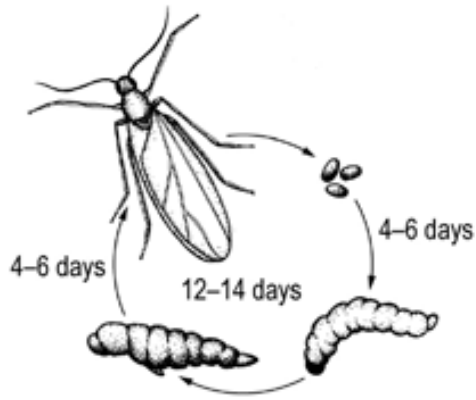
Larva

Pupa

Gall fly—Cecidomyiidae flies

Asphondylia capsici (*Ac*)





Importance: Occasional pest. In Indonesia, damage is most severe early in the season when parasitism rates are low.

Crops: Capsicum, chilli

Other hosts: Not known

Similar to: Other small flies, and mosquitoes

Description:

Egg: Very small eggs are deposited in chilli or capsicum.

Immature: White, semitransparent maggots feed inside the chilli or capsicum.

Adult: Small fly is unlikely to be seen.

Damage: Can cause small, deformed pods when attacked in early development, and twisted, distorted pods when attacked later in development.

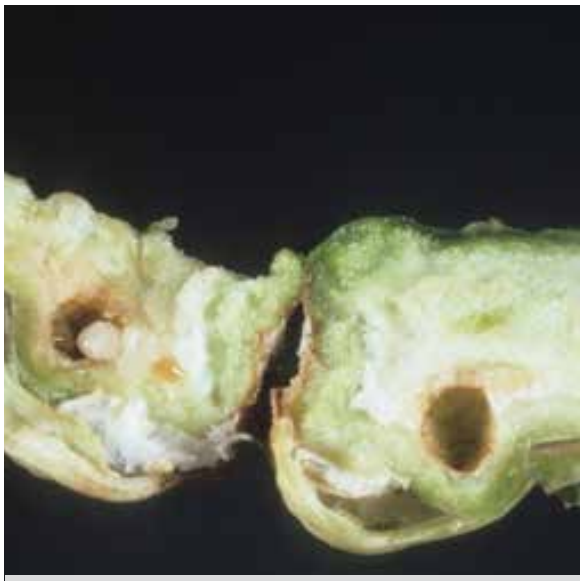
Vector: Not a disease vector

Commonly found: Pupae are often seen partially protruding from pod.

Beneficials: In Indonesia, larval parasitoids are important in regulating populations of this fly.

Management: Not well studied

☐ Seedling ☐ Plant ☐ Root ☐ Stem ☐ Leaf ☐ Flower ■ Fruit



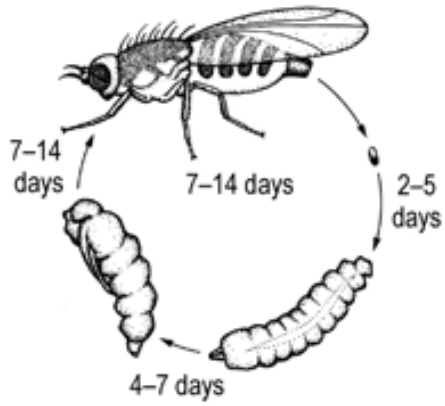
Larva (Shepard, Carner and Ooi)

Pupa (Shepard, Carner and Ooi)

Damage (Shepard, Carner and Ooi)

Leafminers—Agromyzidae

Serpentine leafminer *Liriomyza huidobrensis* (*Lh*), vegetable leafminer *L. sativae* (*Ls*)



Importance: Common, potentially major

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Range of other vegetables and weeds

Similar to: Other small flies (adults) or leafminers (larvae)

Description:

Egg: Single eggs are deposited under the upper surface of leaves; many eggs may be deposited on a single leaf.

Immature: Small, yellow larvae (without head capsule) feed on plant tissue under upper surface of leaf, creating irregular 'mines'. Mature larvae are about 3 mm long before pupating either in the soil or on the leaf.

Adult: Small (1.5 mm long), shiny, black-and-yellow flies with reddish eyes.

Damage: Heavy infestations cause leaves to dry out and drop.

Vector: Not a disease vector

Commonly found: On leaves

Beneficials: Many parasitic wasps

Management:

- Grow seedlings in a well-netted nursery to avoid early infestation.
- Remove alternative host weeds in and around crop.
- Remove or destroy crops immediately after harvest to reduce population increase.

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

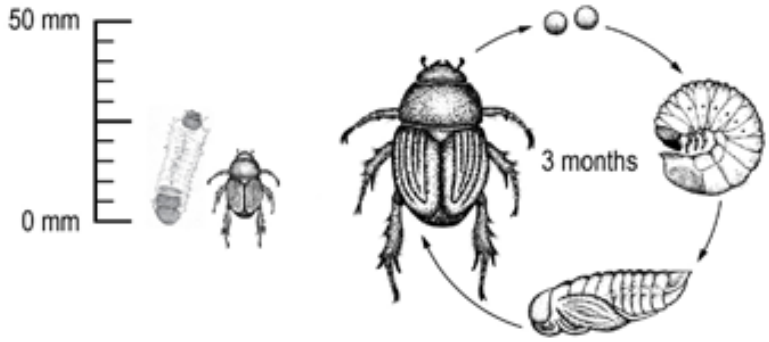
Fly on tomato leaf

Fly on eggplant

Larva removed from tomato mine

Mines on tomato leaf

White grubs, cockchafers or scarabs (Sca)



African black beetle *Heteronychus arator* (*Har*), other species

Importance: Minor and infrequent, field crops only

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Brassicas, potatoes, pastures

Similar to: Other scarabids

Description:

Egg: Greyish-white, oval, laid in soil.

Immature: Typical white curl grubs up to 25 mm long with three pairs of legs on the thorax and a prominent brown head with black jaws. The abdomen is swollen, baggy and grey or blue–green due to the food and soil they have eaten.

Adult: *Har* is 15 mm long with shiny, black, ridged wing covers. Other species may be shades of brown, orange, green or iridescent, and up to 30 mm long. They are slow moving and are mostly found in soil with immediate past history as pasture. These insects overwinter as non-reproductive adults.

Damage: *Har* adults chew stems just below ground level, leaving a frayed edge. Plants may wilt and fall over. *Har* populations are worse after prolonged dry weather. Some scarab beetles feed on leaves, leaving large holes and skeletonised patterns. Young larvae feed on dead organic matter in the soil; older larvae may feed on roots.

Vector: Not a disease vector

Commonly found: *Har* adults are usually found on or under the soil surface. Adults of some other species may be on crop leaves. The eggs, larvae and pupae are all underground stages; the beetles are the only stage that appears above ground.

Beneficials: *Heterorhabditis zealandica* nematode[CA] and insect fungal pathogens

Management:

- Not commonly a problem; however, keep records of timing and place of infestation for future spot treatments.
- It may be necessary to use pre-plant insecticides in areas where infestation is common and serious.
- Remove or destroy infested crops immediately after harvest and cultivate the soil to destroy surviving adults and larvae.

☐ Seedling ☐ Plant ■ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

Adult

Larva

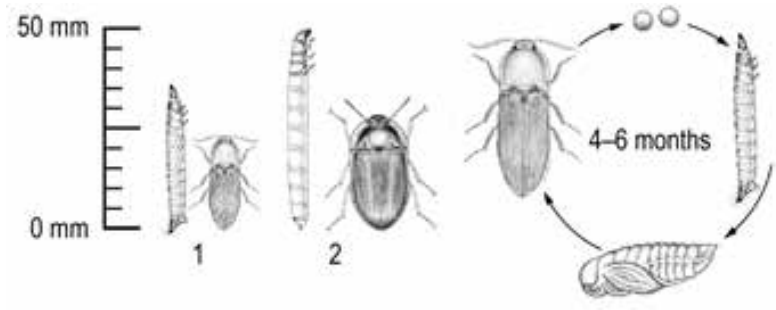
Larva

Larva

Stem damage

Wireworm and false wireworm

Wireworm—elaterids (Ela)[1], false wireworm—tenebrionids (Ten)[2]



Importance: Minor and infrequent, field crops only

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Most field-grown vegetables, field crops and weeds

Similar to: Each other (larvae)

Description:

Egg: Elaterid and tenebrionid eggs are tiny, pearly white, round and usually deposited singly among soil particles, and hence are rarely seen. Elaterids prefer moist soil for depositing eggs, whereas tenebrionids prefer dry soil.

Immature: Elaterid larvae have soft, semi-flattened, smooth, creamy-white or pale-yellow bodies about 20–40 mm long. They have a darker, wedge-shaped head and a forked tooth-edged tail. Tenebrionid larvae have hard, round, smooth yellow–brown or blackish-brown bodies with pointed upturned tails, and vary in length up to 50 mm.

Adult: Elaterid adults are commonly known as 'click beetles'. They are brown or black in colour, and have six legs and a torpedo-shaped body. Tenebrionid beetles are a dull grey, brown or black, and can be either oval or slender in shape. Tenebrionids have two generations a year.

Damage: Most damage is restricted to below the soil surface, where the larvae feed on germinating seed and the roots and shoots of seedlings.

Vector: Not a disease vector

Commonly found: Elaterid larvae are usually found just below the soil surface in moist soil, whereas tenebrionid larvae are more usually found in dry soil.

Beneficials: Predatory nematodes, insect fungal pathogens

Management:

- Know your paddock history—previously weedy or pasture paddocks are at higher risk.
- Apply a pre-sowing insecticide to the soil if high pest numbers are present or expected.
- Note that control measures after the crop has emerged can be difficult and are rarely justified.
- Avoid infestations by leaving fallow for 3–6 months before planting.

☐ Seedling ☐ Plant ■ Root ☐ Stem ☐ Leaf ☐ Flower ☐ Fruit

Elaterid adult

Elaterid larva

Elaterid larva

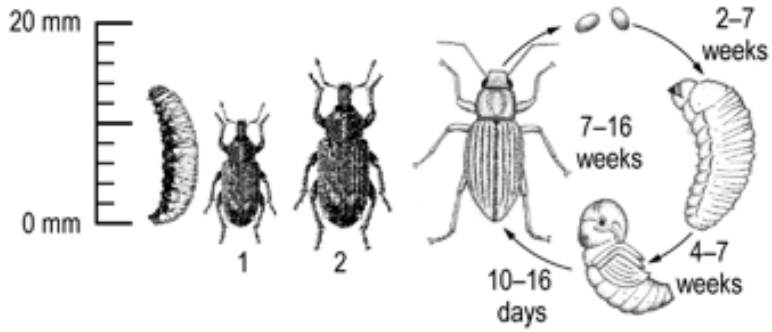
Tenebrionid adult

Tenebrionid larva

Tenebrionid larva

Weevils—Curculionidae (Cur)

White-fringed weevil *Graphognathus leucoloma*[1] (*Gl*), gold dust weevil *Hypomeces squamosus*[2] (*Hs*), vegetable weevil *Listroderes difficilis*[1] (*Ld*)



Importance: Minor and infrequent, field crops only

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide range of vegetables and weeds

Similar to: Other weevils

Description:

Egg: Eggs are oval and about 1 mm long, and laid on the soil surface or soil trash.

Immature: Weevils hatch as legless grubs. *Ld* is cream to pale green, and *Gl* is white or grey. Grubs are up to 12 mm long.

Adult: Weevils are box-shaped beetles with a distinct 'snout' and solid wing covers. *Ld* is 10 mm long, grey–brown in colour and has a characteristic V-shaped marking on the wing covers. *Gl* is 10 mm long with a white band around the edge of the wing covers. *Hs* is yellow and/or green and up to 15 mm long.

Damage: Larvae can feed on the roots and underground stem of plants. The underground stem may become ringbarked or extensively damaged, causing stunting and some plant death. Adults can chew holes in the leaves.

Vector: Not a disease vector

Commonly found: Larvae can be found beneath the soil surface on the roots. Adults are commonly found on the soil surface or on plant material.

Beneficials: Predatory beetle larvae such as carabids are known to attack *Gl* larvae.

Management:

- Note that controlling the larval stage is difficult once the plants have been attacked.
- Avoid infestations by leaving fallow for 3–6 months, and implement weed control before planting.
- Control adults with insecticides if necessary; however, some insecticides may cause population flares in mites, thrips or whiteflies.

☐ Seedling ☐ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

■ Australia (*Ld*, *Gl*) ■ Cambodia (*Hs*)

Graphognathus leucoloma

Graphognathus larva

Graphognathus pupae

Hypomeces squamous (W. Leedham)

Listroderes difficilis eggs, larva and adult

Monolepta beetle

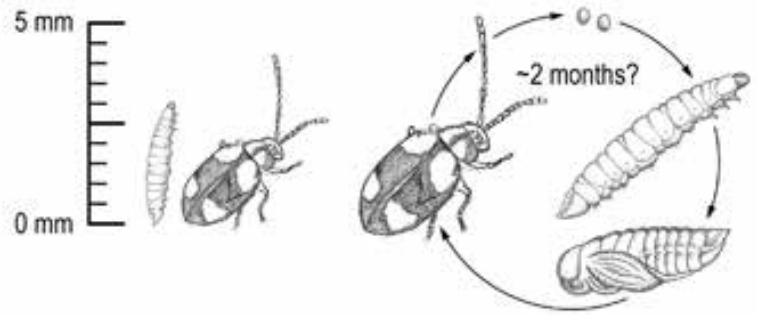
Monolepta signata (*Ms*)

Importance: Major on seedlings

Crops: Capsicum, chilli, eggplant

Other hosts: Soybean, millet, brassicas

Similar to: Other small beetles such as fleabeetles



Description:

Egg: Minute eggs are laid in soil cracks around the base of the host plant.

Immature: Minute worm-like larvae live in the soil and feed on small plant roots and root hairs.

Adult: The hard forewings are black with two yellowish markings, one in front and the other behind the middle. Head, thorax and abdomen are reddish brown in older beetles and much brighter in younger beetles. Beetles are about 3–3.8 mm long with long antennae.

Damage: Adults eat large holes in leaves.

Vector: None

Commonly found: Adults are conspicuous on leaves.

Beneficials: Little is known.

Management:

- Reduce damage on the target crop by planting more attractive trap crops (this has been successfully used for other fleabeetles).
- Screen seedlings or use floating row covers.
- If possible, grow crops or seedlings in raised situations (i.e. on tables).

■ Seedling ☐ Plant ■ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

Adult

Crickets and locusts (Ort)

Australian plague locust *Chortoicetes terminifera* (*Ct*), migratory locust *Locusta migratoria* (*Lm*), black field cricket *Teleogryllus commodus* (*Tc*), mole cricket *Gryllotalpa* spp. (*Gspp*)

Importance: Minor and infrequent, field only

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide range of vegetables and weeds

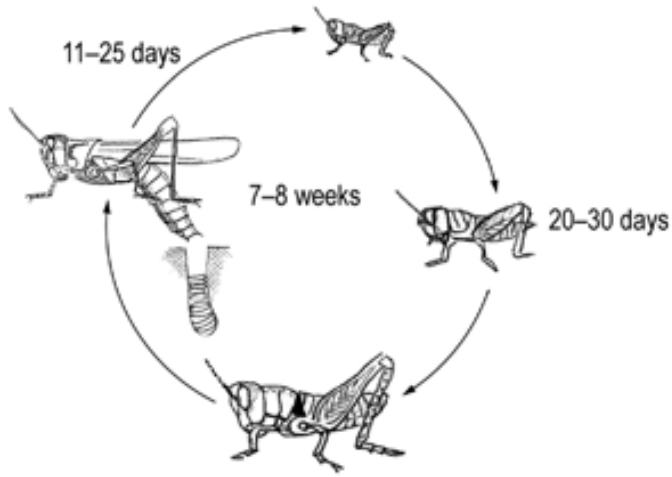
Similar to: Other Orthoptera

Description:

Egg: Locusts and crickets lay creamy-coloured, banana-shaped eggs. *Gspp* lays brown eggs.

Immature: Young Orthoptera look similar to adults but are paler and without wings. Nymphs moult six times before becoming adults.

Adult: *Tc* is dark brown to black and about 25 mm long. *Lm* and *Ct* are up to 65 mm long, and have two pairs of wings (gauzy hindwings folded beneath shorter horny forewings) and large, strong hind legs adapted for jumping. *Gspp* are yellowy to brown and about 30 mm long. They have two pairs of wings, with the hindwings projecting from under the forewings in the form of wisps.



Damage: Crickets and locusts damage young plants by chewing stems and roots, which results in death of seedlings and severe wilting in older plants. Crickets are also capable of chewing holes in irrigation drip tube. Locusts are only a problem when they have banded together—they then act as a large super-organism.

Vector: Not a disease vector

Commonly found: Eggs are laid in large numbers within oval chambers in the soil. Adults are found on and in the soil and soil trash.

Beneficials: In higher-rainfall areas a range of parasites will feed on orthopteran hosts, including egg parasitoids (*Scelio fulgidus*: scelionid wasp), various flies, mites, entomopathogenic nematodes and fungi. Common predators include Asilidae flies, birds, mammals and reptiles.

☐ Seedling ☐ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

■ Australia ■ Cambodia (except *Ct*)

Locusta migratoria

Teleogryllus commodus (QDAFF)

Teleogryllus damage (QDAFF)

Gryllotalpa spp. (QDAFF)

Management:

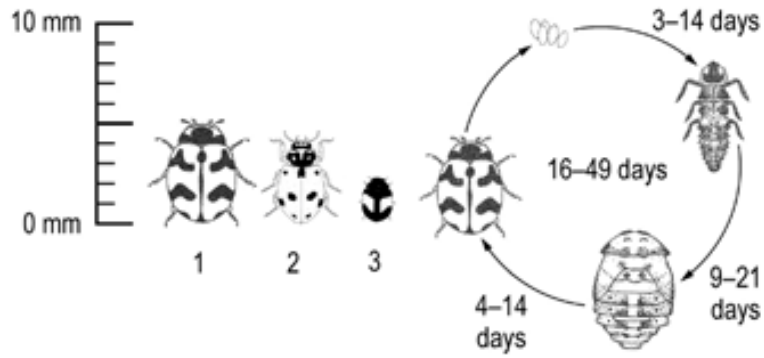
- Use baits that contain insecticide to control crickets.
- Use a heavier gauge drip irrigation tube to reduce damage by crickets.
- Use metarhizium fungus to control locusts (commercially available for locust control in Australia).
- Use row covers to protect crops from locusts.

Beneficial organisms

Ladybird beetles—Coccinellidae

There are many predatory ladybird beetle species. Some of the commonly found ones are:

- six-spotted ladybird *Cheilomenes sexmaculata*[1]
- transverse ladybird *Coccinella transversalis*[1]
- minute two-spotted ladybird *Diomus notescens*[3]
- common spotted ladybird *Harmonia conformis*[1]
- spotted amber ladybird *Hippodamia variegata*[2,CA]
- striped ladybird *Micraspis frenata*[2]
- mite-eating ladybirds *Stethorus* spp.[3]



Description:

Egg: Upright yellow eggs are deposited in clusters.

Immature: 'Crocodile-like' larvae, usually grey or black with white or orange markings, often with small spines. Pupae look hunched.

Adult: Dome-shaped, oval, shiny beetles. Usually black or orange and most commonly orange with black stripes, spots or distinct patterns on their wing covers.

Predatory activity:

- Both larvae and adults are generalist predators and eat a range of insects they can catch.
- Adult *Hippodamia*, *Micraspis*, *Cheilomenes*, *Coccinella* and *Harmonia* beetles feed on aphids, moth eggs and small larvae.
- *Diomus* beetles feed on thrips and mites.
- *Stethorus* spp. beetles feed on mites.

