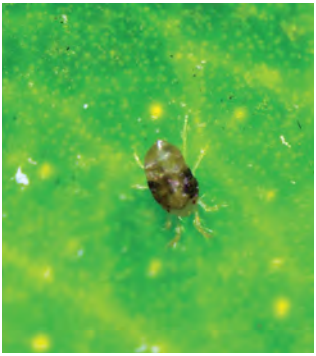
Pests, beneficials, diseases and disorders in citrus: a field identification guide

NSW PRIMARY INDUSTRIES MANAGEMENT GUIDE



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Cover images

From left to right (top) adult two-spotted mite, red scale on an orange, ladybird beetle; (bottom) spider feeding on katydid, asymmetric leaf blotching caused by huanglongbing, striped fruit caused by chimera.

Printing

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Department of Primary Industries
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Pests, beneficials, diseases and disorders in citrus: a field identification guide

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IPDM for the citrus industry

This project has been funded by Hort Innovation, using the citrus research and development levy, contributions from the Australian Government and co-investment from New South Wales Department of Primary Industries, Queensland Department of Agriculture and Fisheries and the Agricultural Produce Commission. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Contents

About this guide

This guide is a diagnostic tool to help citrus growers identify the main pests, beneficials, diseases and disorders found in citrus orchards. It provides descriptions, photographs and basic information about pest status and management. Further information can be found in the *Citrus plant protection guide* (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/manuals-guides/manuals-and-production-guides/citrus-plant-protection-and-management-guide) and on the NSW DPIRD citrus webpage (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus).

Acknowledgements

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We would like to thank those who provided photographs and content for use in this guide. Unless otherwise acknowledged, the photographs herein are from the NSW DPIRD image library or staff collections. We thank the following for the permission to use photographs from their collections:

- Steven Falivene, Andrew Creek, Jianhua Mo, Meena Thakur, Alison Fattore, Dave Monks and Nerida Donovan (NSW Department of Primary Industries and Regional Development, NSW DPIRD).
- Rachelle Johnstone (WA Department of Primary Industries and Regional Development, WA DPIRD)
- Emily Pattison (Qld Government Department of Primary Industries, QDPI)

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

We would also like to thank Dr Amanda Warren-Smith for editing and designing this guide.

Purpose of the guide

This guide is for use in the field to help identify insect pests, natural enemies (beneficials), diseases and disorders commonly found in Australian citrus orchards. Not all pests, natural enemies, diseases and disorders are present in all states and their activity can differ between states and regions.

If identification is not possible using the guide, we recommend showing specimens to your local Department of Primary Industries, pest consultant or rural supply store horticulturists. Control recommendations cannot be made without an accurate diagnosis of the problem. Most states have a diagnostic service. In NSW, you can contact the NSW DPIRD (https://www.dpi.nsw.gov.au/biosecurity/plant/reporting,-diagnostics-and-biosecurity-collections).

Integrated pest and disease management

An integrated pest and disease management (IPDM) strategy draws upon several management tools (Figure 1), with the goal being to use the least ecologically disruptive methods to manage pests, diseases and weeds. The focus is on physical, cultural and biological control options, with chemical controls playing a supportive role. In an IPDM system, pests are managed to economically acceptable levels using a combination of control options. Thresholds, monitoring, and management will vary between orchards, blocks or varieties, and target markets for the product.

Regular monitoring for natural enemies (beneficials), pests, and diseases is important for IPDM and natural enemies are encouraged in the orchard by careful insecticide choices. Alternate row slashing or leaving inter-row grasses long provides habitat and a pollen food source for predatory insects and mites. Natural enemy insect releases can help manage some pests, e.g. parasitoid *Aphytis* spp. wasps for red scale.

Using IPDM does not exclude chemical use but encourages a preference for using 'softer' or selective insecticides that do not disrupt the natural enemies of citrus pests. Using broad-spectrum chemistry usually leads to secondary pest problems in citrus orchards and the need for further chemical application.

This field guide will help you to identify insect and mite pests, natural enemies, diseases and disorders in the citrus orchard. Seek expert confirmation or use a diagnostic service when in doubt.

What is a pest?

Pests are organisms that have a negative effect on crop production and quality. Pests can be insects, diseases, weeds, invertebrates and animals. The pests in this guide can cause damage, loss or pose a risk to productive citrus plantings.

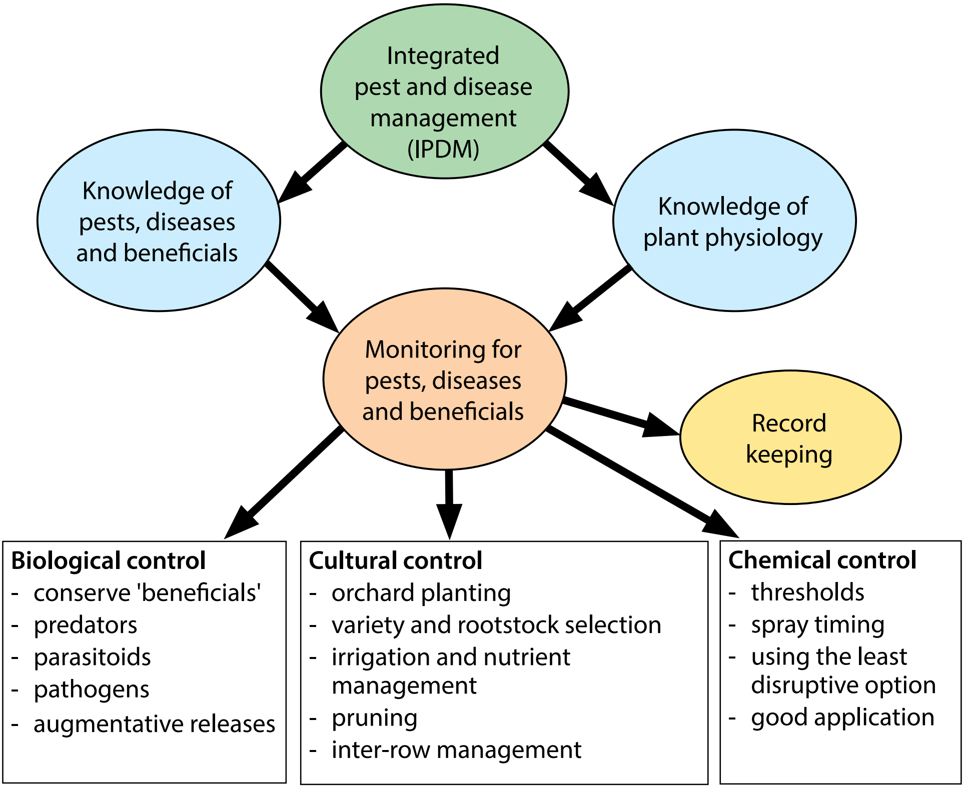


Figure 1. Factors to consider when using integrated pest and disease management (IPDM).

What are natural enemies?

Not all insects are pests; some help manage pests and are known as natural enemies or 'beneficials'. Natural enemies rely on pests as their food source or to complete their life cycle. They vary between crops and regions. The type of natural enemy present depends on the pest species they feed on.

Predatory natural enemies can be specific, targeting a prey group, or generalist predators that eat a variety of organisms. Predators require multiple individuals (prey) to complete their life cycle. Some predatory natural enemies e.g. spiders, can prey on both pests and natural enemies.

Parasitoid natural enemies only parasitise one to a few species of closely related pests by laying their eggs in or on the host pest or in the host pest eggs. The parasitoid larvae then feed on the host, killing it, and emerge as adults to repeat the process. A parasitoid only requires one host to complete its life cycle. Parasitoids of citrus pests are mostly wasps.

Combining augmentative releases of natural enemies with cultural controls and considered chemical use can successfully manage several citrus pests.

Pesticides can harm natural enemies. Identifying natural enemies in the orchard and including them in your pest monitoring and decision making are important factors when selecting a pesticide. Consider the toxicity of a pesticide to natural enemies and choose the least disruptive one (Table 1 on page 89). This can also prevent the need for further chemical use to manage secondary pest flare-ups that usually happen in orchards after applying a broad-spectrum insecticide.

Orchard monitoring

Regularly monitoring for insect pests, natural enemies, signs of their activity, and disease or disorder symptoms will help determine the most appropriate management decisions.

- Regularly check trees using a systematic method. Pest activity is seasonal; insects are more active from spring to autumn, so that is the best time to monitor.
- Select trees randomly on a diagonal or zigzag pattern; do not check the same tree every time.
- Mobile insects are more active and easily seen in the morning, making this the best time to monitor for them.
- Record what you find and any control actions taken for future reference.
- Collect unknown insects or symptomatic tree material for identification (if you suspect insects or diseases are causing the damage).

Identifying insects and mites

Insects are invertebrates, lacking a backbone. They have a segmented body with a hard armour-like casing, jointed legs, one pair of antennae and usually one or two pairs of wings (some insects are wingless). In some insects, adults and juveniles look very different, so make sure you know which life stage you are seeing. Mites are not insects but are arachnids, which are related to spiders and ticks. They can be difficult to see with the naked eye but can be seen with a 10× hand lens or microscope. Adult insects have 6 legs while adult mites have 8 legs (Figure 2).

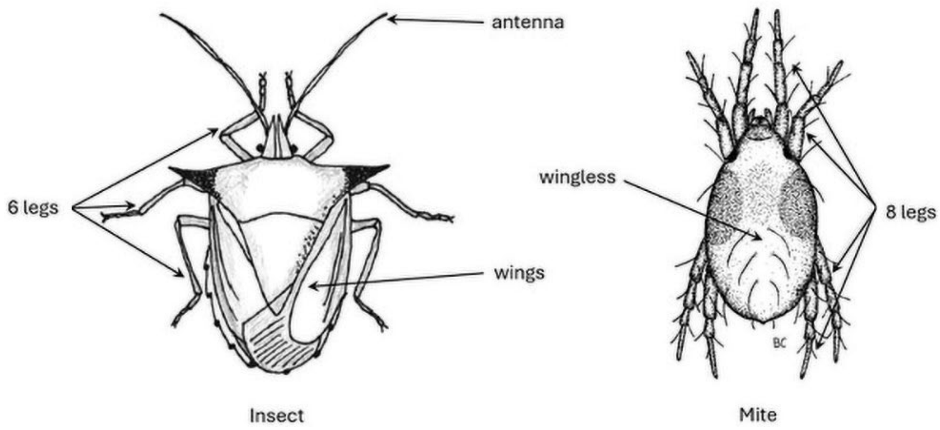


Figure 2. Insect versus mite.

Insect and mite life cycles

Insects and mites go through several life stages. Their transformation into an adult occurs in one of three categories: simple (Figure 3), incomplete (Figure 4) or complete (Figure 5) metamorphosis.

Simple life cycle (no change)

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

Incomplete life cycle (gradual change)

- Young resemble adults but without wings (juveniles do not have functional wings).
- 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, bugs, katydids, mealybugs, praying mantises, scales, and thrips belong to this group.

Complete life cycle (complete change)

- Young look completely different from adults.
- Young are called larvae, maggots, caterpillars or grubs.
- There is a pupal stage.
- Ants, beetles, flies, lacewings, moths, wasps, and weevils belong to this group.

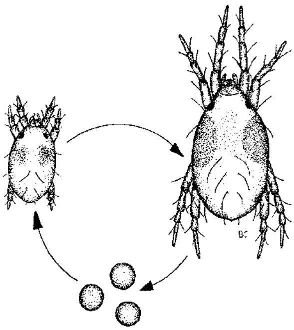


Figure 3. Simple life cycle (no change). Source: Goodwin (2002, p 13).