Cheilomenes adult

Cheilomenes larva

Cheilomenes pupa

Coccinella eggs, larva and adult

Diomus adult

Diomus larva

Harmonia adults and larva

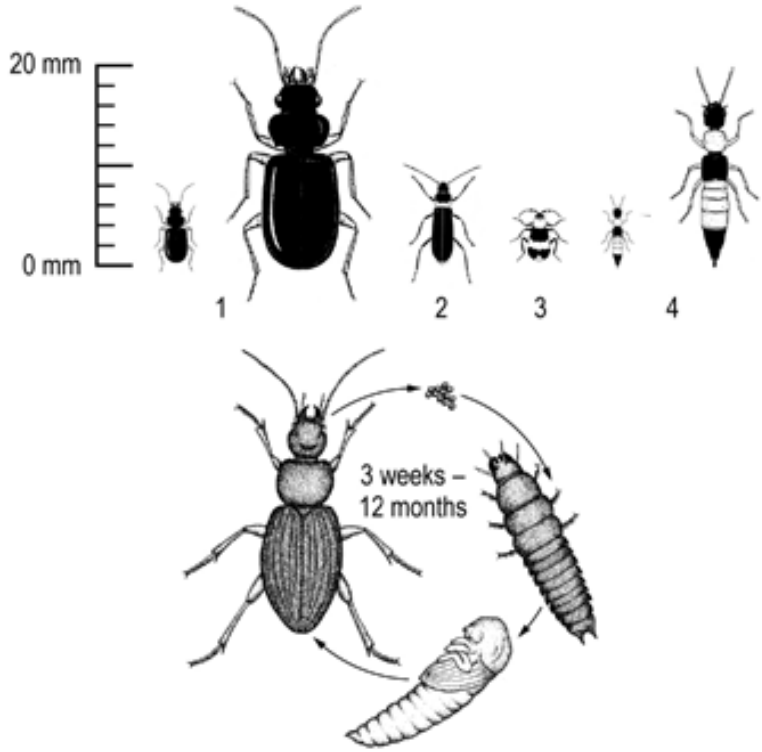
Hippodamia larva and adult

Micraspis adult

Stethorus adult

Other predatory beetles—Coleoptera

Ground beetles or carabids[1], soldier beetle *Chauliognathus lugubris*[2] (*Cl*), red and blue or pollen beetle *Dicranolaius bellulus*[3] (*Db*), rove beetles or staphylinids[4,CA]



Description:

Egg: Laid in clusters in soil debris.

Immature: Larval and pupal stages occur in the soil.

Adult: *Db* and *Cl* beetles search actively during the day over foliage, while the other predatory beetles tend to forage in soil litter. *Db* and *Cl* beetles also like to feed on flower pollen. *Cl* beetles can fly into crops in large numbers. Staphylinid beetles vary in colour and size, depending on the species. They have short wing covers that expose their abdominal segments. There are many species of carabid beetles. They vary in size depending on species and are usually glossy black, live on the soil surface and tend to be active at night. When disturbed, the adult predatory beetles quickly take shelter in soil cracks or leaf debris. This behaviour may help them to survive in crops during an insecticide spraying. Their life cycle generally takes about 1 year. They overwinter as adults.

Predatory activity:

- Both larvae and adults are generalist predators that actively search for small insects, eggs and small larvae.
- Larvae are active predators in the soil; adults are active predators on the soil surface and on plants.
- Larger beetle larvae can feed on *Agrotis* and Elateridae, and potentially on pupating *Helicoverpa,* whereas smaller beetle larvae can feed on *Bradysia* and *Scatella* larvae and thrips pupae.
- Carabids can also be important predators for slugs.

Carabid adult

Carabid (*Calleida* sp.) (Shepard, Carner and Ooi)

Carabid (*Calleida* sp.) larva are also predacious (Shepard, Carner and Ooi)

Chauliognathus adult

Dicranolaius adult

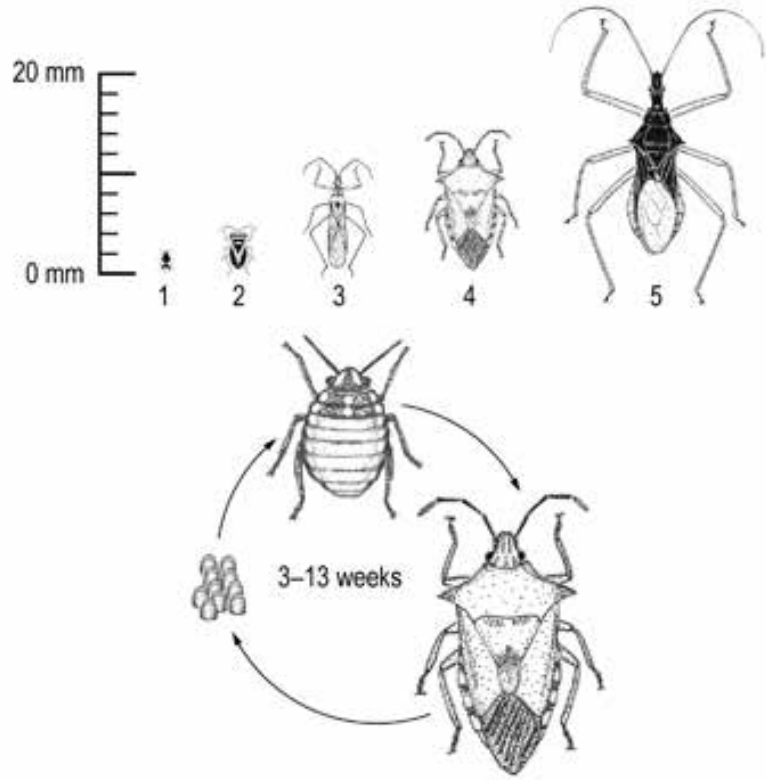
Staphalinid adult

Staphalinid adult (Shepard, Carner and Ooi)

Predatory bugs—Hemiptera

There are many species of predatory bugs, but the most commonly observed include:

- pirate bug, *Orius* spp.[1,CA]—feeds on thrips, caterpillar eggs and very small larvae
- big-eyed bug, *Geocoris lubra*[2]—fast-moving, daytime hunter of soft-bodied insects, caterpillar eggs and very small larvae
- damsel bug or nabid, *Nabis kinbergii*[3,CA]—feeds on caterpillar eggs, small larvae and aphids
- predatory shield bug, *Oechalia schellenbergii*[4]—feeds mainly on caterpillars
- assassin bug, *Pristhesancus* spp.[5]—feeds on a range of insects and can prey on quite large caterpillars.



Description:

Egg: Eggs are often barrel-like and deposited in ordered groups.

Immature: Nymphs look similar to adults but without wings, and they may have different colouring (e.g. *Oechalia*).

Adult: Adults have wings that are partly sclerotised (like a shell) and partly membrane, and these are held flat above the abdomen when not in use. True bugs all have piercing and sucking mouthparts. Nymphs and adults are very mobile.

Predatory bugs can be easily confused with plant-feeding bugs.

Predatory activity:

Predatory bugs have piercing mouthparts and suck out insect or egg contents. They are generalist predators and active hunters. They feed on what is available and usually catch prey that is smaller than themselves.

Geocoris adult (C. Mares)

Nabis adult (D. Ironside)

Oechalia adult (W. Leedham)

Oechalia egg raft

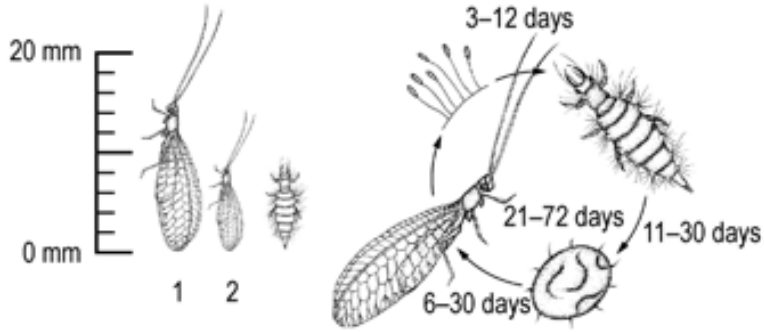
Oechalia first-instar nymphs

Orius adult

Pristhesancus adult (M. Shephard)

Lacewings—Neuroptera

Green lacewing *Mallada signata*[1,CA] (*Ms*), brown lacewing *Micromus tasmaniae*[2,CA] (*Mt*)



Description:

Egg: Oval and white or cream. *Ms* eggs are found on thin, flexible stalks either singly or in groups. *Mt* eggs are found singly on leaves.

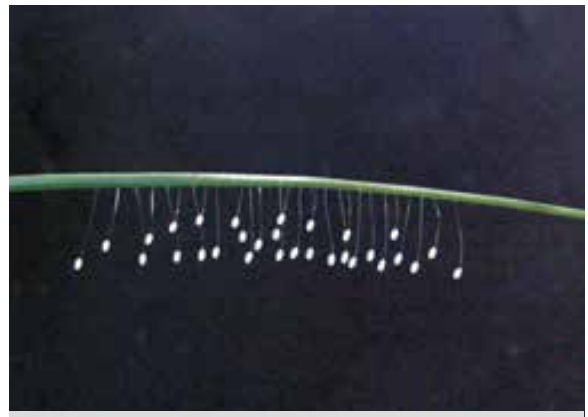
Immature: Lacewing larvae are soft bodied, and pale, mottled brown with large sickle-shaped jaws used for piercing and sucking out the contents of their prey. *Mt* is 5 mm long; *Ms* is 8 mm long and larvae camouflage themselves with the remains of their prey. Larvae pupate in a thin silk cocoon.

Adult: *Ms* adults are 10–15 mm long and have a slender, pale-green body with clear, finely veined wings. *Mt* adults are 8–10 mm long and have a mottled-brown body with lace-like, slightly hairy wings, large eyes and long antennae. *Mt* adults are predatory, while *Ms* adults only feed on nectar and pollen.

Predatory activity:

- Lacewing larvae and *Mt* adults are generalist predators. They are particularly voracious against aphids (can eat 60 per hour), but will also attack other soft-bodied insects such as mealybugs, soft scales, whiteflies, thrips, mites, small caterpillars and moth eggs.
- Larvae can be cannibalistic when food is scarce.
- *Mt* is active during the day and is commonly seen in field crops.
- *Ms* is nocturnal, and its stalked eggs are easily seen.

Mallada adult (non-predacious) (J. Berger)



Mallada eggs

Mallada larva

Mallada larva

Micromus adult (predator)

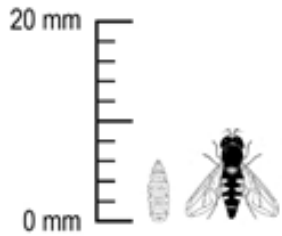
Micromus eggs

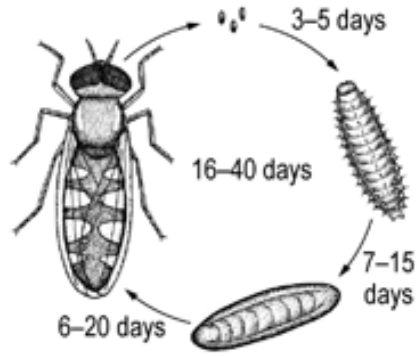
Micromus egg

Micromus larva-feeding aphid (J. Bentley)

Hover flies—Diptera

Syrphidae





Description:

Egg: White, oval eggs laid on their side near aphid colonies.

Immature: Larvae are slug-like maggots, 2–6 mm long, yellow to greenish with pale, mottled stripes along the back.

Adult: Adult flies resemble bees and wasps with black-and-yellow bands across their abdomen, and are readily identified by their 'hover' near plants. The adult flies feed on nectar and pollen, so are most abundant near flowering plants.

Predatory activity:

Larvae are voracious aphid predators and may also feed on eggs, small caterpillars and thrips. Adults are pollen feeders.

Syrphid adult

Syrphid adult

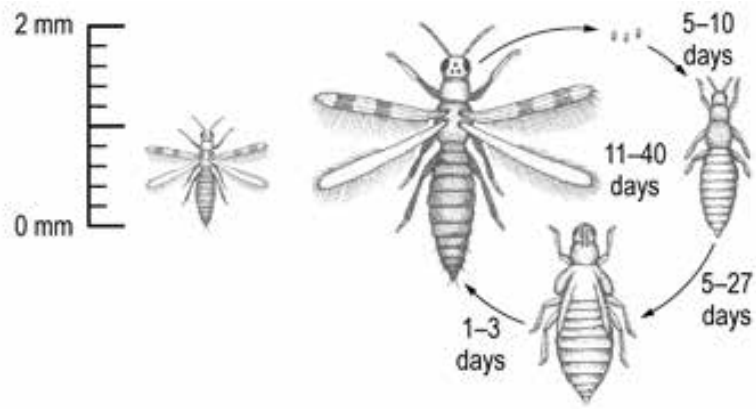
Syrphid pupa (top) and larva (bottom)

Syrphid larva eating an aphid (Shepard, Carner and Ooi)

Syrphid pupa

Predatory thrips—Thysanoptera

Haplothrips victoriensis (*Hv*), *Scolothrips rhagebianus* (*Sr*), Aeolothripidae



Description:

Egg: Eggs are torpedo shaped, about 0.2 mm long and deposited on the surface of flowers or leaves either in groups or singly. *Hv* eggs change colour from milky white to yellow to orange as they develop.

Immature: Thrips larvae are torpedo shaped, about 0.5–1.5 mm long and wingless. Pupa are similar but without legs. Colours vary between species. *Hv* larvae are bright red. Most *Haplothrips* and *Scolothrips* larvae have some red or orange colouring, although *Sr* larvae are yellowish.

Adult: Thrips are tiny, torpedo-shaped insects about 1.5–1.9 mm long. They have two pairs of wings that have fine hairs around the margins. *Hv* is black with transparent wings, Aeolothripidae are black with white segment bands and distinctive black-and-white striped wings, whereas *Sr* is yellowish with six dark wing spots.

Predatory activity:

Predatory thrips are found in three thrips families. Most of the species in the Aeolothripidae are thought to be predacious on mites and other small insects. Of the Tubulifera thrips, the genus *Haplothrips* has a number of predatory species. Although most species within the Thripidae are plant-feeding thrips, thrips in the genus *Scolothrips* are predatory. In the case of predatory thrips, the piercing mouthparts are used to suck out insect or egg contents. They are generalist predators and active hunters but, because of their small size, can only feed on very small prey such as other thrips, mites and small eggs. They are often found among plant-feeding thrips, although they usually have distinctly different colouring.

Haplothrips adult

Haplothrips larva

Haplothrips larva

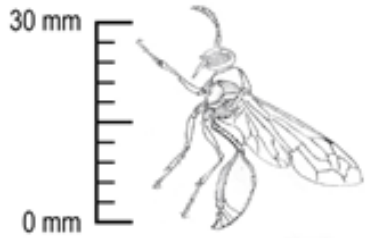
Scolothrips rhagebianus adult

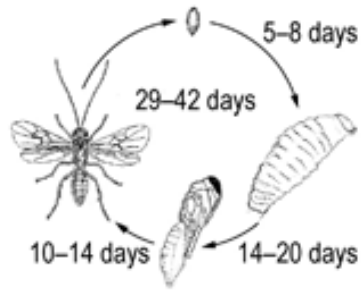
Scolothrips rhagebianus adult (H. Brown)

Scolothrips rhagebianus larva (J. Duff)

Predatory wasps—Hymenoptera

Vespidae, Sphecidae





Description:

Egg: Eggs are laid in mud or paper cells.

Immature: Maggot-like grubs in the wasp nest

Adult: Large and medium wasps (2–3 cm)

Predatory activity:

Predatory wasps from the Vespidae and Sphecidae families are active predators that catch insects, particularly caterpillar larvae and spiders. Some they eat themselves; others they stun and put into paper or mudnest cells, which they seal after depositing an egg. The larvae hatch in the cell and feed on the immobilised (but not dead) insect, pupate and emerge from the cell as adults.

Sceliphron spp. wasp

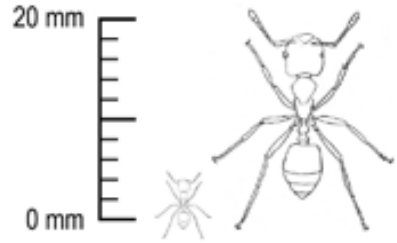
Predatory wasp searching on tomato

Predatory wasp searching on tomato

Predatory wasp searching on ground

Ants—Formicidae

Formicidae



Description:

Egg: Eggs are small, cream coloured and elongated. They are laid by the queen in large numbers within the ant nest.

Immature: Ant larvae are maggot-like and live deep within the ant nest. Larvae are fed and tended by worker ants.

Adult: Ant adults vary considerably in size and form within the same species, depending on their role in the colony. Worker ants are usually small; soldier ants are larger and have a relatively larger head capsule and mandibles. There is a large number of different ant species; they are usually 3–10 mm long, but can be up to 25 mm.

Predatory activity:

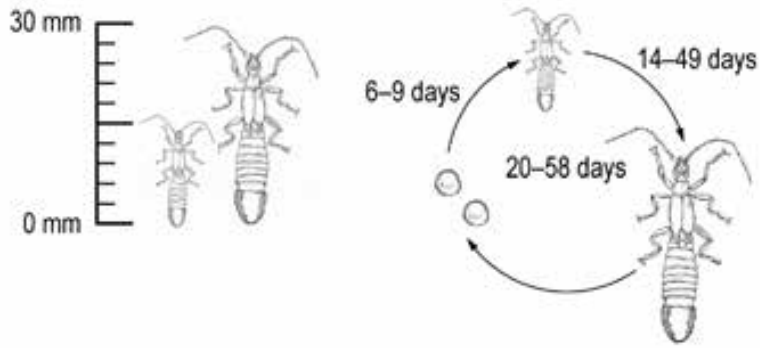
Only some ant species are predatory; they feed on small insects, eggs, caterpillar larvae, mealybugs and aphids. Some ant species 'farm' aphids for their honeydew, and will protect them from predators and parasites.

Ants foraging

Ants foraging

Ants bringing home a *Helicoverpa* caterpillar (P. Chanty)

Earwigs—Dermaptera



European earwing *Forficula auricularia*, common brown earwig *Labidura truncata*, black field earwig *Nala lividipes* and many other species

Description:

Egg: Oval, white eggs deposited in natural crevices or burrows in the soil.

Immature: Nymphs resemble pale, wingless adults and are usually in the burrow.

Adult: Earwigs are 1.5–3 cm long and have distinctive pincers at the 'tail' that are often used to carry prey after it has been killed. Earwigs hide on and in the ground during the day, and hunt for prey at night.

Predatory activity:

Earwigs are poorly researched. Many species are known to be both predatory and plant feeding. Some research suggests that tropical species are usually more predatory than plant feeding, whereas temperate species feed on plants more often. Earwigs like to be under objects or in crevices during the day and are more active at night, feeding on caterpillars, pupae, eggs and other insects.

Cambodian earwig (W. Leedham)

Forficula auricularia—male (left), female (right)

Labidura truncata feeding on *Helicoverpa* larva (M. Shephard)

Labidura truncata

Nala lividipes

Mantids—Mantidae

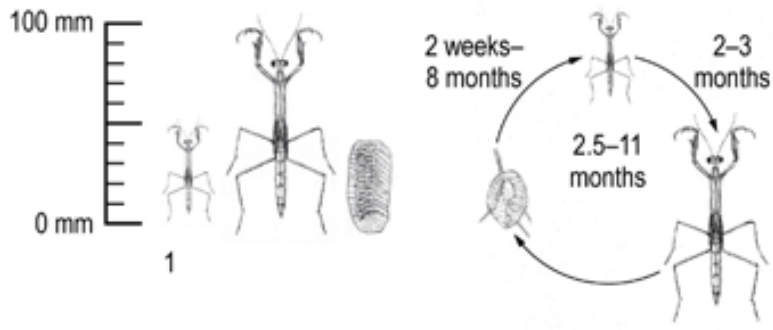
Mantidae

Description:

Egg: Eggs are laid in distinctive white egg masses.

Immature: Small, wingless praying mantis nymphs hatch and disperse from the egg mass to avoid being eaten by other hatching nymphs. The nymphs look like smaller versions of the adults, but are wingless.

Adult: Large, stick-like insects with distinctive raptorial (hooked) front legs or arms to catch prey.



Predator activity:

Mantids are all predators. Newly hatched mantids seek out the nearest food, which may be other newly hatching mantids or small insects. As they grow, they feed on progressively larger insects. Mantids are ambush predators, waiting very still, often hidden and when a suitable prey strays close, they very quickly grab it and usually eat the head first.