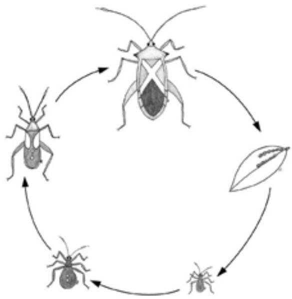


Figure 4. Incomplete life cycle (gradual change).

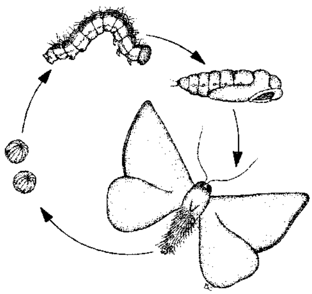


Figure 5. Complete life cycle (complete change). Source: Goodwin (2002, p 43).

Insect and mite damage symptoms

Insects and mites damage trees by either their chewing or sucking mouthparts. Different groups of insects tend to cause different types of damage related to their size, mouthparts and where they feed on the tree.

Chewing causes white traces or skeletonisation of leaves and blemished fruit, and root feeding causes stunted tree growth. Bite holes can indicate the size of the insect that caused the damage. Most leaf-feeding caterpillars are very small when they hatch and feed only on one side of a leaf, causing 'windowing', but they quickly grow and leave ragged holes. Some insects (e.g. leaf-miners) leave a blistered appearance or white trace patterns on leaves or webbing that folds leaves.

Sucking causes a characteristic white speckling on tree leaves, blemished fruit, and reduced tree vigour from depositing honeydew and transmitting viral diseases.

Chewing symptoms

Holes in leaves, white traces, webbing or skeletonisation: caterpillars, earwigs, leaf-miners, loopers, snails, and weevils.

Blemished fruit: caterpillars (e.g. light brown apple moth), earwigs, and katydids.

Sucking symptoms

Speckling on leaves: mites (oriental spider mite and two-spotted mite).

Wilted leaves, growth tips and flowers: true bugs (aphids, scale, mealybugs and crusader bugs).

Honeydew: aphids, mealybugs and scale.

Blemished fruit: leaf-hoppers, mites, scale, spined citrus bugs, and thrips.

What are tree diseases?

Diseases interfere with a tree's normal functioning, development or economic value. They are either infectious (caused by pathogens) or non-infectious (disorders, including those caused by mineral imbalances, herbicide damage and incorrect postharvest storage).

Infectious diseases can be transmitted from tree to tree. The 3 main types of infectious diseases are bacterial, fungal, and viral.

Non-infectious diseases (disorders) are caused by non-living agents such as mineral imbalances (nutrient toxicities or deficiencies), chemical toxicities, mechanical injuries, environmental extremes and unfavourable genetic changes. Disorder symptoms can often be mistaken for an infectious disease. They can also make trees more susceptible to infectious diseases.

Types of diseases (infectious)

Bacterial

Bacterial diseases are caused by bacterial pathogens, which are microscopic, single-celled organisms that can multiply rapidly in favourable conditions. They can survive in soil and on the surface of plant material, even in dry conditions, for long periods. Bacteria can infect tree tissue through wounds and natural openings such as stomata.

Fungal

Fungal diseases are mostly caused by fungi, which consist of threads (hyphae) that radiate to find food. Fungi can survive in various habitats including living and dead plant material and soil. They produce spores and can infect tree tissue through wounds, natural openings or cracks (e.g. leaf stomata, cracks in bark or roots), or via mechanical injury.

Bacteria and fungi can be transmitted by:

- water (rain splash or irrigation)
- wind
- soil
- seed
- insects and other animals
- human activities – moving infected citrus plants, plant parts (e.g. transplants, grafts) or soil, or using contaminated equipment (i.e. machinery and pruning/grafting tools).

Viral

Viral diseases cannot grow and develop outside a living cell. They use the tree's normal processes to replicate themselves. Some viruses are systemic, affecting the entire tree. Other viruses leave some tissue virus-free, affecting only parts or sections of a tree. There is no cure for infected trees, so control depends on prevention. Particular viruses are usually spread by only one insect type.

Viruses can be transmitted by:

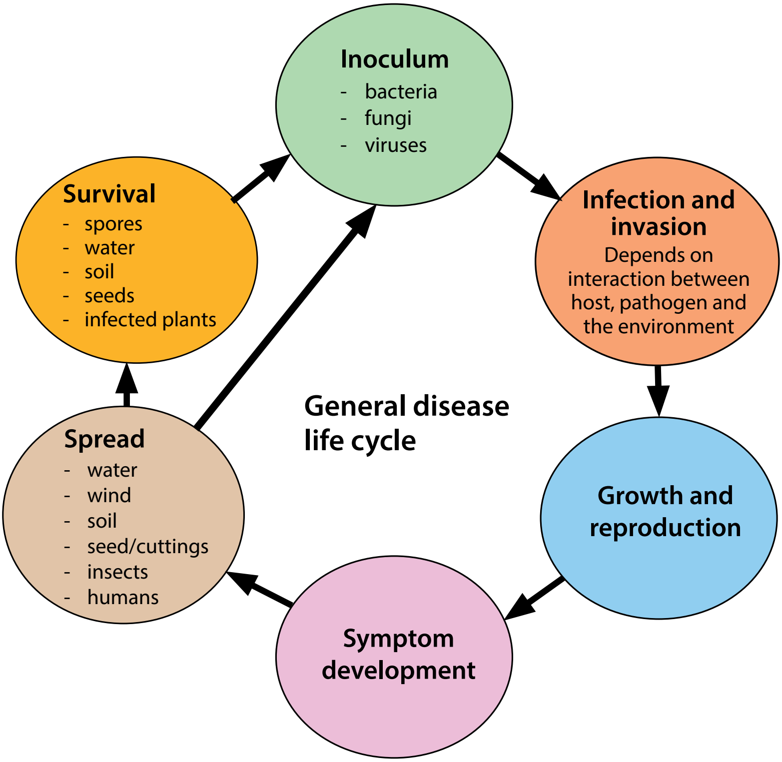
- vectors such as sap-sucking insects and mites
- infected seed and pollen
- human activities – moving infected citrus plants, plant parts (e.g. nursery trees and propagation material) or soil, or contaminated equipment (e.g. machinery and pruning/grafting tools).