Adult

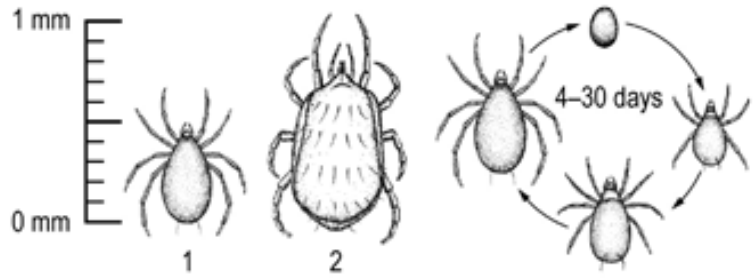
Adult

Egg mass

Egg mass

Nymph

Predatory mites—Acari



Soil predatory mites such as *Hypoaspis* spp.[2] and *Pergamasus* spp.[2,CA], western predatory mite *Galendromus* (= *Typhlodromus*) *occidentalis*[1,CA] (*Go*), cucumeris predatory mite *Neoseiulus cucumeris*[2,CA] (*Nc*), persimilis spider mite predator *Phytoseiulus persimilis*[1,CA] (*Pp*), montdorensis thrips predator *Typhlodromips montdorensis*[1,CA] (*Tm*)

Description:

Egg: Usually clear white (although *Pp* eggs have an orange tinge), slightly oval, 0.1–0.15 mm long, and deposited on soil or leaf surface, often within spider mite colonies. Predatory mite eggs are approximately 1.5 times the size of spider mite eggs.

Immature: Clear, pear shaped and fast moving. The first stage has six legs and the second stage has eight legs. *Pp* larvae are orange.

Adult: Cream in colour, pear shaped and fast moving, with eight legs. *Pp* are orange.

Predatory activity:

Predatory mites are some of the most effective predators of plant-feeding mites. They are active predators that are commonly found within colonies of spider mites. Predatory mites search foliage and are often found on the underside of leaves, in flowers and at the soil surface. Commercially reared predatory mites can be released in greenhouses and be effective biocontrol agents. Releases into field crops are not always successful. Native populations can assist in pest management.

- Soil predatory mites (*Pergamasus* spp. and *Hypoaspis* spp.) can feed on fungus gnats (fly larvae), aphids and thrips pupae on the soil surface and on the crop foliage.
- *Go* feeds on all stages of spider mites (*Tetranychus* spp.). It supplements persimilis predatory mites in dry hot greenhouses, but develops more slowly. It is tolerant to some pesticides.
- *Nc* feeds on thrips larvae and spider mites (*Tetranychus* spp.). It will eat some pollen, and likes humid conditions.
- *Pp* feeds on spider mites (*Tetranychus* spp.), particularly *T. urticae*. It is resistant to a number of pesticides. *Pp* is orange in all stages, and likes humid conditions.
- *Tm* feeds on thrips larvae, but also other mites, including eriophyid mites. All stages feed on prey. It spends most of its time on the underside of leaves, but can also be found on fruit and flowers. It will eat some pollen.
- Commercially reared mites are commonly used effectively in greenhouses. Field releases are less well researched; however, predatory mites naturally colonise field-grown crops.

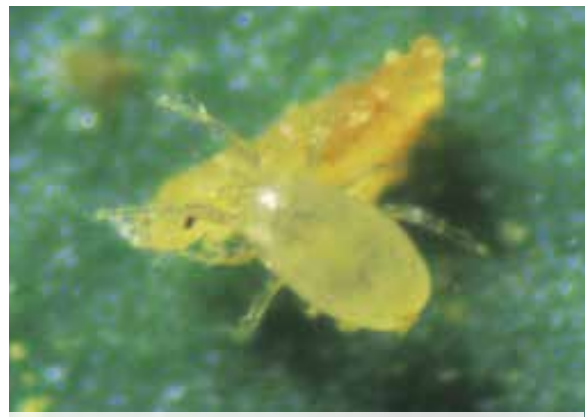
Hypoaspis adult

Cucumeris approaching thrips nymph

Cucumeris adult and egg

Persimilis adult feeding on a *Tetranychus urticae*

Persimilis nymph feeding on a *Tetranychus urticae*

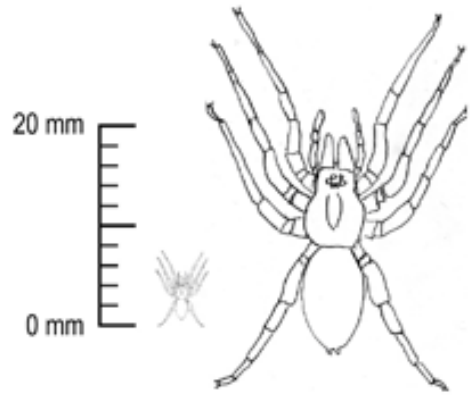


Montdorensis feeding on thrips nymph

Montdorensis eggs

Spiders—Araneae

Orb weavers (araneids) (7–40 mm),
wolf spiders (lycosids) (15–50 mm),
lynx spiders (oxyopids) (12–20 mm),
jumping spiders (salticids) (4–15 mm),
crab spiders (thomisids) (5–10 mm)



Description:

Egg: Eggs are usually contained within a white, silk-coated ball.

Immature: Spiderlings are smaller versions of adults.

Adult: Adults have a head, a body with eight legs and an abdomen. Size varies with species.

Predatory activity:

Different spider groups use different hunting strategies:

- Lycosids are active hunting soil dwellers.
- Thomisids and oxyopids are active hunting foliage dwellers.
- Araneids are web spinners.

Spiders hunt or snare a range of insects, including leafhoppers, caterpillars, thrips and mites. Spiders are usually seen year-round and numbers do not increase with an increase in pest numbers. They can tolerate many pesticides.

Araneid

Lycosid

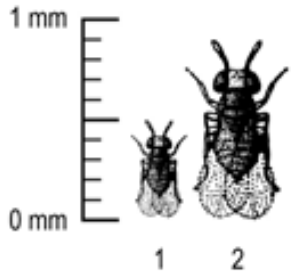
Oxyopid

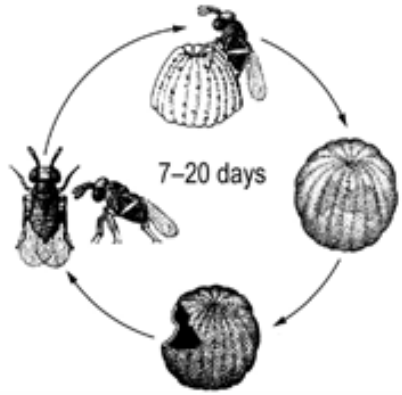
Salticid eating a cockroach

Thomisid (University of California)

Moth egg parasitoids

Trichogramma spp.[1,CA] (*Tspp*), *Telenomus* spp.[2] (*Tespp*)





Description:

Egg: Minute, laid into moth egg.

Immature: Maggot-like larval stages feed on developing caterpillars inside moth egg. When the larvae finish growing, they pupate in the egg and the egg shell turns a uniform, distinctive, silvery-black colour.

Adult: *Tspp* wasps are tiny (0.5 mm long), and yellow–brown to black depending on species. *Tespp* wasps are 0.8 mm long and all black. Both have elbowed antennae and four wings.

Parasitic activity:

Egg parasitoids develop in and kill the eggs of their host. *Tspp* and *Tespp* are parasitoids of a range of moth (Lepidoptera) eggs, particularly *Helicoverpa* spp. and *Spodoptera* spp. Unparasitised moth eggs are initially creamy white, then develop an orange ring, showing the growing caterpillar (particularly its dark head capsule) just before hatching. Parasitised eggs turn a pinkish silvery black when the parasitoid is pupating. The tiny, dark-brown-to-amber wasp chews a circular hole in the egg shell to emerge. Two or three *Tspp* wasps typically emerge from one parasitised moth egg, but only one *Tespp* wasp emerges per parasitised egg. Females can parasitise more than 50 moth eggs in a 7–10 day life span. Moth egg parasitoids are less active in rainy conditions.

Visually monitor leaves for parasitised black eggs, and collect white eggs and hold for a few days to check for parasitism.

Trichogramma carverae female (right) male (left) on light-brown apple moth eggs

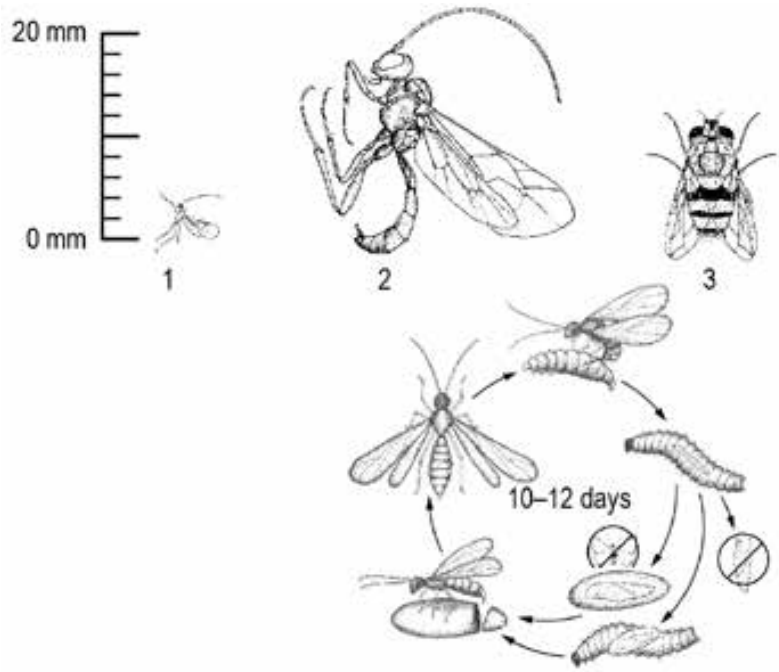
Trichogramma pretiosum parasitising a heliothis egg

Helicoverpa eggs—top shows silver grey of a parasitised egg (J. Bentley)

Telenomus sp. parasitising heliothis eggs (B. Scholz)

Caterpillar parasitoids

Braconids: *Microplitis demolitor*[1] (*Md*) and *Cotesia* spp.[1](*Csp*); ichneumonids: *Netelia* spp.[2] (*Nsp*); tachinid flies[3]



Description:

There are a range of larval and pupal parasitoids of caterpillars in the braconid and ichneumonid families of wasps and tachinid flies.

Egg: Laid on or in the caterpillar. Some tachinids lay eggs on leaves where caterpillars are feeding, which hatch in the caterpillar gut after consumption. Pupal parasitoids lay eggs onto or into caterpillar pupae.

Immature: Pale, maggot-like larvae feed inside the caterpillar. *Md* forms a buff-coloured cocoon (5–7 mm long) on the outside of the immobile (but still alive) caterpillar to pupate. *Csp* completely consumes the entire caterpillar and forms many creamy-yellow cocoons.

Adult: *Nsp* is an orange, medium-sized (25 mm long) wasp. *Md* (3 mm long) and *Csp* (2 mm long) are small, dark-brown-to-black wasps, with long ovipositors. Tachinids are robust flies (7–10 mm).

Parasitic activity:

Adult wasps and tachinid flies search foliage for caterpillars or pupae on which to deposit eggs. When the eggs are deposited on the outside of the host, the egg hatches and the larva burrows into the caterpillar or pupa to feed. Parasitised caterpillars continue to feed but grow more slowly than normal. The parasitoid exits when it has finished feeding and pupates on the outside of the dying caterpillar. In the case of *Nsp*, the caterpillars form their pupa chamber in the soil before the wasp emerges from the host caterpillar to pupate.

Cotesia adult parasitoid

Cotesia larvae exposed from a caterpillar

Cotesia pupae formed around a dead caterpillar

Microplitis demolitor parasitising a *Helicoverpa* caterpillar (M. Shephard)

Microplitis demolitor pupa attached to a *Helicoverpa* caterpillar

Netelia adult (K. Power)

Netelia egg behind caterpillar head

Netelia pupa

Tachinid fly (W. Leedham)

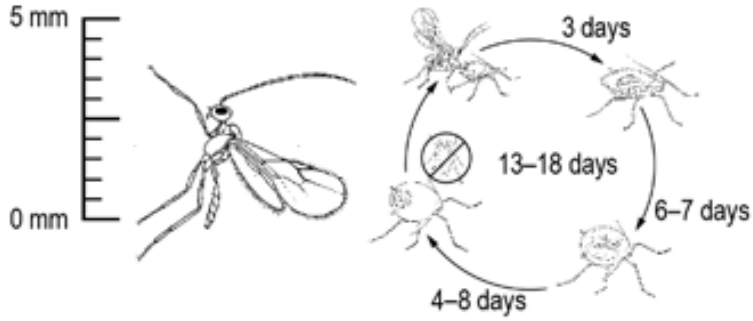
Tachinid egg (D. Ironside)

Tachinid larva (W. Leedham)

Tachinid pupa

Aphid parasitoids

Aphelinus spp., *Aphidius* spp.



Description:

Egg: Minute, laid inside the aphid.

Immature: Grub-like larval stage feeds on the body fluids of the aphid, ultimately causing the aphid's death.

Adult: Small, black wasp emerges through a circular hole in the abdomen of the aphid shell.

Parasitic activity:

Aphid parasitoids can effectively control some aphid species. Parasitised aphids stop feeding and 'puff up'. The aphid shell turns black (*Aphelinus* spp.) or tan (*Aphidius* spp.); these are called 'aphid mummies'.

Aphidius colemani[CA] is used for control of *Myzus persicae*.

Aphelinus sp. parasitised aphid 'mummy'

Aphidius colemani parasitising aphids

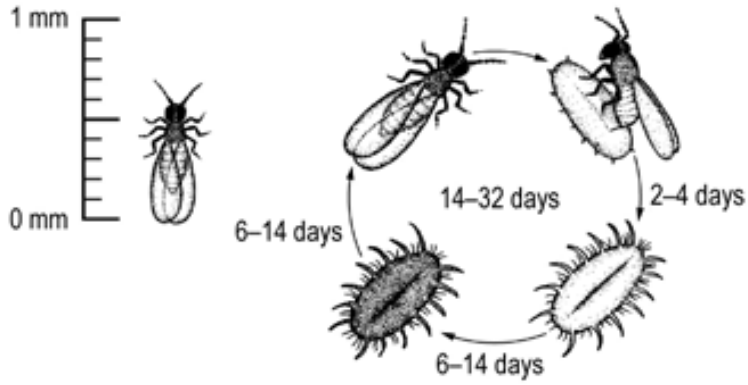
Aphidius colemani adults

Aphidius colemani emerging from an aphid 'mummy'

Aphidius colemani aphid 'mummy' and *Myzus persicae* nymphs

Whitefly parasitoids

Encarsia formosa[CA] (*Ef*),
Eretmocerus hayati[CA] (*Eh*)



Description:

Egg: Usually a single egg is laid inside late third-stage and early fourth-stage whitefly nymphs (known as 'scales').

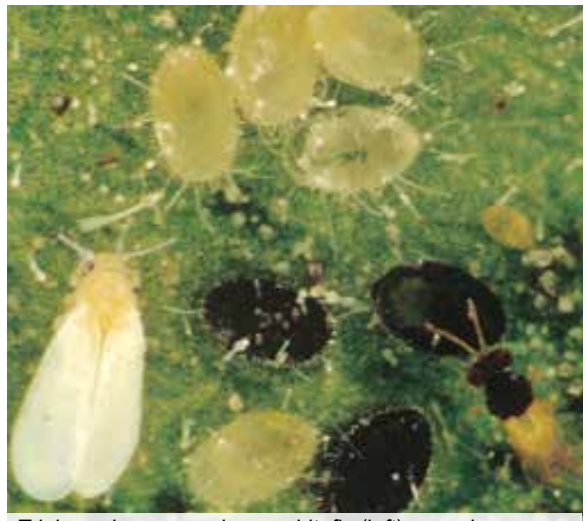
Immature: Soft-bodied larval stages feed and pupae develop inside whitefly scale. Parasitised whitefly pupae turn black, and unparasitised pupae remain creamy white. Black or brown pupae are usually found on leaves that are more than 3 weeks old (lowermost leaves).

Adult: *Ef* females (0.6 mm long) have a dark head and thorax, and a yellow abdomen. Males have a darker abdomen and are rare. *Eh* females (0.7 mm long) are bright yellow; males are common and darker yellow.

Parasitic activity:

- *Ef* attacks greenhouse whitefly. It can kill younger whitefly nymphs by direct feeding, and parasitise older nymphs. It has a very good searching ability and is effective in climate-controlled greenhouses.
- *Eh* was introduced to Australia in 2004 to control *Bemisia tabaci* biotype B. It has spread widely and is helping to reduce the size of *Bemisia* field populations.

Encarsia formosa (right) emerged from parasitised whitefly pupa (left)



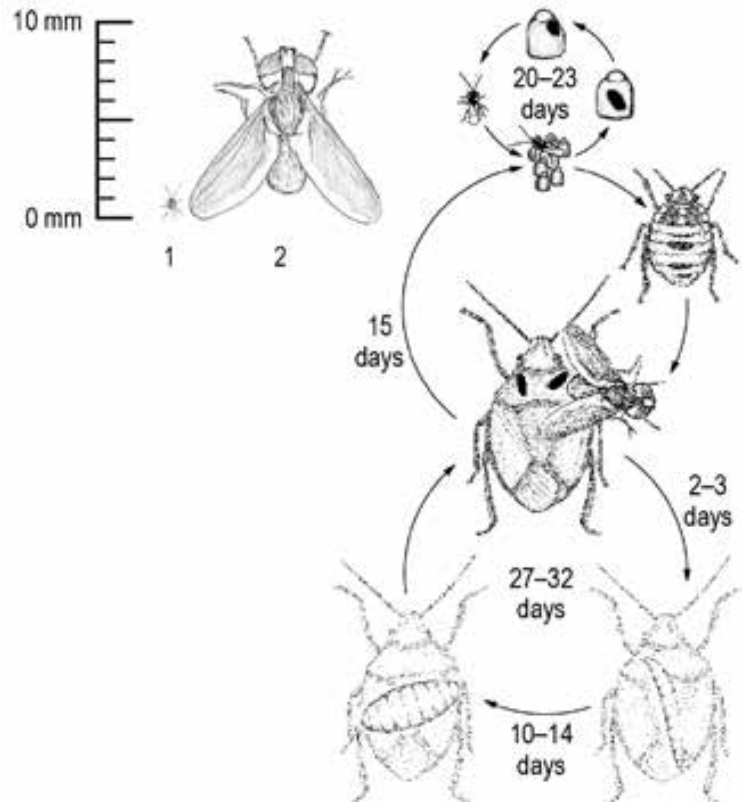
Trialeurodes vaporariorum whitefly (left), nymphs and pupa (parasitised = black, unparasitised = yellow/white), and *Encarsia* wasp (right)

Eretmocerus hayati female (P. De Barro)

Eretmocerus hayati male (P. De Barro)

Nezara parasitoids

Hymenoptera: *Trissolcus basalis*[1] (*Tb*); Diptera: *Trichopoda giacomellii*[2] (*Tg*)



Description:

Egg: *Tb* deposits minute eggs within *Nezara* (*Nv*) eggs, which subsequently turn black. *Tg* lays approximately 1 mm long, creamy-white, oval eggs on the thorax or pronotum (just behind the head) of large nymphs or adults of *Nv.*

Immature: *Tb* has grub-like larvae that develop entirely within *Nv* eggs. After hatching, *Tg* larvae (maggots) burrow into *Nv* to feed for approximately 2 weeks before leaving *Nv* to pupate in the soil.

Adult: *Tb* is a tiny, black wasp (0.5 mm long), with distinctive downward elbowed antennae and a relatively small, flattened abdomen, that emerges through a circular hole in the blackened *Nv* egg. *Tg* is a tachinid fly approximately 8 mm long. Males are yellowish brown with an orange abdomen, and females are dark brown to black. Both sexes have a distinctive fringe on the hind legs.