Hints for diagnosing diseases

Early signs of disease infection are not as obvious as insect damage (e.g. chewed leaves), and by the time symptoms are noticed, it is often too late.

- Look at the whole tree.
- Check for damage to foliage, flowers, twigs, trunk and roots.
- Note the distribution of symptoms on the tree; is only the new leaf growth affected, or only the twigs or fruit?
- Note the pattern of affected trees in the orchard.
- Note the changes to trees over time; the symptoms produced by diseases often vary with weather conditions or tree age.

General disease life cycle



What are tree disorders (non-infectious diseases)?

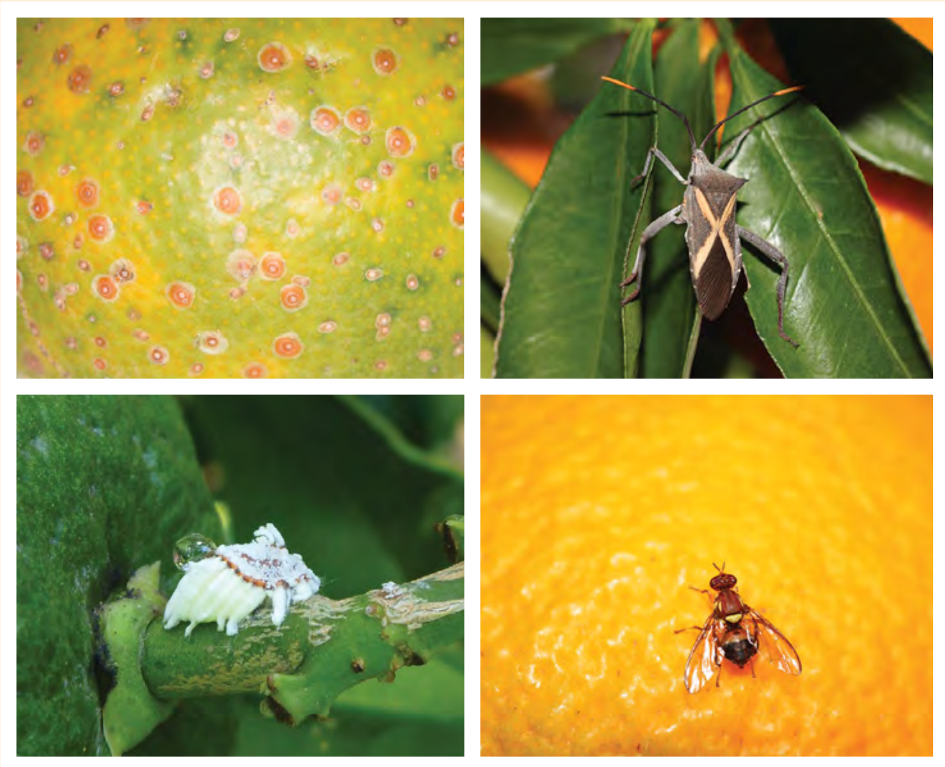
Disorders cannot be transmitted but can be caused by incorrect amounts of water, nutrients, light or environmental factors. Nutrient disorders can appear similar and cause confusion. If the issue is related to nutrition, a tissue test can help determine the cause. Disorders in citrus trees can be promoted by unfavourable:

- temperature
- soil moisture
- humidity
- soil type
- soil pH

as well as:

- nutrient deficiencies and toxicities
- damaging substances (e.g. chemicals)
- mechanical injuries
- genetic abnormalities.

Pests



Mites

Broad mite (*Polyphagotarsonemus latus*)

Description

Eggs: oval, transparent, less than 0.1 mm long, covered with rows of white bumps, giving them a speckled appearance. Eggs are laid underneath the leaf surface.

Immatures: similar to the adults but smaller. Young nymphs (Figure 6) are whitish, slow-moving, and up to 0.2 mm long. Older larvae are clear and pointed at both ends. Larvae begin with 6 legs and moult to become 8-legged (Figure 7).

Adults: very small and barely visible without a hand lens. The female is oval and pale yellow. The male is smaller and more active with enlarged hind legs.

Similar to other mites.

Damage: feeding causes grey scarring, hardening and twisting on young leaves, grey scarring on young green twigs and thin silver–grey skin on fruit.

Risk period: November to June.

Management

Cultural: minimise dust; alternate row slashing provides longer grasses and pollen to support predatory mites.

Biological: predatory phytoseiid mites (*Euseius* spp.) and a ladybird beetle (*Scymnus* sp.) feed on broad mites.

Chemical: decisions to spray should be based on monitoring; avoid calendar spraying. Use selective insecticides to manage citrus pests. Mites can develop resistance to chemicals quickly. Using broad-spectrum chemicals to manage other insect pests also kills natural predators of two-spotted mites and oriental spider mites, promoting mite outbreaks.

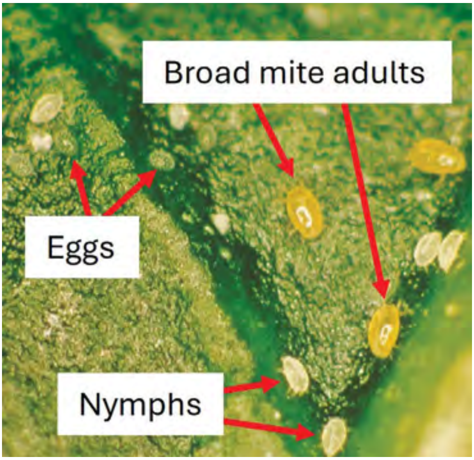


Figure 6. Broad mite adults, nymphs and eggs.