Parasitic activity:

- *Tb* rarely parasitise a whole raft of *Nv* eggs, although parasitism rates may reach 80% of egg rafts and 87% of eggs per raft. A female-biased sex ratio of up to 5:1 increases the effectiveness of the parasitoid.
- *Tg* has been released as a biological control agent in various parts of the world, including Australia, to control *Nv*. Parasitism rates of up to 72% have been measured. Although *Nv* can survive *Tg* parasitism, the females have a significantly reduced ability to reproduce.

Trissolcus basilis wasp on a *Nezara* egg raft (T. Smith)

Trissolcus wasps emerging from *Nezara* eggs (J. Wessels)

Trichopoda giacomellii fly (W. Leedham)

Trichopoda fly eggs on *Nezara* (J. Wessels)

Phthorimaea (potato moth) parasitoid

Orgilus lepidus[CA]

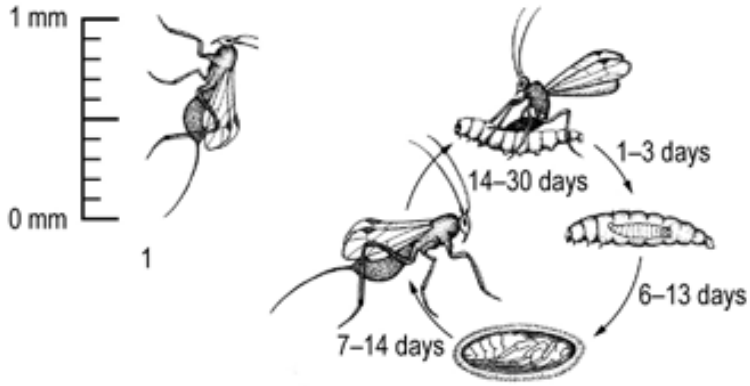
Description:

Egg: Translucent, white, smooth with a pointed end. Laid into the larval stage of the potato moth, *Phthorimaea operculella*.

Immature: Develops inside host with three larval stages.

Adult: Small, yellowish-brown wasp. Female has a long, straight ovipositor that is about the same length as the body, and long antennae.

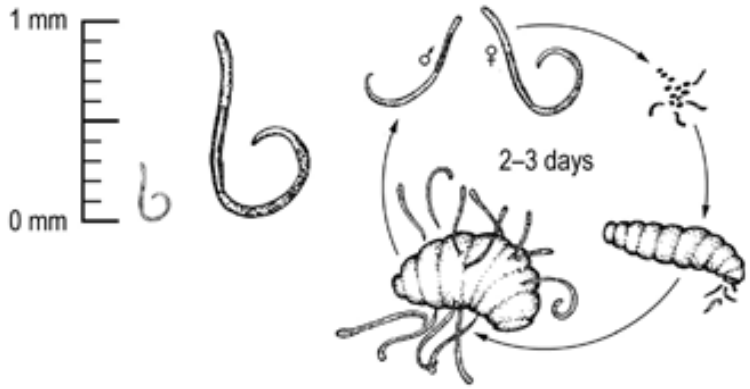
Parasitic activity: Adult wasps (9 mm long) lay one egg in each *Phthorimaea operculella* caterpillar. After hatching, the larva of *Orgilus* feeds on, and develops inside, the caterpillar. The *Orgilus* larva spins a cocoon inside the caterpillar cocoon to pupate. An adult wasp later emerges from the cocoon.



Adult ovipositing into *Phthorimaea operculella* larva within leaf (D. Crawford)

Insect-feeding nematodes

Steinernema feltiae[CA], *Heterorhabditis* spp.[CA] (*Hspp*)



Description:

Egg: Usually laid in host.

Immature: Tiny (< 1 mm), translucent, unsegmented 'worms' (note that earthworms are segmented and much larger). Two or three larval stages are completed inside the host. Commercial formulations sell the nematodes as infectious third-stage larvae, which is the only stage that can survive outside the host.

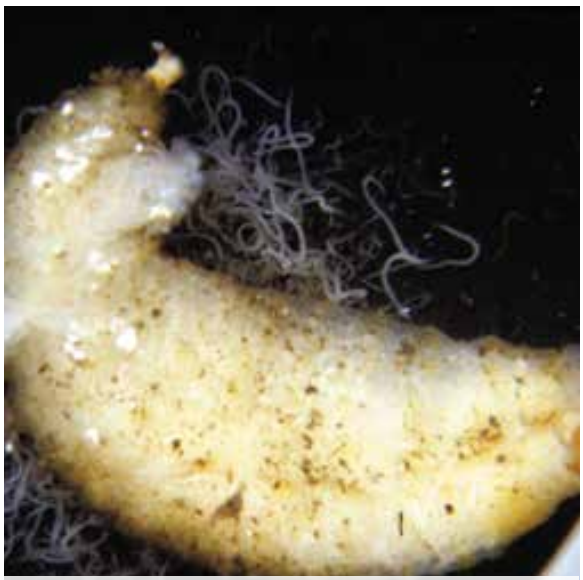
Adult: Similar to immature stages but larger (~1.5 mm). Nematodes cannot withstand dry conditions.

Parasitic activity:

An infective third-stage juvenile enters a suitable host through a natural opening. *Hspp* can also penetrate the skin to colonise a new host. They release symbiotic bacterial cells that rapidly multiply and kill the host within 24–48 hours. The nematodes then feed on the bacteria and host tissue. After two or three generations, they emerge from the dead body as infective third-stage juveniles to find another host. Infested hosts become brown to tan (steinernematid) or reddish (heterorhabditids) and cease feeding before death.

Commercial formulations are available for biocontrol of flies, thrips, beetles, termites, wasps and caterpillars. These are applied to soil in water suspension, but the nematodes may also colonise naturally in wet conditions.

Nematodes that infect insects (magnification x80)



Nematode-infected larva

Insect viral diseases

Nuclear polyhedrosis virus (NPV)

Description:

Caterpillars can be affected by species-specific NPV. Heliothis NPV^{CA}, *Spodoptera litura* NPV and *Spodoptera exigua* NPV are commercially available as biological insecticides. When infected, larvae tend to bloat and turn a pale-to-dark-brownish colour. They usually die 4–9 days after infection near the top of the plant and disintegrate, releasing a virus-laden fluid. Other larvae may be infected from an NPV spray or from eating foliage contaminated by a previously infected larva.

NPV sprays work best under situations of higher humidity or leaf wetness. Sprays made from field-collected infected larvae have successfully spread the disease. Natural infections of NPV are seen occasionally in field crops.

NPV-infected *Helicoverpa* caterpillar climbs to top of plant to die

Insect bacterial diseases

Bacillus thuringiensis (*Bt*)

Description:

Bt is a naturally occurring bacterial disease of insects. Strains of this bacteria are specific against different insect groups, and a number of strains have been commercialised as insecticides. Larvae have to eat a lethal dose from contaminated foliage to be affected by the bacteria. Feeding usually stops immediately after ingestion; however, it may take 2–5 days to kill the caterpillar. *Bt*-infected larvae do not change colour, but they do become limp.

- *Btk* (kurstaki strain)[CA] and *Bta* (aizawai strain)[CA] affect many Lepidoptera caterpillar species.
- *Bti* (israelensis strain)[CA] is effective against mosquito larvae and fungus gnats.
- Other strains (san diego/tenebrionis) are effective against beetle larvae.
- Large larvae need to eat more *Bt* than small larvae to ingest a lethal dose.
- *Bt* products are broken down by ultraviolet light, so schedule sprays for evening or early morning.

Bt-infected *Helicoverpa* caterpillar (QDAFF)

Insect fungal diseases

Metarhizium spp.[CA] (*Mspp*), *Nomuraea rileyi* (*Nr*), *Beauveria bassiana* (*Bb*)

Description:

A large number of different fungal groups attack insects. They are most common under warm, moist conditions where the spores can rapidly infect other insects. They can cause significant insect mortality, especially when host insect populations are high. Some fungal pathogens are host specific (*Nr*), while others have broader host ranges (*Mspp*). Different strains of the same fungus can have different host ranges (*Bb*).

Fungal spores germinate on or in the insect body. The fungus feeds within the insect host and, after killing the host, penetrates out of the host's cuticle, giving the characteristic white, yellow or greenish fur covering. Some of the common insect-attacking fungi are:

- *Bb*—life cycle takes 5–15 days to complete, but typically kills host in 2–9 days
- *Nr*—attacks caterpillars (Lepidoptera). Its life cycle takes 10–20 days, with host death occurring within 6–7 days
- *Mspp*—more than 200 species from more than 50 families are reported to be attacked by *Mspp*, and some strains have been commercially formulated. In Australia, the only commercial strains of *Mspp* available are for locust control.

Nomuraea rileyi–infected caterpillar (D. Holdom)

Nomuraea rileyi–infected *Helicoverpa* caterpillar

Beauveria bassiana–infected small *Helicoverpa* larva (D. Holdom)

Beauveria bassiana–infected sciarid fly

Beauveria bassiana–infected *Nysius vinitor* bug

Beauveria bassiana–infected whitefly

Fungal-diseased *Helicoverpa* pupa

Fungal-diseased tenebrionid beetle

Fungal-diseased scarab larva

Fungal-diseased aphids (Shepard, Carner and Ooi)

Bacterial diseases

Bacterial canker

Cause: *Clavibacter michiganensis* subsp. *michiganensis*

Crops: Tomato

Other hosts: Some species of nightshade (*Solanum* species)

Signs: Infected seedlings may be killed, stunted or malformed, or may show no signs until they are transplanted. In larger plants, initial signs are scorched or 'firing' markings on leaflets and wilting of lower leaves. As infection advances through the vascular system, wilting progresses until the whole plant collapses. Often only the leaflets on one side of the leaf are affected. They turn yellow, then brown, and die. Parts of the pith may collapse and become hollow. Internal browning of vascular tissue and pith cavities can be seen by snapping off a leaf at a node (the point where the leaf joins the stem). In wet conditions, brown, raised cankers may form on the stems and fruit. The fruit cankers have pale halos and are called 'bird's-eye' spots. The roots and lower stem may show little evidence of the disease although the vascular tissue inside the lower stem is brown when exposed.

Sources of infection: Infected seed or seedlings are the primary source of this pathogen. The bacterium can survive in plant residues in soil for up to 6 months, or longer if dry plant material remains on the surface. It does not survive for long periods in soil or water outside of plant material. Weed hosts provide a source of infection for subsequent crops.

Spread by: A few infected seedlings can spread the disease through the seedbed or nursery; cultural operations spread the disease easily during transplanting, pruning, tying and picking. Bacteria in the sap enter plants through wounds or abrasions produced by cultural operations; and bacteria can spread from cankers on the stems and leaves in water droplets via rain, dew or overhead irrigation.

Favoured by: Temperatures of 18–24 ºC with high relative humidity.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓			✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—bird's-eye spots

Tomato—one-sided death of leaves

Tomato—scorch marks on leaves

Tomato—scorch marks on leaves

Tomato—vascular browning

Tomato—plant looks 'silver', with scorched leaves

Bacterial soft rot

Cause: *Pectobacterium carotovorum* subsp. *carotovorum*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide range of plant species, including many vegetable crops

Signs: Initial signs in capsicum leaves show darkened veins followed by leaf chlorosis and necrosis. The pith and vascular system within nearby stems may show dark-brown discoloration. As the disease progresses, dry, dark-brown or black stem cankers develop, often resulting in the breakage of branches. Bacterial ooze may be evident from diseased tissues, but this is not always the case. The affected plants wilt and die. The fleshy fruit peduncle is highly susceptible and most often is the point of infection. Both ripe and green fruit may be affected. Initially, the lesions on the fruit are light-to-dark coloured with a water-soaked appearance, and somewhat sunken. The affected areas expand very rapidly, particularly under warm (25–30 °C) and wet environments. In later stages, bacterial ooze may develop from affected areas, and secondary organisms often invade the rotted tissue. Affected fruit hang from the plant like soft, water-filled bags and can give off a rotting odour.

Sources of infection: The bacterium is a common soil inhabitant and may survive on the surface of seed.

Spread by: Irrigation water and contact between fruit. The bacteria can enter through wounds caused by machinery, insect feeding or natural openings. Insects such as flies can also spread bacteria.

Favoured by: Warm, moist conditions. Once established, temperatures of 25–30 °C and relative humidity of more than 95% result in rapid collapse of infected plants.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓		✓	✓	✓	

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Capsicum—early fruit rot (AVRDC)

Capsicum—late fruit rot (AVRDC)

Tomato pith necrosis

Cause: *Pseudomonas corrugata* and other *Pseudomonas* species

Crops: Tomato

Other hosts: May survive on the roots of many plants.

Signs: The signs of tomato pith necrosis are similar to bacterial canker. Disease appears on older plants, where early signs include yellowing of the young leaves followed by overall plant wilt. Stems may have brown-to-black lesions on their surface, and the internal pith may also be dark or even hollow. Roots develop profusely in areas where the pith is affected, or on lower stems of affected plants.

Sources of infection: The bacteria are common in soil but signs may be scattered within a field.

Spread by: Pruning equipment and workers' hands

Favoured by: Periods of high humidity and low night temperatures. High nitrogen levels, particularly ammonium (as found in fresh poultry manure), are associated with disease occurrence.

Management:

- Do not over-fertilise with nitrogen fertilisers; avoid using fresh poultry manure.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
			✓	✓		✓				✓			✓				✓	✓	

☐ Seedling ■ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

Tomato—roots develop where necrosis affects stem

Tomato—stem dark and hollow internally

Bacterial speck

Cause: *Pseudomonas syringae* pv. *tomato*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: None

Signs: Tiny, dark spots develop on affected leaves, extend through the tissue and, if numerous, cause yellowing of the surrounding leaf areas. Stem signs occur as brown or black lesions. Affected fruit have many small, black, slightly raised spots less than 2 mm in diameter. The spots do not extend deeply into the fruit.

Sources of infection: Infected seed, seedlings and contaminated soil are primary sources of this pathogen. The disease spreads rapidly in seedbeds and many seedlings can be infected by the time they are planted out. The bacterium can survive in plant debris in the soil for 30 weeks.

Spread by: Cultural operations (cultivation and pruning); bacteria are also washed from the spots in water droplets by rain, dew or overhead irrigation.

Favoured by: Wet conditions and temperatures of 18–24 ºC.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—leaf spotting

Tomato—stem blackening

Tomato—fruit spots

Capsicum—leaf spots

Bacterial wilt

Cause: *Ralstonia solanacearum*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Potatoes, tobacco and many solanaceous weeds are infected by some strains; other strains have a wider host range.

Signs: Affected plants wilt rapidly and die without any spotting or yellowing of the leaves. If the stem of a wilted plant is cut across near ground level, the vascular tissue is dark and water-soaked, and a greyish-yellow, slimy bacterial mass can sometimes be pressed out of it. The rapid onset of wilting distinguishes this disease from bacterial canker and fungal wilts.

Sources of infection: The bacteria become established in soil and can persist indefinitely in weed hosts on uncropped land. The bacteria are carried in soil washed down by surface water following rain or irrigation. Infection occurs through roots that may have been damaged, or by feeding nematodes.

Spread by: Contaminated farming equipment and soil on tractor tyres and workers' boots.

Favoured by: High temperatures and is usually most destructive at temperatures between 21 °C and 32 °C. The disease is often severe in areas of poor drainage or after wet weather, but it can also develop in relatively dry soil. Very moist soil seems to favour initial infection but, once infected, plants wilt more readily under dry soil conditions.

Management:

- Graft susceptible commercial varieties onto resistant rootstocks.



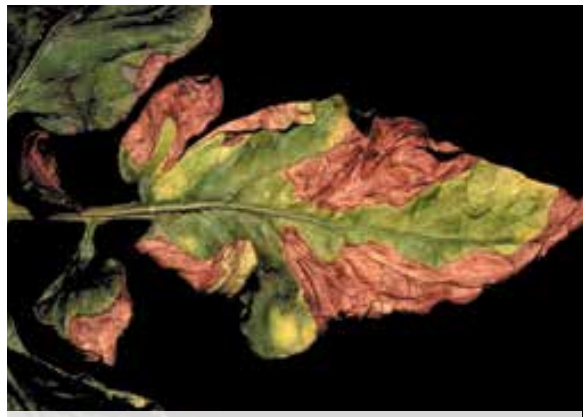



Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
			✓	✓		✓				✓			✓				✓	✓	✓

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

Tomato—severe wilting of all plants (AVRDC)



Tomato—leaf necrosis

Tomato—browning of stem vascular tissue

Eggplant—wilting (AVRDC)

Eggplant—early wilting

Eggplant—stunted plant

Capsicum—severe wilting (AVRDC)

Bacterial spot

Cause: *Xanthomonas euvesicatoria, X. vesicatoria, X. perforans, X. gardneri*

Crops: Tomato, capsicum, chilli

Other hosts: Some solanaceous weeds, especially nightshades

Signs: On leaves, small, irregular areas with a grassy appearance develop first. These areas dry out and form slightly raised dry spots that are greyish brown, particularly at the centre. The bacteria often ooze from these spots and, when dry, form a glistening, cream-coloured film on and around the lesions. Where infection is severe, the dried-out parts may combine and kill large areas of leaf. Marginal and tip burns on leaves have often been noted.

On flowers, water-soaked dark-brown-to-black areas develop, which later dry out and turn grey. Flower infection often causes blossoms and young fruit to wither and fall.

Main stems are occasionally attacked. Spots are often elongated but retain the same greyish, scab-like characteristics as other affected parts.

Small, water-soaked areas develop on green fruit. These dry out and form slightly raised and wrinkled, brown-to-grey, scab-like bodies, making the fruit unmarketable and susceptible to secondary rots.

Sources of infection: The disease is usually introduced first on the seed.

Spread by: Infected seed and water droplets. Large numbers of bacteria occur in the spots and escape as soon as the surface becomes wet. The bacteria, carried in water droplets, can form new spots on the leaves, stems or fruit where the droplet comes to rest. In wet weather, particularly if strong winds are blowing, the disease may spread rapidly through a crop from a few affected plants. Overhead irrigation acts in a similar manner to rain. Once the bacterium is established in the soil it may persist for 2 or 3 years.

Favoured by: Wet, windy weather and temperatures of 24–30 °C.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓			✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ■ Fruit


Tomato seedlings (AVRDC)


Tomato—leaf spots (I. Walker)


Tomato—leaf spots (I. Walker)


Tomato—leaf spots (I. Walker)


Tomato—stem spots (T. Cooke)


Tomato—leaf spots and yellowing at base of leaflets (I. Walker)


Tomato—leaf death (AVRDC)


Tomato—fruit spots (AVRDC)


Capsicum—leaf spots

Fungal and fungal-like diseases

Late blight

Cause: *Phytophthora infestans*

Crops: Tomato, eggplant

Other hosts: Potatoes are an important host, but other solanaceous plants can harbour the pathogen.

Signs: Tomatoes may be affected at any stage of growth. Serious losses from late blight fungus are sometimes caused in the seedbed through damping off. Dark areas develop on the stems at or near ground level. The tissues in these areas shrivel and the whole plant lodges and withers. Late blight also causes the development of dark diseased areas on the stems of older plants. Dark, water-soaked areas develop mainly on the margins of leaves, and enlarge rapidly until the whole leaf is affected. The leaves may blacken and shrivel, or, if the weather stays humid, may rot away. In the early stages, the delicate downy outgrowth of the fungus can be seen next to the healthy tissue, particularly on the underside of the leaf. Blackened, elongated areas may then develop on the leaf stalks. Developing tomato fruit may be affected. Dark-green, water-soaked areas appear on the surface of the fruit and small, downy outgrowths of the fungus may develop on affected tissue. Sometimes the damage is not apparent until the fruit reaches market.

Sources of infection: Spores of the fungus survive in crop residues and soil.

Spread by: Spores produced by the fungus on diseased tomato and potato plants can be carried by wind and water splash. Under favourable conditions, each spore gives rise to a number of smaller spores that can move in the moisture on the leaves. Each of these small spores may cause a new infection within a few hours.

Favoured by: Free water; humid weather with cool nights (10–15 °C) and warm days (21–27 °C). A spell of dry weather will check its progress.