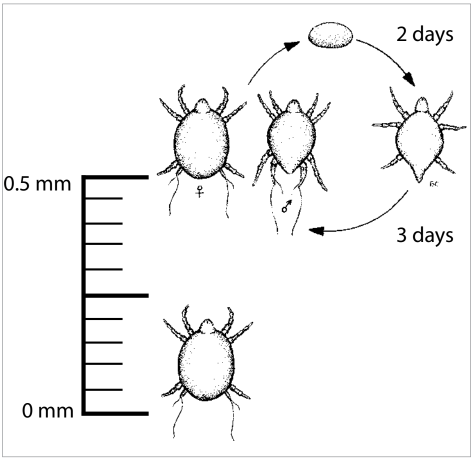


Figure 7. Broad mite life cycle. Source: Goodwin (2002, p 17).

Brown citrus rust mite (*Tegolophus australis*)

Description

Eggs: translucent white, disc-shaped and less than 0.1 mm long. Eggs are laid singly or in groups on fruit and in leaf depressions.

Immatures: similar to adults but smaller, slimmer and paler.

Adults: light brown and wedge-shaped, with the head end being the widest (Figure 8).

Similar to citrus rust mite.

Damage: feeding damages fruit rind cells, and the fruit surface has a shiny brown russeting (Figure 9), which can be confused with melanose or chemical burn. Fruit size is reduced, and fruit shrivelling occurs. Leaf upper surfaces appear bronzed with yellow patches. Twigs develop areas of bronze stippling and blisters. Brown citrus rust mites are usually found on the side of the fruit facing the tree's exterior. All citrus varieties are susceptible.

Risk period: November to May.

Management

Cultural: minimise dust and use alternate row slashing to provide longer grasses and pollen to support predatory mites.

Biological: predatory phytoseiid mites (*Euseius* spp. and *Neoseiulus* spp.), stigmaeid mites and cecidomyiid flies.

Chemical: decisions to spray should be based on monitoring; avoid calendar spraying. Use selective insecticides to manage citrus pests. Mites can quickly develop resistance to chemicals. Using broad-spectrum chemicals to manage other insect pests also kills natural predators of two-spotted mites and oriental spider mites, promoting mite outbreaks.

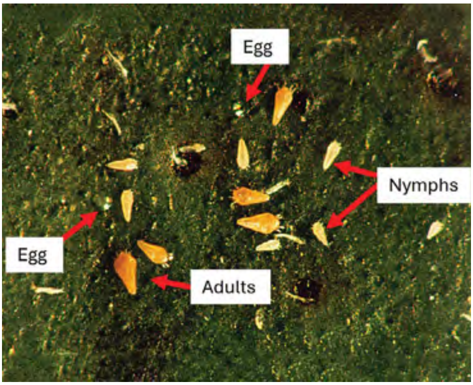


Figure 8. Brown citrus rust mite adults, nymphs and eggs. Photo: Smith et al. (1997, p 17).

Figure 9. Brown citrus rust mite damage to oranges.

Citrus rust mite (*Phyllocoptruta oleivora*)

Description

Eggs: translucent, sphere-shaped, and very small (difficult to see without a hand lens). They are laid singly or in groups on fruit and in leaf depressions.

Immatures: yellow, carrot-shaped nymphs that look similar to adults.

Adults: 0.15 mm long, yellow and carrot-shaped (Figure 10).

Similar to broad mite and brown citrus rust mite.

Damage: citrus rust mite primarily feeds on the outer surface of citrus fruit and leaves, piercing fruit rind cells and extracting their contents, disrupting the epidermal layer. This causes russeting, a bronzed or silvery rough texture on the fruit surface (Figure 11). The damage is most visible on exposed surfaces of the fruit, especially the side facing the sun. Severe infestations can lead to hardened, cracked skin, reducing fruit quality and marketability. On leaves, their feeding causes bronzing, curling and distortion, sometimes leading to leaf drop and reducing tree vigour.

Risk period: November to May.

Management

Cultural: minimise dust and use alternate row slashing to provide longer grasses and pollen to support predatory mites.

Biological: predatory phytoseiid mites (*Euseius* spp. and *Neoseiulus* spp.), stigmaeid mites and cecidomyiid flies.

Chemical: decisions to spray should be based on monitoring; avoid calendar spraying. Use selective insecticides to manage citrus pests. Mites can quickly develop resistance to chemicals. Using broad-spectrum chemicals to manage other insect pests also kills natural predators of two-spotted mites and oriental spider mites, promoting mite outbreaks.

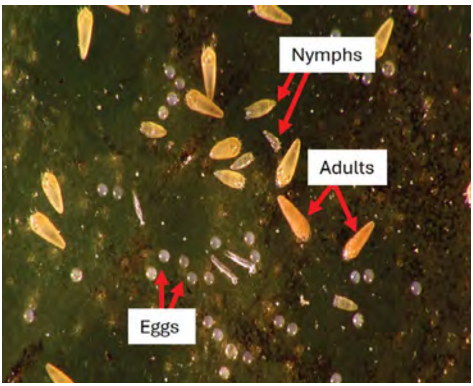


Figure 10. Citrus rust mite adults, nymphs and eggs. Photo: Smith et al. (1997, p 21).

Figure 11. Citrus rust mite damage on fruit.

Pests

Two-spotted mite (*Tetranychus urticae*)

Description

Eggs: sphere-shaped (Figure 12), with colour changing from translucent to yellowish–white (Figure 13) closer to hatching.

Immatures: very tiny pale yellowish–white larvae hatch with 6 legs and moult to become 8-legged.

Adults: very small (0.5 mm) and difficult to see with the naked eye. They have a dark spot on either side of their body (Figure 14) and are often found underneath leaves.

Similar to oriental spider mite.

Damage: yellow spotting on leaves (Figure 15), fruit (Figure 16), twigs and premature leaf drop. Mature fruit will have yellow stippling or spotting on the rind. All citrus varieties are susceptible.

Risk period: January to April.

Management

Cultural: flowering inter-row vegetation provides protein (pollen as food) and protection for natural enemies. Alternate inter-row slashing ensures a continual supply of food and shelter for beneficial insects. Mites favour dusty conditions, so avoid bare soil in the inter-rows. Establish orchard windbreaks.

Biological: natural enemies can usually control two-spotted mite numbers. Predators include ladybird beetles (*Stethorus* spp.), lacewings, predatory thrips and predatory mites. The predatory mites *Neoseiulus californicus*, *Phytoseiulus persimilis*, and *Typhlodromus occidentalis* are available commercially for augmentative release.

Chemical: decisions to spray should be based on monitoring; avoid calendar spraying. Use selective insecticides to manage citrus pests. Mites can quickly develop resistance to chemicals. Using broad-spectrum chemicals to manage other insect pests also kills natural predators of two-spotted mites, promoting mite outbreaks.

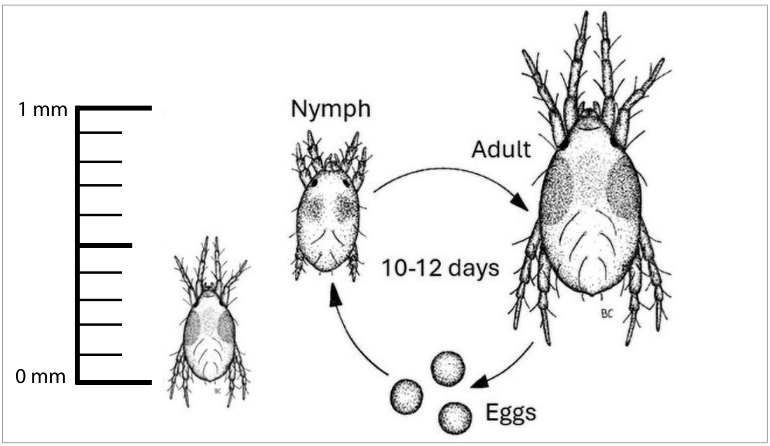


Figure 12. Two-spotted mite life cycle. Source: McDougall et al. (2017, p 17).

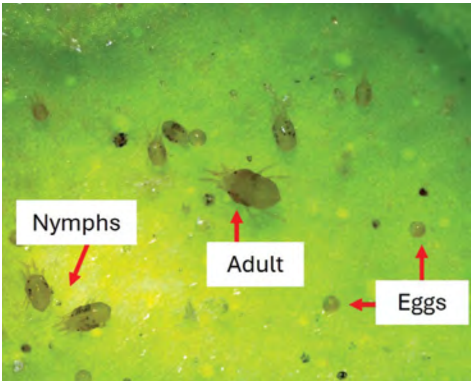


Figure 13. Two-spotted mite adult, nymph and sphere-shaped eggs.

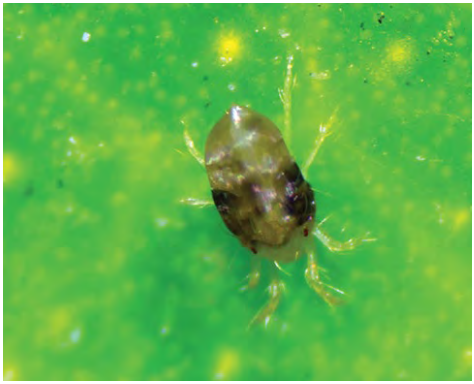


Figure 14. Two-spotted mite adult with 2 dark spots on either side of the body.

Figure 15. Two-spotted mite damage to leaves.

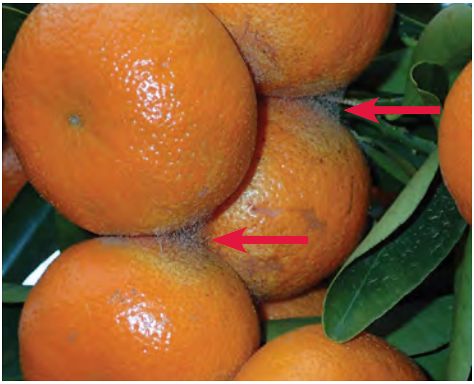


Figure 16. Two-spotted mite webbing with yellow spotting damage on fruit.

Pests

Oriental spider mite (*Eutetranychus orientalis*)

Description

Eggs: orange–brown, sphere-shaped but flattened, 0.14 mm in diameter and laid singly on the upper leaf surface (Figure 17).

Immatures: larvae grow up to 0.3 mm long and are pale brown to light green. Larvae emerge with 6 legs and moult to become 8-legged.

Adults: 0.5 mm long and reddish. Males are smaller and have long legs (Figure 18). White shed skins are often seen on the damaged leaf tissue.

Similar to brown citrus rust mite, citrus rust mite, and two-spotted mite.

Damage: spotted chlorosis (grey stippling of leaves and fruit). Leaf drop can occur in heavy infestations. They prefer to feed on upper leaf surfaces and outward-facing fruit surfaces. All citrus varieties are susceptible.

Risk period: November to May.

Management

Cultural: minimise dust and use alternate row slashing to provide longer grasses and pollen to support predatory mites.

Biological: predatory ladybird beetles (*Stethorus* spp.) and predatory phytoseiid mites (*Euseius* spp.).

Chemical: decisions to spray should be based on monitoring; avoid calendar spraying. Use selective insecticides to manage citrus pests. Mites can quickly develop resistance to chemicals. Using broad-spectrum chemicals to manage other insect pests also kills natural predators of two-spotted mites and oriental spider mites, promoting mite outbreaks.