Management:

- Ensure that solanaceous weeds are well controlled in and around crops.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓		✓		✓	✓	✓		✓	✓	✓			✓	✓	

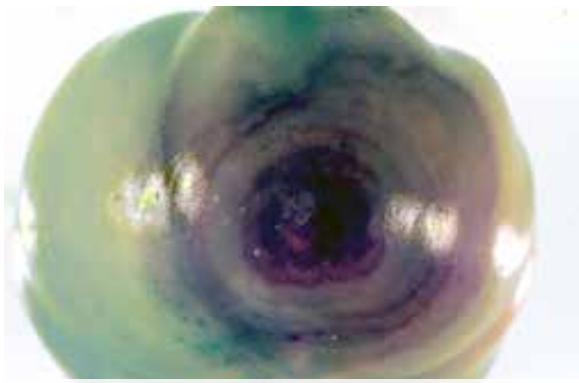
☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ■ Fruit

Tomato—dark, water-soaked areas develop on leaf margins and stems

Tomato—leaves may blacken and shrivel (AVRDC)

Tomato—stem blackening

Tomato—downy outgrowth on affected areas (A. Drenth)



Tomato—dark, water-soaked areas on fruit 'buckeye' (T. Cooke)

Tomato—fruit damage (AVRDC)

Tomato—fruit damage (AVRDC)

Damping off

Cause: Species of *Pythium*, *Phytophthora*, *Fusarium, Phomopsis* and *Rhizoctonia*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Numerous

Signs: The disease occurs in the field or seedbeds, where seedlings may not emerge at all or, if they do, may topple over and rot away. The disease can spread rapidly.

Sources of infection: Contaminated soil, propagation mix or seed

Spread by: Movement of infested soil from nursery to field, including on workers' boots and equipment, and by cultivation practices.

Favoured by: Moist, crowded conditions in seedbeds and boxes. In field-raised seedlings, wet conditions favour disease.

Management:

- Sterilise seedbed soil.
- Time planting to allow plants to emerge rapidly.
- Minimise seedling stress from excess water or poor drainage.
- Use clean water on seedlings in seedling trays.
- Use fungicide seed dressings.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	

■ Seedling ☐ Plant ☐ Root ☐ Stem ☐ Leaf ☐ Flower ☐ Fruit

Tomato—infected seedling tray with areas where non-emerged and around edges where dying

Tomato—seedling on left is healthy, others on right are *Pythium* infected

Tomato—*Pythium* root rot (I. Walker)

Tomato—note plant trying to grow new roots above infection (I. Walker)

Capsicum seedlings—many killed by *Pythium* (AVRDC)

Fruit rots

Cause: Various species of *Alternaria* (target spot), *Colletotrichum* (anthracnose), *Fusarium*, *Penicillium*, *Phoma, Phomopsis*, *Phytophthora* (late blight) and *Rhizoctonia*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Numerous

Signs: Signs of fruit rots are various but generally the fruit becomes soft, with or without the appearance of fungal growth. Fruit may not show signs until after harvest.

Fruit affected by anthracnose (*Colletotrichum* spp.) first show small, slightly sunken, water-soaked, circular spots that become darker than the surrounding tissue. These spots become depressed, are about 12 mm wide and develop concentric markings. The centres become tan and show dark specks, which are the fruiting bodies of the fungus. *Rhizoctonia* can infect fruit that is touching the soil. Green fruit display signs as small, circular brown spots with definite concentric rings.

Sources of infection: Infected seed (*Colletotrichum* and *Alternaria*), infected fruit and soil debris.

Spread by: Wind, water splash and contact with diseased fruit.

Favoured by: Contact with soil, via skin injuries, and high storage temperatures.

For *Colletotrichum* and *Rhizoctonia*, optimal temperatures are around 26 °C and relative humidity above 93%. *Phomopsis* prefers temperatures between 29 °C and 32 °C and relative humidity above 55%. *Phytophthora* prefers free water and humid weather, with cool nights (10–15 °C) and warm days (21–27 °C).

See specific-species information on *Alternaria*, *Fusarium, Phoma*, *Phomopsis, Phytophthora* and *Rhizoctonia*.

Management: Where fungi cause diseases on other plant parts, such as leaves and stems, controlling the disease on these plant parts will reduce the levels of fruit infection. Fruit infections will be reduced when:

- seed is treated with hot water before planting to remove potential for *Colletotrichum* spp. and *Alternaria solani* seed-borne infections
- fruit does not come in contact with soil
- fruit is kept cool and dry after picking to reduce fungal growth.

Management (see inside back cover)

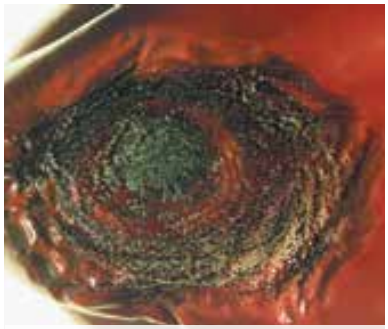
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓		✓		✓		✓				✓		✓		✓		✓	✓	✓	

☐ Seedling ☐ Plant ☐ Root ☐ Stem ☐ Leaf ☐ Flower ■ Fruit

Capsicum—*Alternaria* fruit rot

Tomato—anthracnose fruit rot

Capscium—anthracnose fruit rot (AVRDC)



Capsicum—anthracnose fruit rot

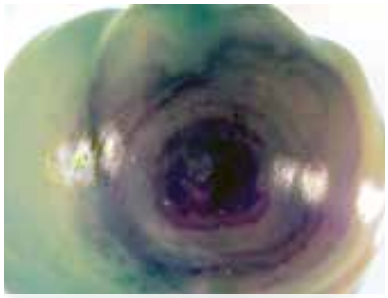
Chilli—anthracnose fruit rot (AVRDC)

Tomato—*Penicillium* fruit rot (T. Cooke)

Tomato—*Phoma* fruit rot (T. Cooke)

Eggplant—*Phomopsis* fruit rot (C. Chen)

Chilli—*Phomopsis* fruit rot (AVRDC)



Tomato—*Phytophthora* fruit rot (T. Cooke)

Tomato—*Phytophthora* fruit rot (AVRDC)

Tomato—*Rhizoctonia* green fruit rot

Tomato—*Rhizoctonia* red fruit rot

Rhizoctonia stem, root and fruit rot

Cause: *Rhizoctonia solani*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Numerous

Signs: Dark-brown, sometimes sunken lesions occur on the stem near soil level. When young seedlings are affected, it is referred to as 'damping off'. Rotted roots appear brown and the cortex (outer tissue) can be easily stripped off.

Affected plants are often smaller than healthy ones and fail to survive long enough to mature the upper hands of fruit. Fruit can be affected if it is touching the soil. Green fruit display small, circular brown spots with definite concentric rings. Riper fruit are even more susceptible.

Source of infection: The fungus is a common soil inhabitant.

Spread by: Contaminated soil, water, equipment and plant parts.

Favoured by: Stem infection requires damp soil. Warm, wet weather favours fruit infection and disease development.

Management:

- Avoid fruit touching soil.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
									✓	✓			✓				✓	✓	

☐ Seedling ☐ Plant ■ Root ■ Stem ☐ Leaf ☐ Flower ■ Fruit

Tomato—seedlings

Tomato—stem lesions

Tomato—stem and root lesions

Tomato—fruit rots

Tomato—green fruit rot

Tomato—advanced fruit rots

Tomato—fruit rots

Cercospora leaf spot

Cause: *Cercospora capsici*

Crops: Tomato, capsicum, chilli

Other hosts: None

Signs: Leaves, petioles and stems may be affected. Signs appear as small and round lesions with a watery appearance. As the spots get bigger, they are light brown in the centre with a darker brown appearance on the edge. The spots may develop with concentric rings and a yellowish halo around the ring, resulting in a 'frog-eye' appearance. Older spots may dry and tissue may crack.

Sources of infection: Diseased crop debris is the main source of infection.

Spread by: Splashing water, wind-driven rain, wind, farm tools, workers and leaf-to-leaf contact.

Favoured by: Warm, wet weather. The disease is mainly found in tropical and subtropical areas.

Management:

- This disease is often minor and does not usually need control.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
									✓	✓			✓				✓		

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ☐ Fruit

Capsicum—spots looking slightly ‘watery’ (T. Cooke)

Capsicum—concentric rings with yellowish halo (AVRDC)

Capsicum—concentric ring spots (AVRDC)

Capsicum—older spots dry and crack (AVRDC)

Leaf mould

Cause: *Fulvia fulva*

Crops: Tomato

Other hosts: Weeds that are members of the genus *Solanum*.

Signs: Pale-green spots that later turn yellow appear on the upper leaf surface of older leaves. Olive green, downy growth appears on the underside of leaves, beneath the yellow areas. Under favourable conditions, the downy growth enlarges rapidly, changing colour from white to pale off-white, then to light brown. At this stage, the growth is velvety and each area has a downy white margin. Ultimately, the leaf dies and the fungal growth turns purple. Occasionally, flowers and young stems are affected. Infected flowers fail to set fruit. Yield losses depend on the stage at which plants are infected; more mature plants withstand the disease better than young ones.

Sources of infection: New infections of the fungus develop from diseased crop trash, mature diseased crops and sclerotia in soil. Spores can survive over summer and infect the following crop.

Spread by: Spores carried by wind and rain, and on equipment. Large numbers of spores are produced on the velvety fungal growth and are easily dislodged and carried by air currents.

Favoured by: Warm temperatures, high relative humidity and shade. Temperatures around 21 ºC are most favourable for rapid disease development, but severe infections can develop slowly at temperatures as low as 10 ºC, provided relative humidity is high.

Management:

- Control solanaceous weeds well in and around crops.
- Regulate humidity in greenhouses.

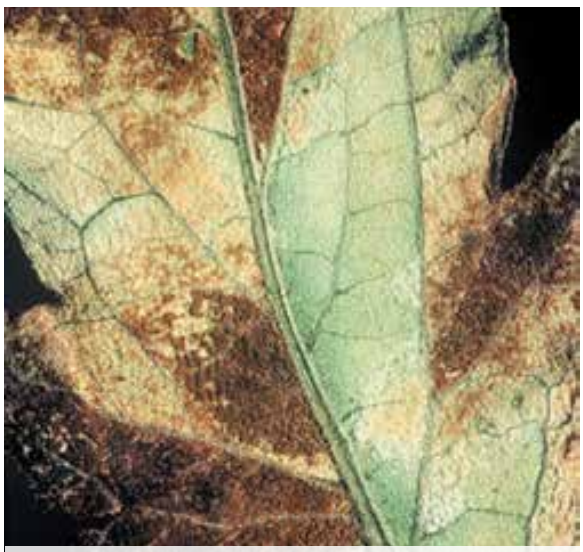
Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓				✓		✓	✓	✓	✓	✓		✓	✓	✓			✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ☐ Fruit

Tomato—leaf underside (left), upperside (right)

Tomato—downy growth on underside of leaf (AVRDC)



Tomato—underside of leaf showing off-white and brown downy growth

Septoria spot

Cause: *Septoria lycopersici*

Crops: Tomato

Other hosts: None

Signs: Small, circular spots develop on the leaves and occasionally on stems and fruit. The spots are visible first on the lower surface of the leaves, but they develop quickly and are soon seen on the upper surface. The spots are commonly 3 mm in diameter, and are white or grey with a dark-brown margin. Badly infected leaves turn yellow and fall, finally leaving only a tuft of small, green leaves at the top of the plant. The reduced leaf area slows development of both plant and fruit, and exposed fruit is prone to sunscald.

Sources of infection: Diseased crop debris is the most important source of infection; however, infected seed may also introduce the pathogen into previously disease-free sites. Black, pinpoint-sized fruiting bodies (pycnidia) form in the centre of the spots and produce the fungal spores that spread infection.

Spread by: Spores carried by water droplets during rain or irrigation.

Favoured by: High temperatures and high relative humidity.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		✓		✓				✓	✓	✓		✓	✓		✓		✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—leaf spots (T. Cooke)

Phomopsis fruit rot

Cause: *Phomopsis vexans*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Only a major pathogen on eggplant. However, solanaceous weeds can act as a host, as can cauliflower and carrots.

Signs: *Phomopsis* rot may appear on eggplant leaves, stems and fruit. Post-emergence damping off of seedlings can also occur. Leaf spots first appear as small, grey-to-brown lesions with light centres. Lesions often increase in number and join to cover large areas of leaves. Severe infection causes leaves to become torn, yellowed and withered, giving the blighted appearance. On stems and branches, lesions may appear as dry, brown, cracked and sunken cankers. If this occurs at the base of a stem, it can girdle and kill the stem. Most important are fruit lesions, which first appear as small, sunken spots with a grey centre and brown-to-black margin. These enlarge and join together, producing concentric rings of yellow and brown regions. If dry conditions follow fruit infection, fruit become shrivelled. Fruit rot may not be observable until after harvest.

Sources of infection: Infected seed or seedlings. The pathogen can survive in the soil and on plant debris.

Spread by: Fungal spores in water splash. Free water is also required for spore germination.

Favoured by: Hot and wet weather. Temperatures of 29–32 °C with relative humidity above 55% are ideal for disease development.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓		✓		✓	✓	✓		✓	✓	✓			✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Eggplant—fruit rot (T. Cooke)

Eggplant—fruit rot (C. Chen)

Chilli—stem lesion (AVRDC)

Chilli—fruit rot (AVRDC)

Powdery mildew

Cause: *Leveillula taurica* (*Lt*), *Oidium lycopersici, Oidium neolycopersici*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Various weeds

Signs: Similar powdery growth for all powdery mildews, with slight differences between the different pathogens. In the case of the *Oidium* species, pale-yellow spots occur on leaves, with a white powdery fungal growth appearing on the spots on both leaf surfaces. In the case of *Lt*, spores are produced only on the underside of leaves. Spots increase in size and number, and the leaf eventually dies. Defoliation can cause sunburn of the fruit. Powdery mildews often appear late in the crop cycle.

Sources of infection: Powdery mildews require a living host or alternative host to survive; however, some can produce a type of spore that can survive on dead host material.

Spread by: Spores that can be transported by movement of people, equipment, rain splash and wind. Insects such as thrips, aphids and whiteflies can also transport the spores, but this is a less common source.

Favoured by: Development of *Lt* is favoured by warm (25 ºC) and dry (< 80% relative humidity) days followed by humid (> 85% relative humidity) nights. Young plants are less susceptible than older plants. Higher humidity and overhead irrigation can reduce the levels of powdery mildew.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
									✓	✓		✓	✓				✓	✓	

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

Tomato—powdery growth on leaf;
yellow spots indicate *Oidium* sp.

Tomato—*Oidium* sp. (T. Cooke)

Tomato—*Oidium* sp. (T. Cooke)

Tomato—*Oidium* sp.

Capsicum—infected leaves

Capsicum—leaf death (T. Cooke)

Botrytis rot, ghost spot, grey mould

Cause: *Botrytis cinerea*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide host range that includes many fruit and vegetables

Signs: Following initial infection, decay progresses rapidly as a slightly sunken, water-soaked, greyish-green area with a definite margin. Brown lesions form on leaves and stems; leaf lesions often have concentric darker zones. In humid weather, grey spore masses form on rotted plant material. The fungus spreads rapidly through the tissues and can completely girdle the stem, killing all plant parts above the lesion. On green tomato fruit, ghost spot produces white, circular, superficial ring spots, usually 3–6 mm across.

Sources of infection: Dead or dying organic matter on which the fungal spores quickly multiply. Fruit can be infected through dying flower petals, or infection can occur through cracks, leaf scores or wounds anywhere on plants.

Spread by: Spores carried on wind or air currents. A food source for the fungus (such as decaying petals) assists with the infection process. Grey mould of foliage is often associated with plant injury. Ghost spots occur when fungal spores germinate on green fruit, causing a hypersensitive reaction.

Favoured by: Cooler weather, free water and high relative humidity. Dew, fog and mist, or a heavy crop canopy can result in favourable conditions.

Management:

- Remove all dead or dying leaves and take prunings or other decaying organic matter away.

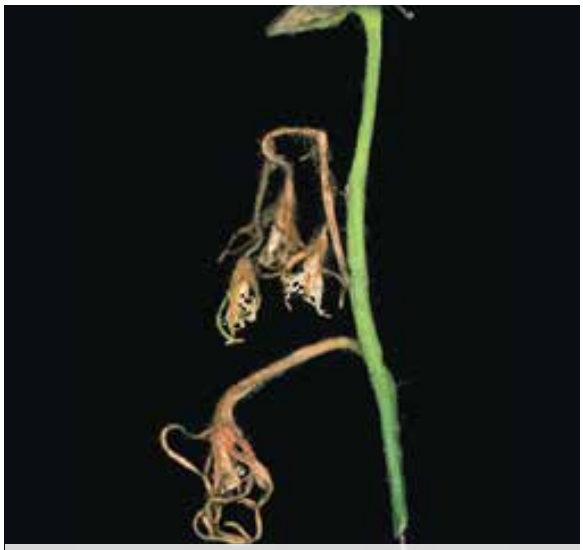





Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓			✓			✓		✓			✓		✓	✓	

☐ Seedling ■ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit



Tomato—lesions can girdle stem causing tissue above to die

Tomato—grey spore masses form on infected tissue (AVRDC)

Tomato—ghost spots on fruit

Tomato—grey spore masses on caylx, and fruit rot (AVRDC)

Tomato—spores forming on fruit

Capsicum—grey spores covering fruit rot (AVRDC)

Sclerotinia rot

Cause: *Sclerotinia sclerotiorum, Sclerotinia minor*

Crops: Tomato, capsicum, chilli

Other hosts: Numerous

Signs: A rapidly spreading, light-brown, watery rot develops on the stem either at ground level or on the branches. Parts of the plant above these areas wilt. Under humid conditions, the rotted areas become covered with white fluffy growth (mycelia), in which *S. sclerotiorum* produces irregularly shaped black bodies (sclerotia), usually 5–10 mm long, but sometimes larger. *S. minor* forms smaller and rounder sclerotia that are 0.5–2 mm in diameter. Sclerotia also form inside affected stems.

Sources of infection: If the soil remains damp for several weeks, sclerotia in the top 50 mm of soil can germinate. For *S. sclerotiorum*, sclerotia either germinate to form small, light-brown, saucer-shaped bodies (apothecia), or they germinate directly. For *S. minor*, the sclerotia germinate and directly infect lower stems or leaves on the ground. Large numbers of sclerotia accumulate in the soil where an infected crop has grown. They remain viable for several years, enabling the fungus to survive between seasons.

Spread by: *S. sclerotiorum* spores are carried by wind and air currents to nearby plants. Under moist conditions, the spores land, germinate and infect plants; however, some senescing plant material such as blossoms or leaves is needed for infection. Sclerotia of both species spread through movement of infected soil or plant material.

Favoured by: Cool, moist conditions. Drying and rewetting of the soil surface stimulates sclerotia near the surface of the soil to produce mycelia.

Management:

- Eliminate alternative host weeds to lower the humidity around the plants and destroy apothecia under the crop.
- Spray with recommended fungicides. In dry weather, the disease can usually be controlled by spraying during the latter stages of crop growth. If the weather is wet or the disease is known to be well established in the area, it may be necessary to spray young crops.





Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓		✓	✓			✓		✓			✓		✓	✓	✓

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

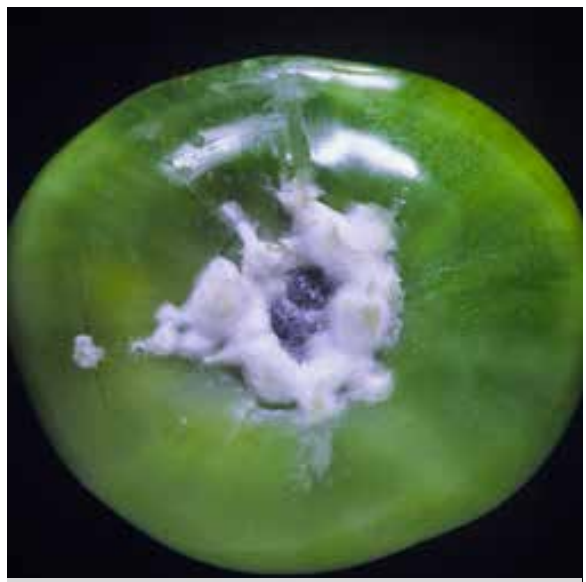
Tomato—plant wilting above stem infection

Tomato—*S. sclerotiorum* causing plant death (AVRDC)

Tomato—*S. sclerotiorum* sclerotia in dead stem (AVRDC)

Tomato—*S. minor* sclerotia at base of stem

Tomato—*S. minor* sclerotia and mycelium



Tomato—green fruit with mycelium

Sclerotium stem rot or southern blight

Cause: *Sclerotium rolfsii*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: A wide host range including potatoes, beans, carrots, cucurbits and beetroots

Signs: The fungus attacks the stem near ground level, producing a distinctive white, threadlike growth. It then spreads rapidly up the stem and down into the root, radiating out into the surrounding soil. The plant wilts and dies rapidly. As the fungus matures, it becomes dotted with white tufts that develop into small, round bodies about 1–1.2 mm wide. These are white at first, but later become brown; they are the resting bodies (sclerotia) of the fungus. Fruit in contact with the ground may also be infected. Plants can be attacked at any stage of growth.

Sources of infection: The source of new infections is commonly undecomposed plant material from the previous crop. The fungus can persist on alternative hosts and for many years on organic matter in the soil.

Spread by: Movement of contaminated soil.

Favoured by: Hot conditions. Sclerotia near the soil surface are stimulated to germinate by drying and rewetting of the surface soil. Disease outbreaks usually occur under relatively dry conditions following rain or irrigation.

Management:

- Plough deeply to bury sclerotia.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓						✓		✓			✓		✓	✓	✓

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—rot at base of stem (I. Walker)

Tomato—rot at base of stem (T. Cooke)

Tomato—mycelium and sclerotia at base of stem

Tomato—mycelium and sclerotia at base of stem

Tomato—affected plant wilting

Tomato—affected plant wilting (I. Walker)

Tomato—fruit in contact with ground become infected (I. Walker)

Tomato—fruit in contact with ground become infected (T. Cooke)

Choanephora blight

Cause: *Choanephora cucurbitarum*

Crops: Capsicum, chilli, eggplant

Other hosts: Beans, cucumbers, peas, squash and various weed species

Signs: Chilli and eggplant are susceptible from seedling to early flowering stage. Water-soaked lesions appear on the leaves, with the margins and leaf tips becoming blighted. Under ideal conditions for the disease, the entire plant may wilt. Once established, entire flowers are overgrown, resulting in a brown-to-black mass of soft tissue. Flower stalks, buds and leaves may then be invaded. The disease is characterised by the appearance of a stiff, silvery mass of hairy strands growing out of the affected leaf tissue, topped with a black ball. Stems that are infected appear wet and green, and the bark peels off easily in shreds.

Sources of infection: Typically from plant debris that has fallen to the ground and become infected. The spores of the pathogen survive in the soil on plant debris for long periods.

Spread by: Spore masses produced at the end of the white threads that are dispersed by wind, water splash, insects and mechanical means.

Favoured by: Extended periods of rainfall, high relative humidity and warm temperatures (25–30 °C). These conditions favour the movement of spores from plant debris to living tissue.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓			✓	✓	✓	✓		✓	✓					✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ☐ Fruit

Capsicum—stiff hairs growing out of infected tissue (AVRDC)

Capsicum—whole plants might wilt (AVRDC)

Target spot (early blight)

Cause: *Alternaria solani*

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Potato and solanaceous weeds, including common thornapple and nightshade

Signs: All parts of the plant may be infected, including leaves, stems and fruit. Small, irregular brown spots, often surrounded by a yellow halo, develop on the leaves. The spots enlarge and may fuse to form large, irregularly shaped dead areas. Isolated lesions are oval and may be 6–13 mm in diameter. The oldest leaves show the largest lesions and die rapidly, though sometimes they fail to drop. They give the lower portion of the plant a dead, drooping appearance, which extends upwards as the disease progresses. In many cases, the lesions on stems and leaves develop a series of ridged, concentric rings, hence the name 'target spot'. Sometimes lesions appear higher on the stem as dark, slightly elongated areas, often with a greyish centre. The fungus cannot penetrate the unbroken skin of the fruit, and fruit lesions are mostly observed around the fruit stalk scar. A dark-brown-to-black, slightly sunken area develops, mostly on one side, resembling a thumbprint. The fungus penetrates into the fruit as a spherical black mass. The affected area later breaks down and the fruit rots. In wet weather, fruit showing 'star-crack' is often attacked by fungi closely related to *A. solani* and develops signs that are easily mistaken for target spot.

Sources of infection: Disease starts from infected seed, infected crop trash or local infected weeds.

Spread by: Spores on wind or water splash from existing infections.

Favoured by: Wet and warm weather. Plant stress will also increase disease.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		✓		✓		✓		✓	✓	✓		✓	✓		✓		✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—leaf target spots

Tomato—leaf target spots (T. Cooke)

Tomato—stem target spots (T. Cooke)

Capsicum—fruit rot

Phoma rot

Cause: *Phoma destructiva*

Crops: Tomato, chilli, capsicum

Other hosts: Weeds of the genus *Solanum*

Signs: Small, irregular spots develop on the leaves, commonly with concentric rings. Seedlings may be infected before transplanting. Slightly sunken brown spots develop on the fruit near the stem scar. As the fruit ripens, the spots may enlarge rapidly and reach over 25 mm in diameter. The affected areas become brown and leathery and dotted with minute black fungal fruiting bodies. A black rot develops in the underlying tissue.

Sources of infection: The fungus survives on crop residues. Fruit infection occurs through injuries.

Spread by: Spores, formed on leaf spots, are dispersed by rain, irrigation water or cultural operations onto the fruit. The spores can be spread over fruit during picking and transport.

Favoured by: Wet weather that allows spores to be released from infected plant material.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
				✓		✓		✓	✓	✓		✓	✓	✓			✓	✓	

■ Seedling ☐ Plant ☐ Root ■ Stem ☐ Leaf ☐ Flower ■ Fruit

Tomato—fruit rot (T. Cooke)

Grey leaf spot

Cause: *Stemphylium* spp.

Crops: Tomato, capsicum, chilli

Other hosts: Numerous

Signs: The disease affects mainly the leaves and occasionally the stem. It does not affect young fruit, but may affect mature fruit. Lower leaves are affected first. Numerous small, dark-brown spots, which may grow to about 3 mm in diameter, extend through to the underside of the leaf. As the spots enlarge, they develop a greyish-brown, glazed appearance, and the centres may crack and tear. Badly affected leaves turn yellow, wither and drop. Under conditions favourable for the disease, all leaves except the youngest may be killed, and fruit production is severely reduced.

Sources of infection: The source of the infection is from diseased crop trash and older diseased crops.

Spread by: Spores carried by wind, wind-driven rain or water splash.

Favoured by: Warm, moist weather

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓				✓				✓	✓	✓		✓	✓				✓	✓	

☐ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—lower leaves first affected

Tomato—as spots enlarge, centres crack and tear (J. Chen)

Tomato—badly affected leaves wither (T. Cooke)

Capsicum—early infection (J. Chen)

Fusarium wilt

Cause: *Fusarium oxysporum* f. sp. *lycopersici*

Crops: Tomato

Other hosts: *Fusarium oxysporum* f. sp. *lycopersici* is specific to tomatoes, but there are many other *Fusarium* wilt diseases specific to their hosts that display similar signs.

Signs: The soil-borne fungus infects through the roots and invades the stem's vascular (water-conducting) tissue, causing wilting, yellowing and browning of the leaves. Signs are first noticed on leaves towards the base of the plant but gradually spread up the plant. The whole plant may wilt and die. There are no external markings on the stem, but if the stems of affected plants are split lengthwise, a brown discolouration of the vascular tissue is seen.

Sources of infection: The pathogen is soil-borne and can persist in the soil for a long time without a host. Most infections originate from fungus associated with infected tomato debris.

Spread by: Contaminated soil and farm equipment.

Favoured by: Warm, moist soil. The pathogen can remain in the soil for many years.

Management:

- Ensure all equipment is free of soil before being brought onto the farm.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓				✓						✓			✓				✓	✓	✓

☐ Seedling ☐ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—stems show internal browning of vascular tissue (T. Cooke)

Tomato—yellowing and then browning of leaves

Tomato—signs first evident near base of plant (I. Walker)

Tomato—whole plant may wilt (I. Walker)

Verticillium wilt

Cause: *Verticillium dahliae*

Crops: Tomatoes, capsicum, chilli, eggplant

Other hosts: A wide range of crops and weeds

Signs: Early signs of the disease are wilting of the older leaves, followed by yellowing and then death, often with a V-shape from the leaf margin. The whole plant may wilt and die. Similar to *Fusarium* wilt, there are no external markings on the stem, but if the stems of affected plants are split lengthwise, a brown discolouration of the vascular tissue is seen.

Source of infection: Contaminated soil. The fungus infects through the roots and invades the stem's vascular (water-conducting) tissue.

Spread by: Contaminated soil

Favoured by: Temperatures around 20–24 ºC. Note slightly lower temperatures than are optimal for *Fusarium* wilt.

Management:

- Keep infected soil away from disease-free areas.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓						✓				✓					✓		✓	✓	✓

☐ Seedling ■ Plant ■ Root ■ Stem ■ Leaf ☐ Flower ☐ Fruit

Tomato—leaf signs (T. Cooke)

Tomato—stem signs

Eggplant—early leaf signs

Capsicum—leaf wilt (AVRDC)

Viral diseases

Chilli leaf curl or pepper leaf curl, eggplant yellow mosaic and pepper yellow leaf curl/tomato leaf curl

Cause: Begomoviruses: tomato yellow leaf curl virus (TYLCV), tomato leaf curl virus (ToLCV) and many other species depending on crop and location; regional examples include chilli leaf curl, pepper yellow leaf curl and eggplant yellow mosaic virus.

Crops: Tomato, capsicum, chilli, eggplant (depending on which begomovirus type is present)

Other hosts: TYLCV alternative hosts include nightshades (*Solanum* species), thornapples (*Datura* species) and French beans (*Phaseolus vulgaris*). ToLCV alternative hosts also include nightshades and thornapples.

Signs: All begomoviruses cause signs that include bright-yellow-to-chlorotic mosaic on leaves, usually with some leaf distortion or leaf curling. Plants that are infected with either TYLCV or ToLCV at an early growth stage become severely stunted. Leaflets are reduced in size and misshapen. Emerging leaves are cupped downwards. Leaves developing later are upright with yellowing between veins; their leaf margins roll upward. Plants infected when they are young lose vigour, flowers abort and they stop producing marketable fruit. When infections occur in older plants, any fruit already present ripen normally but no further fruits are formed.

Sources of infection: Old infected crops are a major source of new infections. Weeds such as the common thornapple and nightshades can be infected by TYLCV.

Spread by: Silverleaf whiteflies (*Bemisia tabaci*)

Management:

- Use reflective mulches to deter whiteflies when plants are young.




Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓			✓		✓	✓					✓				✓		✓		

☐ Seedling ■ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

■ **Australia**
Tomato/yellow leaf curl

■ **Cambodia**
Chilli/pepper leaf curl
Eggplant yellow mosaic
Pepper/yellow leaf curl

Eggplant—eggplant yellow mosaic

Eggplant—eggplant yellow mosaic (W. Tsai)

Eggplant—eggplant yellow mosaic (W. Tsai)

Eggplant—eggplant yellow mosaic (W. Tsai)

Eggplant—eggplant yellow mosaic (W. Tsai)

Tomato—tomato yellow leaf curl

Tomato—tomato yellow leaf curl (T. Cooke)

Capsicum—capsicum yellow leaf curl (C. Chen)

Capsicum—capsicum yellow leaf curl (C. Chen)

Chilli—chilli yellow leaf curl (W. Tsai)

Chilli—chilli yellow leaf curl (W. Tsai)

Chilli—chilli yellow leaf curl (W. Tsai)

Chilli—chilli yellow leaf curl (W. Tsai)

Chilli—chilli yellow leaf curl (W. Tsai)

Chilli—chilli yellow leaf curl (W. Tsai)

Tomato torrado disease

Cause: Torradovirus: tomato torrado virus (TTV)

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Several weed species belonging to various plant families including Amaranthaceae, Caryophyllaceae, Chenopodiaceae, Cruciferae, Malvaceae and Polygonaceae

Signs: Early signs include brown spots on the leaves, which often disintegrate and leave a hole. Leaflets may have a yellow area at the base. When severely infected, whole plants turn brown with the death of leaves.

Sources of infection: Weeds may be infected by the virus but, as the virus is new to Australia, the major hosts have not been confirmed.

Spread by: The greenhouse whitefly (*Trialeurodes vaporariorum*) and the silverleaf whitefly (*Bemisia tabaci*).

Management:

- Use reflective mulches to deter whiteflies when plants are young.

Tomato—browning at base of leaflet (T. Cooke)

Tomato—leaf browning and distortion (T. Cooke)

Tomato (T. Cooke)

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓			✓		✓	✓				✓	✓				✓		✓		

☐ Seedling ■ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ☐ Fruit

Tomato yellow top and pepper yellows

Cause: Polerovirus: potato leafroll virus (= tomato yellow top virus) (PLRV)

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Potatoes, other nightshades (*Solanum* species), thornapples (*Datura* species)

Signs: Signs develop 18–21 days after infection. Affected plants are stunted, with stiff, upright growth at the growing point. The margins of the leaflets are yellow and the tips and margins tend to curl downwards. Leaves and leaflets are smaller, and leaflets are wider than normal. Dead, brown spots sometimes develop on the severely yellowed tissues. Yield is reduced and the fruit is small if infection occurs at an early stage. The older the plant when it is infected, the less it is affected.

Sources of infection: Infected plants in or near the crop.

Spread by: Aphids, *Myzus persicae* and *Macrosiphum euphorbiae*. Infective aphids that have bred on the initially infected tomato plants are responsible for the worst outbreaks of the disease as they spread among the crop.

Tomato leaf signs (T. Cooke)

Tomato leaf signs

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
			✓			✓					✓				✓		✓		

☐ Seedling ■ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ■ Fruit

Alfalfa mosaic

Cause: Alfamovirus: alfalfa mosaic virus (AMV)

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Alfalfa, clover, many legumes

Signs: Capsicum and chilli leaves develop a white mosaic or bleached appearance, usually with no distortion. Infection of plants at an early growth stage results in stunting and development of misshapen fruit.

Tomato leaves are irregularly shaped, and develop bright-yellow areas and often a bronze colouring. Severe infection results in leaves with a downward curl. Fruits are misshapen with irregular, sunken lesions, rings or patches.

Sources of infection: Infected plants and possibly via infected seed.

Spread by: Aphids; however, mechanical transmission and grafting practices also result in new infections.

Chilli leaf signs (AVRDC)

Chilli leaf and fruit signs (AVRDC)

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
			✓							✓			✓	✓	✓		✓		

☐ Seedling ■ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ■ Fruit

Fern leaf

Cause: Cucumovirus: cucumber mosaic virus (CMV)

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide range of hosts

Signs: Signs first develop about 10 days after infection. In tomatoes, the leaf blade tissue is reduced or absent, but the midrib grows to its normal length. Affected leaves twist and curl, and all leaves of an affected plant can show a yellow-and-green mosaic pattern. Affected plants do not set fruit. On capsicum, signs include mosaic or mottling patterns on leaves. Fruit may be deformed with ring spots or yellow blotches. Considered to be only a mild disease but can be important on capsicum.

Sources of infection: Infected plants, especially weeds, near the crop.

Spread by: Several species of aphids, infected seed and mechanical means.

Capsicum—early leaf signs

Capsicum—leaf signs (C. Chen)

Tomato—shoestringing can be caused by CMV or ToMV

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	✓		✓			✓				✓	✓		✓	✓	✓		✓		

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ■ Fruit

Chilli veinal mottle, potato virus Y (or leaf shrivel in tomatoes) and tobacco etch

Causes: Potyviruses: chilli veinal mottle virus (ChiVMV), potato virus Y (PVY) tobacco etch virus (TEV)

Crops: Tomato, capsicum, chilli, eggplant (depending on which potyvirus type is present)

Other hosts: Tobacco, weeds in the Solanaceae and Amaranthaceae families

Signs: Leaves of infected plants generally develop a mottled or mosaic appearance with dark-green vein banding, most obvious on younger leaves. Infection of seedlings and young plants results in stunting and dark-green streaking of stems and branches. Fruit set is affected by early flower drop. Fruit is generally deformed and mottled.

Sources of infection: Infected hosts, particularly weeds, near the crop.

Spread by: Aphids, and mechanical means such as pruning, grafting and other cultural operations. Not transmitted by seed.




Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓			✓			✓				✓	✓		✓	✓	✓		✓		

■ Seedling ☐ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Australia
Potato virus Y

Cambodia
Potato virus Y
Chilli veinal mottle
Tobacco etch (?)

Chilli—ChiVMV leaf signs

Chilli—ChiVMV plant signs

Chilli—ChiVMV leaf and fruit signs

Capsicum—PVY-affected leaves

Capsicum—PVY-affected fruit

Capsicum—TEV-affected leaves (C. Chen)

Capsicum—TEV-affected fruit (AVRDC)

Tobacco mosaic and pepper mild mottle

Causes: Tobamoviruses: tomato mosaic virus (ToMV), tobacco mosaic virus (TMV), pepper mild mottle virus (PMMoV)

Crops: Tomato, capsicum, chilli, eggplant (depending on which tobamovirus type is present)

Other hosts: Weeds in the Solanaceae (ToMV and TMV). *Datura*, *Chenopodium* and *Nicotiana* species (PMMoV).

Signs: Signs appear on new growth 10–20 days after infection. Leaves are mottled, with irregular, light-green and dark-green areas. Certain strains of the virus produce yellow areas in the mosaic. Leaves formed when the plant was healthy remain normal. Mottling varies in severity, and severely mottled leaves may have a puckered appearance. In cool weather, with short days and low light intensity, infected leaves can become narrow and pointed as with fern leaf disease. In young plants, the main effect is slight stunting, although some strains of the virus can kill young plants. In older plants, stunting and poor blossom set can reduce yield, sometimes considerably. Fruit that does set may ripen unevenly, becoming blotchy and unsaleable.

Sources of infection: Plants can be infected in a number of ways, including from seed. Seed produced from infected plants usually carries the virus on the seed coat, but sometimes the virus is within the seed coat or endosperm. It is not present in the embryo. Seedlings produced from infected seed are infected at germination. In seedbeds, the disease can spread from a few infected seedlings during transplanting. The virus is very resistant and can remain infective in dead plant material for several years. Infective root debris may be found several metres deep where a diseased crop has been grown. Weeds may carry the virus over from year to year.

Spread by: Sap transmission during pruning and other cultural operations.

Management:

- Milk powder (20% wt/vol) is effective at inactivating tobamoviruses. Use it to wash hands and hand tools, and dip hands in milk every 5 minutes when handling plants.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓	✓		✓	✓		✓				✓	✓		✓	✓	✓		✓		✓

☐ Seedling ☐ Plant ☐ Root ☐ Stem ■ Leaf ■ Flower ■ Fruit

Capsicum—PMMoV-affected leaves (C. Chen)

Capsicum—PMMoV-affected green fruit (C. Chen)

Capsicum—PMMoV-affected fruit (severe infection) (C. Chen)

Capsicum—PMMoV-affected green fruit (C. Chen)

Tomato—ToMV leaf signs

Tomato—shoestringing can be caused by CMV or ToMV

Tomato—TMV fruit signs (T. Cooke)

Capsicum—TMV leaf signs (C. Chen)

Bushy stunt

Cause: Tombusvirus: tomato bushy stunt virus (TBSV)

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Wide host range including lettuce, apple and cherry

Signs: Signs can be variable. Leaves may show irregular white banding patterns to necrotic lesions or rings, and turn from green to pale yellow, falling from the plant at later stages. New growth is frequently distorted and an abundance of side shoots emerge, resulting in a plant with bushy, stunted growth. Lower leaves become chlorotic and purple as the disease progresses. Fruits are generally smaller, with chlorotic blotching, rings and necrosis.