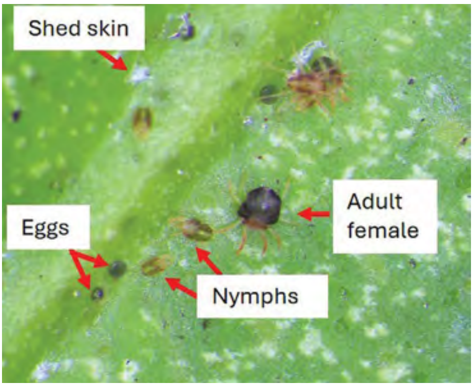


Figure 17. Oriental spider mite adult, nymphs and eggs. Photo: QDPI.

Figure 18. Oriental spider mite adult males are smaller than females and have longer legs. Photo: QDPI.

Fruit flies

Mediterranean fruit fly (*Ceratitis capitata*)

Description

Eggs: banana-shaped, white, 1 mm long and deposited under the fruit skin.

Immatures: larvae are cream maggots about 1 mm long, growing up to 8 mm, and have a pointed head and a blunt rear. Pupae are small, oval, brown capsules about 4 mm long that pupate in the soil.

Adults: 4–5 mm long flies with yellow bodies, black markings and distinctive brown bands on the wings (Figure 19). They tend not to fly and remain where they are if food sources are available. They can naturally disperse 1 or 2 km.

Similar to other pest fruit flies.

Damage: sting marks on the fruit skin appear as discolouration and/or gum-like exudates. The fruit are destroyed by feeding larvae, making it susceptible to secondary fungal infections such as brown rot and moulds. Fruit decay causes early fruit drop.

Risk period: September to May.

Management

Cultural: remove all mature fruit from host trees in and near the orchard (including near back gardens and sheds). Sweep fallen fruit from under the trees into the inter-row and mulch it. Remove feral and neglected fruit trees.

Biological: area-wide release of sterile adult male flies (sterile insect technique or SIT) will result in fewer offspring to reduce Mediterranean fruit fly populations. Parasitoid braconid wasps and predatory assassin bugs are natural predators that help control local populations.

Chemical: mass trapping (e.g. a three-part pheromone-based lure) and attract-and-kill devices are effective.

Figure 19. Mediterranean fruit fly adult.
Photo: Andrew Jessup, Janren Consulting.

Pests

Queensland fruit fly (*Bactrocera tryoni*)

Description

Eggs: banana-shaped, white, 1 mm long and deposited under the fruit skin.

Immatures: larvae are cream maggots 1 mm long, growing up to 10 mm, tapering at one end (Figure 20). Mature larvae typically 'flick' themselves into the air to exit the fruit and pupate in the soil. Pupae are hard-skinned, brown, barrel-shaped, and 4–5 mm long.

Adults: a reddish-brown fly with yellow markings (Figure 21) and 6–8 mm long (Figure 22). They tend not to disperse if food resources are available. They are strong fliers and can spread many kilometres, especially after fruit is harvested.

Similar to other pest fruit flies.

Damage: sting marks on the fruit skin (Figure 23) appear as discolouration and/or gum-like exudates. The fruit are destroyed by feeding larvae, and the resulting breakdown (Figure 24) allows secondary fungal infections such as brown rot and moulds. Fruit decay causes early fruit drop.

Risk period: September to May.

Management

The best results are gained from area-wide fruit fly control where the whole region works together implementing cultural, biological and chemical control techniques.

Cultural: remove all mature fruit from host trees in and near the orchard (including nearby gardens). Sweep fallen fruit from under the trees into the inter-row and mulch them. Remove feral and neglected fruit trees.

Biological: area-wide release of sterile adult male flies (sterile insect technique or SIT) will result in fewer offspring, thereby reducing Queensland fruit fly populations. Parasitic braconid wasps and assassin bugs are natural predators that help control local populations.

Chemical: protein bait sprays mixed with insecticide and male annihilation technique (MAT) help manage Queensland fruit fly populations.

Figure 20. Queensland fruit fly larva. Photo: Andrew Jessup, Janren Consulting.

Figure 21. Queensland fruit fly adult.

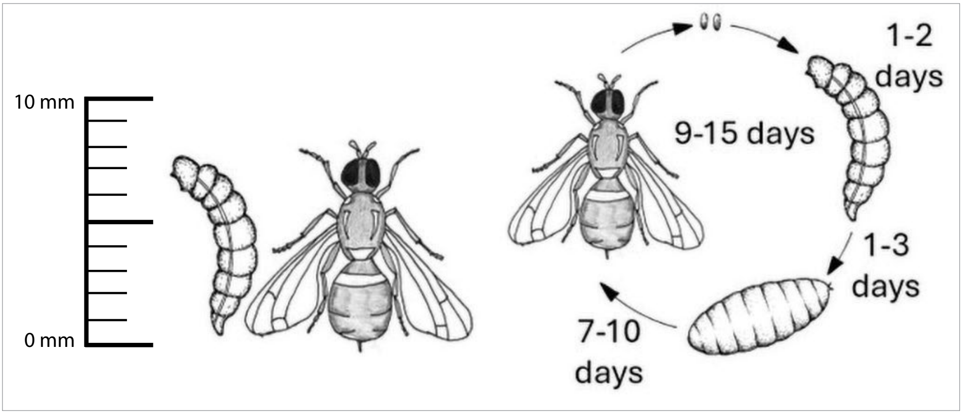


Figure 22. Queensland fruit fly life cycle. Adapted from McDougall et al. (2013, p 70).

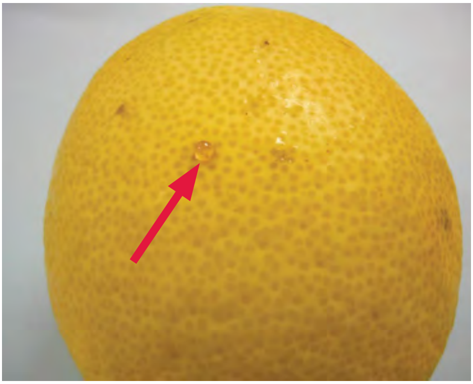


Figure 23. Queensland fruit fly sting marks on the skin appear as discolouration or gum-like exudates.