Source of infection: No vector is known.

Spread by: Water splash, grafting of infected material and (at low levels) seed.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
			✓			✓				✓			✓	✓	✓		✓		

☐ Seedling ■ Plant ☐ Root ☐ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—new leaves distorted (C. Chen)

Tomato—new leaves distorted (C. Chen)

Spotted wilt and capsicum chlorosis

Cause: Tospoviruses: tomato spotted wilt virus (TSWV), capsicum chlorosis virus (CaCV)

In Thailand, the related (serogroup 4) tospoviruses melon yellow spot virus (MYSV), watermelon silver mottle virus (WSMoV) and tomato necrotic ringspot virus (TNRV) also are reported to cause similar ringspot-wilt diseases of tomato and capsicum.

Crops: Tomato, capsicum, chilli, eggplant (TSWV only)

Other hosts: Wide range of vegetables, ornamentals, field crops and weed species

Signs: TSWV signs appear 7–20 days after infection. Small areas of bronzing develop on the upper side of young leaves in the top growth and spread over the whole leaf. On older leaves, the disease usually appears as bronze spots or rings between the veins. These spots may extend and join together. As the disease develops, the affected tissues blacken and shrivel until the shoot looks as though it has been scorched by flame. Brownish-black streaks may also appear on the stems and leafstalks. Young, vigorously growing plants may be killed in a few days. In older plants, the disease may take several weeks to develop fully. Fruits on affected plants often show irregular or circular blotches as they ripen. Many young fruits shrivel and fall.

CaCV is similar to TSWV, with yellowing of younger leaves between the veins and around the margins. Older leaves may show a ringspot pattern similar to TSWV. Infected fruit may be small and distorted. Whole plants are stunted.

Sources of infection: Infected plants, especially weeds, near the crop

Spread by: Species of thrips. TSWV is carried by *Thrips tabaci*, *T. palmi*, *Frankliniella occidentalis*, *F. schultzei* and *Scirtothrips dorsalis*. CaCV is spread by *T. palmi*, *F. schultzei* and *S. dorsalis*. In Thailand, the CaCV vector is reported to be *Ceratothripoides claratris.*

Management:

- Note that controlling thrips with insecticide is difficult because the first and second-instar larvae (which acquire the virus) are usually hidden from pesticide sprays in flower buds or leaf folds, they pupate underground, many species are resistant to insecticides and thrips can move in from outside the treated area.

Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓			✓			✓				✓	✓				✓		✓		

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ☐ Flower ■ Fruit

Tomato—TSWV leaf signs

Tomato—TSWV leaf signs

Tomato—TSWV leaf signs (I. Walker)

Tomato—TSWV-affected fruit (I. Walker)

Tomato—TSWV-affected green fruit (I. Walker)

Tomato—TSWV-affected green fruit (I. Walker)

Tomato—TSWV-affected red fruit (I. Walker)

Tomato—TSWV fruit signs (I. Walker)

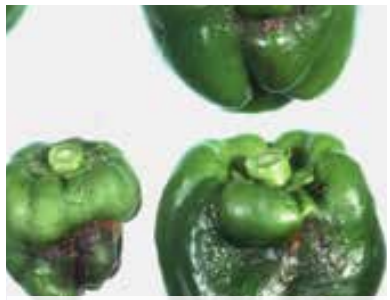
Tomato—TSWV-affected red fruit

Capsicum—TSWV-affected fruit

Capsicum—TSWV-affected fruit (I. Walker)

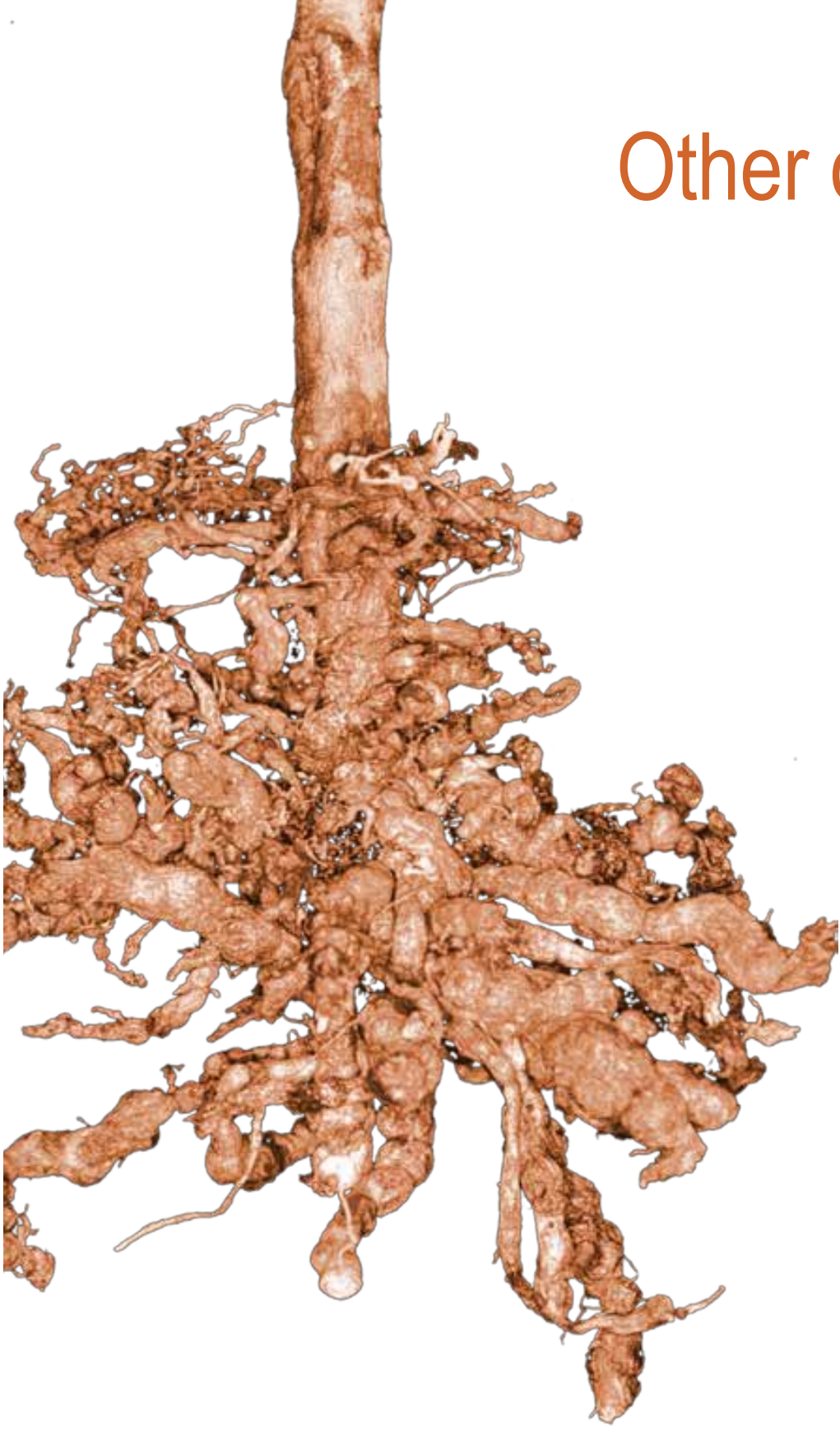
Chilli—TSWV leaf and fruit signs

Capsicum—CaCV leaf signs (T. Cooke)



Capsicum—CaCV green fruit signs (T. Cooke)

Other diseases



Big bud

Cause: Big bud phytoplasma

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Potatoes, lettuce and a large group of weed species

Signs: May not develop until 6 weeks after infection or later. Stems thicken and the plant looks stiff and upright. Plants branch prolifically to produce many small, stiff shoots with shortened internodes. Root initials may develop high on the stem, and the stem may split. Flower buds are greatly enlarged and do not develop properly. The sepals often fail to separate and the whole bud is green. Abnormal flowers do not set fruit. Immature fruit at the time of infection becomes distorted, with an enlarged, woody core.

Sources of infection: Infected plants, especially weeds, near the crop.

Spread by: The common brown leafhopper (*Orosius argentatus*), which is a brown, speckled insect about 3 mm long. It breeds on weeds that may be infected with big bud phytoplasma. Leafhoppers usually migrate in late spring in southern Australia, particularly after hot weather, from drying weeds to tomatoes and other crops.

Favoured by: Dry, mild to warm weather

Management:

- Monitor leafhopper populations and control vector species.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
						✓				✓	✓								

☐ Seedling ■ Plant ☐ Root ■ Stem ■ Leaf ■ Flower ■ Fruit

Tomato

Tomato

Tomato (I. Walker)

Eggplant

Eggplant

Root knot nematode

Cause: *Meloidogyne* spp.

Crops: Tomato, capsicum, chilli, eggplant

Other hosts: Potatoes, weeds, and a wide range of other vegetable, field, ornamental and fruit crops.

Signs: Affected plants are stunted, often paler green than normal, and wilt readily in hot weather. In severe cases, the plants are killed. Besides interfering with normal movement of water and food materials through the plant, root knot makes the plants more susceptible to rootrots and vascular wilts. Young roots are invaded by the nematodes and form swellings (galls) in which the nematode goes through its life cycle. Galls may be quite small or may grow up to 2.5 cm in diameter.

Source of infection: Infested soil. One female nematode may produce 1,000 eggs or more. Under favourable conditions, the eggs hatch in a few days and produce mature nematodes within a month. In subtropical regions, 10 generations of nematodes have been produced in a year.

Spread by: Infected seedlings, tubers and young plants; running water; and soil adhering to cultivation implements, truck tyres, animals and footwear.

Favoured by: Sandy and loamy soils, and warmer weather.

Management:

- Avoid using infested land for susceptible crops, particularly summer crops.
- Do not grow susceptible crops in succession.
- Use break crops such as cereals.
- Reduce nematode populations by leaving fallow for 3–6 months.
- Monitor nematode level through soil testing.
- Use nematicides only after other integrated control options are tried first.
- Destroy residues rapidly following harvest because nematodes and eggs are contained in root galls; remove and destroy as many roots as possible.






Management (see inside back cover)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓	✓		✓	✓						✓		✓					✓	✓	✓

☐ Seedling ■ Plant ■ Root ☐ Stem ☐ Leaf ☐ Flower ☐ Fruit

Tomato—nematode nodules on roots

Tomato—severely affected roots

Disorders

Calcium (Ca) deficiency (blossom end rot)

Signs: Emerging leaves appear scorched and distorted, and may cup downwards as leaf margins fail to expand fully. Blackening and sometimes death of growing points. Fruits develop a sunken, black or dark leathery patch that may enlarge to cover the entire blossom end of fruit. Small to large cracks on and around the blossom end are evident on some varieties.

Cause/favoured by: Deficiency of calcium or insufficient uptake and translocation of calcium to growth points. Can occur when plant is rapidly growing and calcium requirements cannot be met. Both very low and high soil moisture can inhibit calcium uptake and cause nutrient imbalances (e.g. excess nitrogen, high potassium or insufficient boron). More commonly found in acidic soils with a pH less than 5.5.

When to look: During vegetative growth, look for leaves that are scorched, distorted or cupped downwards. During fruiting stages, signs become evident on blossom end of fruit.

Quick correction: Increase the rate, frequency and timing of calcium nutrition using foliar sprays or fertigation with calcium nitrate or other calcium fertilisers. Consider boron nutrition in conjunction with calcium to provide a balanced remedy.

Useful information: Soil test results: optimal calcium levels of 65–80% of total cation exchange capacity and a calcium:magnesium ratio of 1:1–6:1. Excess calcium can inhibit boron, manganese, zinc and iron uptake.

Prevention:

- Check soil pH and calcium levels during land preparation and before planting. Correct acid soils by applying lime. Correct alkaline soils with acidifying or sulfate forms of fertilisers (e.g. sulfate of ammonia, sulfate of potash).
- Maintain adequate soil moisture levels and avoid high levels of nitrogen.
- Apply calcium nutrition regularly during crop growth from early flowering through fruiting to harvest.
- Check calcium levels, and check that nitrogen levels are in balance with other nutrients, using a petiole sap test of the youngest mature leaves during early stages of crop growth.

Tomato—scorched appearance

Tomato—end rot in green fruit (C. Chen)

Tomato—end rot in red fruit (C. Chen)

Tomato—sunken black rot in blossom end of fruit

Capsicum—sunken black rot in blossom end of fruit

Chilli—sunken black rot in blossom end of fruit (C. Ma)

Eggplant—end rot

Iron (Fe) deficiency

Signs: The youngest leaves develop a light-green chlorosis of all tissue between the veins. This produces a distinctive pattern formed by the midrib and veins, which initially remain green. If the condition is severe and persistent, chlorosis becomes more yellow or even bleached white, and burnt patches develop within the chlorotic areas.

Cause/favoured by: Iron deficiency is also known as iron-induced or lime-induced chlorosis because it often occurs in crops grown in calcareous soils where the alkaline soils (high pH) makes iron unavailable. It may also occur in soils that have free lime or a limestone layer that the plant roots grow into. Soils with a high watertable and low soil temperatures may add to the problem.

When to look: Check soil pH and iron levels with a soil test during land preparation. Observe all growth stages up to and during harvest.

Quick correction: Increase the rate, frequency and timing of iron nutrition by using foliar sprays with iron chelate, iron sulfate or other iron nutrients.

Useful information: None

Prevention:

- Reduce alkaline (high pH) soils to below pH 7.5.
- Check iron levels, and check that nitrogen levels are in balance with other nutrients, using a petiole sap test of the youngest mature leaves during early stages of crop growth.

Tomato—light green chlorosis

Tomato—veins remain dark green (I. Walker)

Tomato—affects youngest leaves

Tomato—chlorosis becomes yellow or white in severe cases

Tomato—not all plants are affected (I. Walker)

Magnesium (Mg) deficiency

Signs: Bright yellowing of older leaves that spreads from the tips and margins towards the main veins, often leaving a green triangular area near the base of the leaf.

Cause/favoured by: More likely to occur in acidic and light-textured or sandy soils. May also occur when potassium or calcium levels become too high through the overuse of potassium fertiliser, or after heavy applications of agricultural lime.

When to look: Check magnesium levels with a soil test during land preparation. Observe all growth stages up to and during harvest.

Quick correction: Increase the rate, frequency and timing of magnesium nutrition using foliar sprays or fertigation with magnesium sulfate or other magnesium nutrients.

Useful information: Optimal soil test magnesium levels are 10–15% of cation exchange capacity.

Prevention:

- Check soil pH and magnesium levels before planting. Correct acid soils by applying dolomite (calcium magnesium carbonate) or magnesite (magnesium carbonate, $MgCO_3$).
- Check magnesium levels, and check that nitrogen levels are in balance with other nutrients, using a petiole sap test of the youngest mature leaves during early stages of crop growth.

Tomato—bright yellowing of older leaves

Tomato—veins remain green (C. Chen)

Tomato—veins remain green (C. Chen)

Tomato—veins remain green (C. Chen)

Capsicum—yellowing starts from tips

Capsicum—often leaving green base of leaf

Manganese (Mn) deficiency

Signs: Young tomato leaves develop a net-like pattern, where major and minor veins remain green and the tissue between the veins becomes progressively more yellow. Chlorosis due to manganese deficiency tends to be more of a progression from pale green to yellow, rather than to the whitish-cream colour found with severe iron deficiency. A strip of pale-green tissue surrounds the veins in the case of manganese deficiency.

Cause/favoured by: Rapid growth and alkaline soils.

When to look: Check manganese levels with a soil test during land preparation. Observe all growth stages up to and during harvest.

Quick correction: Increase the rate, frequency and timing of manganese nutrition using foliar sprays with manganese sulfate or other manganese nutrients.

Useful information: Manganese, like iron, is less available in high-pH calcareous soils. Heavy liming, especially of light sandy, poorly buffered soils, sometimes produces mild to moderate signs in tomato crops.

Prevention:

- Check manganese levels, and check nitrogen levels are in balance with other nutrients, using a petiole sap test of the youngest mature leaves during early stages of crop growth.
- Do not use excessive amounts of agricultural lime.
- Reduce alkaline (high pH) soils to below pH 7.5.

Tomato—young leaves develop a net-like pattern

Tomato—progresses from pale green (middle) to yellow (left) as severity increases

Tomato—pale green tissue surrounds the veins

Molybdenum (Mo) deficiency

Tomato—older leaves showing chlorotic mottling (QDAFF)

Signs: Older leaves become chlorotic and pale, then brown, and have necrotic margins. Tomato leaves are pale, thickened and tend to curl upwards because of the death of the margins. Leaves may be brittle, misshapen and, in severe cases, leaf margins will curl and leaves will die. Plants are stunted.

Cause/favoured by: More common in acidic soils with pH < 6.0.

When to look: Observe from seedling stage through to flowering.

Quick correction: Ammonium molybdate or sodium molybdate sprayed two or three times on early plant growth stages.

Useful information: In acid soils (soil pH < 6.0), molybdenum availability to plants is reduced and foliar applications of molybdenum are required.

Prevention:

- Check soil pH and nutrient levels with a soil test during land preparation and before planting.
- Correct acid soils by applying lime.
- Apply molybdenum nutrition in the early growth stages if a petiole sap test indicates a deficiency or pH < 6.0.

Nitrogen (N) deficiency

Signs: Growing tips are pale and weak. Older leaves are pale green to yellow, and eventually dry up. Leaves may develop a purplish colour. Plants are small, do not thrive, have fewer flowers, poor fruit set and small fruit with thin skin. Fruit are more slender and pinched at the blossom end.

Cause/favoured by: Too little nitrogen applied, or nitrogen leaching due to overwatering. Organic mulches (e.g. straw) around plants can lead to nitrogen deficiency because they use nitrogen to decay. Poor root system development, root diseases and root knot nematode will limit nitrogen uptake by plants.

When to look: Observe all stages, including up to the beginning of harvest.

Quick correction: Foliar spray, fertigate or sidedress with nitrogen fertilisers (e.g. potassium nitrate, calcium nitrate, urea, low biuret urea, sulfate of ammonia). If the nitrogen deficiency is caused by poor root development due to diseases, nematodes or other soil conditions, these need to be treated to help correct the nitrogen deficiency.

Useful information: Nitrogen levels in relation to other nutrients need to be monitored and kept in balance for optimum plant and fruit growth and quality. Plants will take excess nitrogen in preference to other nutrients, resulting in other nutritional deficiencies. Check potassium, boron, calcium and copper levels in relation to nitrogen levels from pre-flowering to fruiting.

Prevention:

- Apply recommended rate of nitrogen divided into small, frequent applications.
- Check nitrogen levels regularly with a petiole sap test of the youngest mature leaves.
- Improve irrigation management to reduce leaching losses and excessive soil moisture.

Tomato—growing tips are pale and weak

Tomato—older leaves are paler green

Capsicum—pale-green to yellow nitrogen-deficient leaf (right), healthy leaf (left)

Phosphorus (P) deficiency

Signs: Poor germination and establishment of seedlings. Leaves are small, dark and appear dull, grey–green. Seedlings show reddening or yellowing of leaf margins and purple colouration of the undersides of leaves. Oldest leaves turn bright yellow, but leaves directly above remain dark green. Brown patches appear between the veins on mature leaves. At flowering stage, crops may have fewer flowers. Plants may have a weak root system and shortened internodes, and be stunted and slow growing.

Cause/favoured by: Insufficient pre-plant phosphorus fertiliser, and acidic or cold soil conditions.

When to look: Check phosphorus levels with a soil test during land preparation. Observe all stages, up to the beginning of harvest.

Quick correction: Application of phosphorus fertilisers (e.g. MAP tech grade, phosphoric acid [drip irrigation], DAP or other commercial phosphorus fertilisers) can increase flowering and crop health in phosphorus-deficient soils.

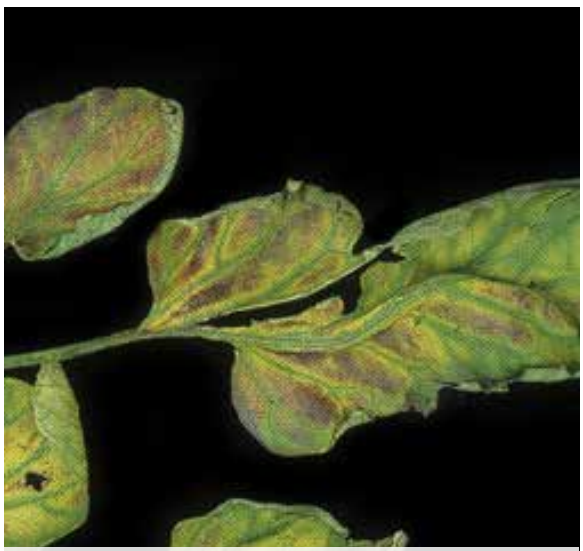
Useful information: Phosphorus can adhere to soil particles and move slowly in the plant system. Phosphorus fertilisers are usually applied at or before planting in sufficient quantities to meet all the crop's needs. Placement of fertiliser below the seed or seedling at depths of approximately 10 cm is optimal.

Prevention:

- If soil or leaf tissue tests indicate phosphorus deficiency, increase the rate, frequency and timing of phosphorus nutrition.
- Conduct a soil test to determine phosphorus levels and adjust as necessary.
- Check phosphorus levels regularly with a petiole sap test of the youngest mature leaves.

Tomato—phosphorus-deficient seedling (right) is dark reddish and stunted

Tomato—reddening of leaf margins



Tomato—oldest leaves turn yellow with brown patches (C. Chen)

Potassium (K) deficiency

Tomato—scorched leaf margins

Signs: Leaf margins may be yellow or scorched, with signs spreading to the area between the veins, then the leaf centre. Scorching of the leaf margins may cause the leaves to curl downwards and cup upwards. In tomatoes, compressed growth characterised by shortened internodes can be observed. Fruit from potassium-deficient tomatoes are often poorly and unevenly coloured or distorted.

Cause/favoured by: Insufficient potassium nutrition or imbalance with other nutrients. Potassium is often required on lighter sandy soils. Overwatering or heavy rainfall can cause nutrient leaching. Signs can develop rapidly in hot weather.

When to look: Check potassium levels with a soil test during land preparation. Observe all stages up to and during harvest.

Quick correction: Foliar spray, fertigation or sidedress with potassium nitrate, potassium sulfate or other potassium fertilisers.

Useful information: Optimal soil test potassium levels are 1–5% of total cation exchange capacity (CEC) and a magnesium:potassium ratio of 2:1–4:1. Nutrient interrelationships, including excess nitrogen and calcium, can inhibit potassium uptake. Excess potassium can inhibit manganese and boron uptake. Use of potassium chloride in saline soils may make leaf signs worse. Potassium deficiencies are more likely to occur on light sandy soils.

Prevention:

- If soil or leaf tissue tests indicate potassium deficiency, increase the rate, frequency and timing of potassium nutrition.
- Apply potassium nutrition before planting and regularly during crop growth, particularly from early flowering through to harvest.
- Check potassium levels regularly with a petiole sap test of the youngest mature leaves.

Zinc (Zn) deficiency

Signs: Leaves are small and distorted. The shoot length becomes shortened, giving the leaves a clustered arrangement near the growing tip. The stunted crops look pale from a distance, but closer inspection reveals yellowing between veins, as well as an overall paleness of the whole plant. Flowers may drop off and fruit fail to set.

Cause/favoured by: More common on soils where the pH is above 7.5 (alkaline soils) or lower than 5.0 (acid soils).

When to look: Observe from seedling stage through to flowering.

Quick correction: Several foliar sprays of zinc sulfate or other zinc nutrients in the early growth stages are required to reduce signs.

Useful information: In acid soils (soil pH < 6.0), zinc availability to plants is reduced and foliar applications of zinc are required.

Prevention:

- Check soil pH and nutrient levels with a soil test before planting.
- It may help to apply zinc fertilisers before planting.
- Correct acid soils by applying lime.
- Correct alkaline soils by applying acidifying fertilisers.
- Check zinc levels regularly with a petiole sap test of the youngest mature leaves.

Tomato—leaves small, pale and distorted

Chloride (Cl) toxicity

Signs: Dull, dark, leathery leaves. Yellow leaf margins, worsening to scorched appearance and premature leaf fall. Older leaves usually show signs first. Poor plant vigour and wilting plants, even when soil moisture seems adequate.

Cause/favoured by: Saline soil, watertable rising to root zone, irrigating with saline water with electrical conductivity greater than 800 deci-Siemens per metre, or sulfate fertilisers moving into root zone. Problems are worse where drainage is poor. Be cautious if using muriate of potash fertiliser, which has 50% chloride content.

When to look: If seeing signs then it is too late, so use preventive measures.

Quick correction: Correction of saline conditions usually takes time and planning. To correct saline soil, leach salts from root zone with leaching irrigation of fresh, good-quality water. To correct for saline water, avoid sprinkler irrigation of crop foliage with highly saline water; if this is unavoidable, irrigate at night. Higher salinity levels are tolerable for a short period if drip irrigation is used. If possible, follow with a leaching irrigation to flush salts from root zone.

Useful information: Excess salts (chloride, sodium, magnesium, sulfates, carbonates, bicarbonates, borates) can damage roots and result in stunting and reduced yields. Sufficient drip irrigation may help move salts from the root zone; inadequate drip irrigation will result in accumulation of salts in the root zone. Where furrow irrigation is used, placing plants on the sides of beds may allow them to escape excessive salts.

Prevention:

- Conduct a soil test before planting to determine salt levels. Test for chloride and sodium levels.
- Lower the watertable level with improved irrigation management and/or subsurface drainage.
- Check the function of installed subsurface drains. Leach salts from root zone with leaching irrigation.
- Test and monitor irrigation water quality.
- Do not use saline water for irrigation.
- Avoid potassium chloride fertilisers if salinity is an existing problem.

Tomato—dark, leathery leaves with intervein scorching

Tomato—dark, leathery leaves with yellow to scorched leaf margins

Catface

Signs: Extreme malformation and scarring at the fruit's blossom end. Cavities that are lined with scar tissue lie between puckered or swollen areas. Locules (seed-containing compartments) of the fruit are sometimes exposed. Damage causes uneven ripening, and some signs make fruit unmarketable.

Cause/favoured by: Growth disturbances during flowering (pistillate formation) are thought to be the cause of catface. Various factors before and during flowering (including periods of prolonged, unseasonal cool to cold temperatures; thrips feeding on young fruit; and excessive nitrogen fertiliser) may aggravate the problem and affect fruit development.

When to look: Catface becomes evident during fruit development stages.

Quick correction: None

Useful information: Mainly affects large, fresh, market tomato varieties. Jointless varieties are more prone to catface than jointed varieties.

Prevention:

- Use tolerant cultivars or those that are not known to exhibit catface.
- Ensure optimal irrigation, and nutritional and temperature management in greenhouses to reduce losses.
- Prevent soils from becoming waterlogged.

Tomato—mild-to-severe scarring at end of fruit blossom

Tomato—scarring at end of fruit blossom (I. Walker)

Tomato—extreme catface (I. Walker)

Fruit splitting or skin cracking

Signs: Radial cracking and concentric cracking are two types of cracking that occur on fruit. Radial cracking is splitting from the stem end to the blossom end of the fruit. Concentric cracking occurs in a circular pattern or as rings around the stem end.

Cause/favoured by: Various conditions, including:

- periods of very fast fruit growth with high temperature and moisture levels
- initial fruit growth during a dry period followed by heavy rain or irrigation during ripening
- overpruning or lack of leaf cover for fruit
- wide fluctuations in day and night temperatures
- high nitrogen and low potassium levels.

When to look: During fruit development. As fruit mature, they become more susceptible to cracking, especially as colour develops.

Quick correction: None

Useful information: Cracking occurs more frequently in vine-ripe tomato production than in mature-green tomato production. The problem is usually more severe on the lower trusses. More susceptible varieties crack in the mature-green stage and more tolerant varieties at later stages.

Prevention:

- Monitor soil moisture monitoring and optimise irrigation management. Do not over-irrigate, and minimise fluctuations in soil moisture, particularly at fruit maturity.
- Maintain a balanced fertiliser program that prevents overly succulent plants.
- Maintain good foliage cover, as exposed fruit are more susceptible.
- Select tolerant varieties.

Tomato—heat stress radial cracking

Tomato—concentric cracking of green fruit (C. Chen)

Tomato—radial cracking of green fruit (C. Chen)

Tomato—radial cracking of red fruit (C. Chen)

Tomato—concentric cracking (I. Walker)

Tomato—splitting of blossom end (I. Walker)

Capsicum—blossom end split (I. Walker)

Misshapen fruit

Signs: Misshapen fruit exhibit various signs, including malformation, irregular shape and lack of full shape development.

Cause/favoured by: Disruption to pollination and flowering processes by environmental conditions such as strong winds or extremes of temperatures. Occasionally fruit in early stages of development can be damaged by insects, disease or farm operations, which leads to misshapen fruit.

When to look: Signs only become evident during fruit development stages.

Quick correction: None

Useful information: On high-value crops, misshapen fruit may be removed by hand-picking at early stages.

Prevention:

- Grow windbreaks to provide crop protection from winds. This can be helpful to crops at flowering stages.
- Select low-toxicity pesticides (and foliar sprays) when spraying during flowering.

Tomato—misshapen (I. Walker)

Tomato—misshapen (I. Walker)

Tomato—misshapen (I. Walker)

Tomato—misshapen (I. Walker)

Capsicum—misshapen (I. Walker)

Eggplant—misshapen

Sunburn

Signs: Damage occurs as sunken, dark-brown-to-light-brown patches on the side or shoulder of fruit. On capsicum, a white, soft, sunken area develops that later dries out and becomes papery. On tomato, the damaged area is white, shiny and blistered, becoming sunken and wrinkled. Signs occur on fruit of any size, although maturing fruit tend to be more susceptible to damage.

Cause/favoured by: Inadequate foliage protection, particularly during extremely hot and/or humid conditions, that leaves developing fruit exposed to sun. Poor foliage protection may be due to trellising methods, inadequate fertiliser resulting in poor leaf development, or heavy pruning or leaf removal. Sunburn is a physiological problem and is not caused by insects, fungi, bacteria or other pathogens. Also known as sunscald.

When to look: During fruit development stages, and following extremely hot temperatures.

Quick correction: None

Useful information: None

Prevention:

- Ensure optimal nutrition and irrigation management that produces adequate vegetative growth and leaf cover for fruit.

Tomato—sunburn (QDAFF)

Tomato—sunburn

Eggplant—sunburn

Capsicum—sunburn (I. Walker)

Capsicum—sunburn (I. Walker)

Herbicide damage

Signs: Upward-curling, pale-green to yellow younger leaves and severe stunting of plants. Distortion of leaves and shoots and vein clearing may occur. Various chlorotic leaf patterns occur that are unrelated to leaf venation. The chlorosis is often an artificially bright hue of yellow, orange, cream or white.

Cause/favoured by: Spray drift in windy conditions or when a temperature inversion layer is formed, which can trap spray droplets in the lower air mass that moves sideways rather than mixing with the upper atmosphere. Herbicide residue left in a spray tank that is then used for a fungicide or insecticide application.

When to look: After spraying and from seedling through to harvest.

Quick correction: Plants damaged by herbicide may recover with optimal water and nutrient management. Plant tissue analysis may indicate nutrient applications that can improve plant growth and crop health.

Useful information: Check weather forecasts, temperature and wind speed before spraying, especially for herbicide sprays.

Prevention:

- Apply sprays under appropriate conditions to avoid spray drift.
- Follow instructions on chemical labels and record sprays.
- Triple-rinse spray tanks after use.

Tomato—stunting of roots caused by herbicide residue in soil and reduced nutrient uptake

Tomato—herbicide damage resulting in chlorosis near base of leaflets

Tomato—vein clearing caused by herbicide

Tomato—2,4-D herbicide injury

Tomato—2,4-D herbicide injury to roma fruit (I. Walker)

Tomato—dicamba, 2,4-D herbicide injury (I. Walker)

Tomato—glyphosate herbicide injury

Tomato—glyphosate herbicide injury (I. Walker)

Glossary

acidic soil	Soil with pH less than 6.0.
antennae	Paired, segmented appendages on each side of larva and adult insect head that function as sense organs.
beneficial	An insect, mite, fungus or other organism that performs a service to humans by feeding on pest organisms, preventing infection or pollinating.
biocontrol/biological control	The human use of living organisms, such as predators, parasitoids and pathogens, to control pest insects, weeds or diseases.
blight	A disease sign in which there is sudden and severe necrosis of the above-ground portions of a plant.
bronzing	A damage sign leaving a red-brown sheen on leaf, fruit or stem that may be caused by insect or mite feeding, a plant pathogen or environmental conditions.
canker	A localised, diseased area on a root or stem where the tissue is sunken and cracks open.
cation exchange capacity	A measure of a soil's capacity to hold cations.
chlorosis/chlorotic	The yellow or white discolouration of normally green tissue.
cocoon	The silken covering of a pupa.
damping off	The rotting of seedlings at or below soil level.
electrical conductivity (EC)	A method of measuring salinity.
fertigation	The application of nutrient to the crop through the irrigation system that allows the nutrient to be placed in the root zone.
fungicide	A chemical used to control fungi.
fungus (pl. fungi)	A microscopic organism with threadlike cells that grows on living and/or dead plants, or insects.
gall	A swelling of roots, stems and leaves caused by abnormal growth of tissue.
herbicide	A substance used to control weeds.
honeydew	A sweet secretion produced by some sap-sucking insects such as aphids and whiteflies.
infection	The process in which an organism attacks a plant.
instar	An insect stage between moults before adulthood.
larva	The young stage of an insect that does not resemble the adult in appearance.
leaching	The loss of water-soluble plant nutrients from the soil.
lesion	A well-defined, but limited, diseased area on a plant.
metamorphosis	Complete change in an insect, where the juveniles look quite different to the adults.
mosaic	The pattern of light and dark areas on a plant, typically the leaf, often caused by viruses or nutritional deficiencies.
moult	The shedding of an insect's exoskeleton as it grows.

necrotic	Tissue that turns brown and dies.
nematode	Tiny worms that can live in plants, animals, soil or water.
nymph	The juvenile stage of an insect.
parasitise	The process of laying eggs in or on a host. The eggs then hatch and the juvenile stage feeds on the host.
parasitoid	An insect that generally develops on or within the egg, larval or adult stage of their host, and kills them.
pathogen	An agent that causes disease.
petiole	The stalk of a leaf.
pH	A measure of the acidity or alkalinity of the soil or solution.
pith	The soft, spongy tissue in the centre of a plant stem.
predator	An organism that preys on others.
pupa	The metamorphosis stage of some insects between the larval and adult stages.
pupation	The process in which an insect changes from one distinct form (e.g. a caterpillar) into another (e.g. a moth). Only insects with a complete metamorphosis life cycle pupate.
saline soil	Soil that contains sufficient soluble salts to impair plant growth.
sap test (petiole)	A rapid test that indicates plant nutrient levels from the plant sap of the youngest mature leaves.
sclerotium (pl. sclerotia)	The hard, black, reproductive survival structure of some fungi.
seed-borne	Carried on or in a seed.
shot hole	Sign of pests or disease where pieces of dead leaf fall out to form holes. Many holes occur together.
skeletonise	The act of a pest eating leaf tissue between the veins.
solanaceous	Plants in the nightshade family, including tobacco, tomato, potato, eggplant, capsicum and chilli.
spore	A reproductive body (single cell or several cells) that becomes detached from the parent and gives rise either directly or indirectly to a new individual (e.g. fungal spore).
systemic	Spreading internally throughout a plant.
thorax	The middle portion of the body between the head and the abdomen.
translucent	Semitransparent, allows light to pass through.
vascular	Referring to the conductive system of a plant (xylem and phloem).
vector	An animal that can transmit a pathogen.
virus	A submicroscopic disease-causing agent.
water-soaked	Lesions or spots that appear wet, dark and usually sunken and translucent.
wilt	Loss of rigidity and drooping plant parts due to inadequate water supply or excess water loss by a plant.
<	less than
>	more than

Resources and further reading

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Fullelove G., Wright R., Meurant N., Barnes J., O'Brien R. and Lovatt J. 1998. Tomato information kit: Agrilink, your growing guide to better farming guide. Department of Primary Industries, Queensland Horticulture Institute: Brisbane. At <era.deedi.qld.gov.au/1655>, accessed 19 July 2013.

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Useful websites

AVRDC The World Vegetable Center. At <avrdc.org>, accessed 19 July 2013.

Crop Protection Compendium database. CABI. At <cabi.org/cpc>, accessed 19 July 2013.

Plant viruses online: descriptions and lists from the VIDE database. Version: 20 August 1996. At <pvo.bio-mirror.cn/refs.htm>, accessed 19 July 2013 [not updated since 1996].

Vegetable resource database. New South Wales Department of Primary Industries. At <dpi.nsw.gov.au/agriculture/horticulture/vegetables>, accessed 19 July 2013; or <vegdb.arris.com.au>, accessed 19 July 2013.

Impact of pesticides on beneficials

Kovach J., Petzoldt C., Degni J. and Tette J. [undated] A method to measure the environmental impact of pesticides. New York State Integrated Pest Management Program: New York. At <nysipm.cornell.edu/publications/eiq>, accessed 19 July 2013.

Two producers of beneficial organisms in Europe have excellent online databases on the impact of pesticides on beneficials, but note that they primarily cover their commercially reared beneficials. Both have phone versions:

- Biobest. At <biobest.be/neveneffecten/3/3>, accessed 19 July 2013.
- Koppert. At <side-effects.koppert.nl>, accessed 19 July 2013.

Insect and mite management practices

- ☐ Where possible, choose resistant or less susceptible varieties.
- ☐ Grow seedlings in clean soil on raised tables, covered with insect exclusion screening.
- ☐ Use insect and mite-free seedlings.
- ☐ Control weeds in and around crops (weeds can be a source of pests).
- ☐ Monitor crops for insects and mites and their damage, and for beneficials.
- ☐ As soon as possible after harvest, remove the remaining crop to prevent further pest increases.
- ☐ Physically remove insect pests if feasible (e.g. on small holdings).
- ☐ If control is necessary, choose selective insecticides.
- ☐ Be aware that spraying broad-spectrum insecticides may cause population increases in some species of mites, whiteflies and thrips.
- ☐ Work in insect or mite-free areas first.
- ☐ Plan crop rotations to include non-host crops for the most serious insect and mite pests.

Disease management practices

Management																			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

1 Use resistant varieties or resistant rootstocks where possible.

2 Use disease-free seed, seedlings or cuttings.

3 Treat seeds with hot water to reduce seed-borne infection.

4 Raise seedlings in soil that is known to be free of disease pathogens, screen for insect vectors and discard any unhealthy seedlings before planting.

5 Ensure that crop residues are well decomposed before planting new crops.

6 Keep new plantings isolated from old plantings.

7 Ensure that weeds are well controlled in and around crops.

8 Use practices to reduce humidity in the canopy such as increased plant spacing, pruning lower leaves and improving drainage.

9 Avoid overhead irrigation.

10 Use mulches to prevent water splash from soil to crop.

11 Monitor crops regularly for disease signs.

12 Monitor insect vectors visually or with sticky traps, and control their presence if vectored diseases are present in the crop or surrounding area.

13 Spray with recommended chemicals as necessary.

14 Adopt sanitation precautions of working in unaffected areas first, regularly disinfecting tools in 10% sodium hypochlorite solution (particularly after being in contact with diseased plants), regularly washing hands and contaminated clothing, and avoiding activity while foliage is wet.

15 Handle plants and fruit gently to avoid damage during weeding, pruning and harvesting.

16 Remove diseased plants off-site, including roots (be careful not to contaminate neighbouring plants), put them in a plastic bag and leave them to dry in sun before burning or burying.

17 Remove infected fruit before sending the clean fruit to market.

18 Destroy crop residues as soon as possible after harvest.

19 Rotate crops with unrelated non-host crops (e.g. cereals, which are not hosts for many vegetable diseases).

20 When a field has significant bacterial, fungal, virus or nematode disease problems, do not plant susceptible crops for four years.

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