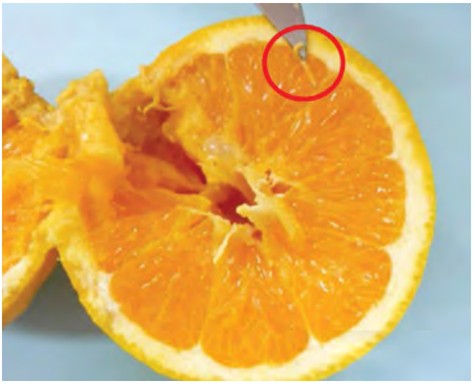


Figure 24. Queensland fruit fly larvae feeding and associated fruit rot.

Aphids

Black citrus aphid (*Toxoptera aurantii*)
Black or brown citrus aphid (*Toxoptera citricida*)
Melon aphid (*Aphis gossypii*)
Spiraea aphid (*Aphis spiraecola*)

Description

Eggs: aphids produce live young (Figure 25).

Immatures: nymphs resemble adults but are smaller.

Adults: small, soft-bodied insects with a pair of tube-like appendages (cornicles) on the rear of the abdomen. Aphids have winged and wingless forms (Figure 26). Citrus aphids are black or brown (Figure 27). Melon aphids and spiraea aphids are green.

Similar to other aphid species.

Damage: aphids deform leaves and shoots with their piercing-sucking mouthparts (Figure 28). They produce honeydew as they feed (Figure 29), promoting sooty mould growth, which turns the leaves and fruit black. All citrus varieties are susceptible. *Toxoptera aurantii* and *Toxoptera citricida* are vectors for the citrus tristeza virus.

Risk period: September to October and February to April.

Management

Cultural: do not over-fertilise trees as aphid numbers are higher on nutrient-rich plants.

Biological: natural enemies are important for suppressing aphid numbers. These include parasitoid wasps (*Aphelinus* spp. and *Aphidius* spp.), predatory ladybird beetles (*Coccinella transversalis* and *Hippodamia variegata*, Figure 30 and Figure 31), lacewings (*Mallada* spp. and *Micromus* spp.) and hoverflies (*Simosyrphus grandicornis*). Parasitised aphids become swollen 'mummies' after a parasitoid wasp completes its life cycle (Figure 26).

Chemical: use selective chemical options that are least disruptive to natural enemies.

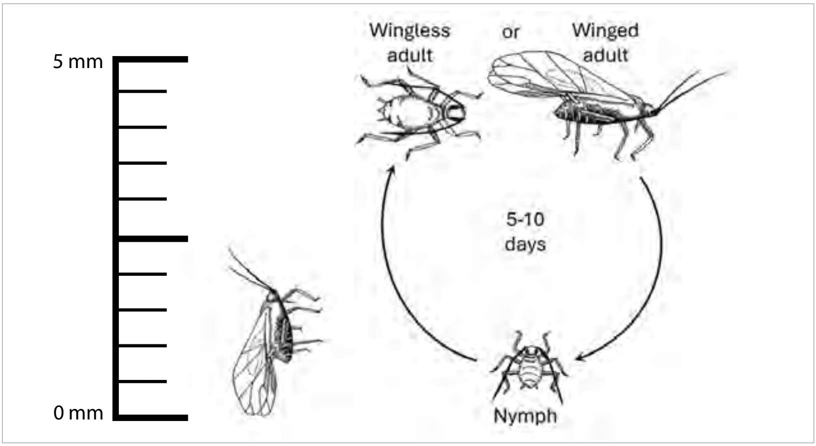


Figure 25. Aphid life cycle. Adapted from Smith et al. (1997, p 90) and McDougall et al. (2017, p 21).

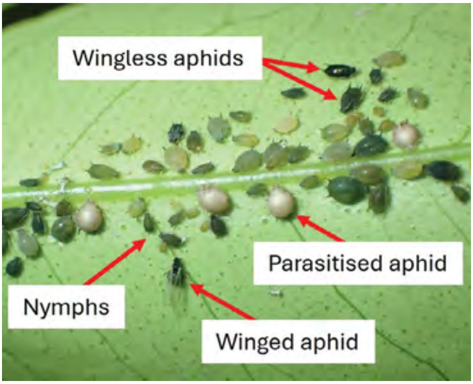


Figure 26. Aphids on a citrus leaf. Note the winged and parasitised aphids.

Figure 27. Aphids feeding on a shoot.

Figure 28. Aphids feeding on young citrus shoots will deform the leaves and shoots.

Figure 29. Aphid honeydew secretions on a citrus leaf.

Figure 30. Hippodamia variegata adult feeding on aphids.

Figure 31. Ladybird beetle larvae feeding on aphids.

Australian citrus whitefly

Orchamoplatus citri

Description

Eggs: oval-shaped and laid on the undersides of leaves in circular patterns (Figure 32).

Immatures: flat, pale yellow (Figure 33) and elongated.

Adults: 2.5 mm long, small white insect with wings (Figure 34).

Similar to young stages of scales and aphids; adult whiteflies look like tiny moths.

Damage: adults cluster on young shoots and leaves and fly off in masses when disturbed. Leaves develop chlorosis (Figure 35). Feeding whiteflies excrete honeydew, promoting sooty mould growth on the leaves and fruit (Figure 36). Leaf drop can result from high whitefly populations and excessive feeding damage.

Risk period: October to November and March to May.

Management

Cultural: whiteflies are not usually a problem if natural enemies are encouraged and broad-spectrum insecticides are avoided.

Biological: parasitoid wasps (e.g. *Encarsia* sp.), green lacewings (*Mallada signatus*) and ladybird beetles, e.g. citrus whitefly ladybird beetle (*Serangium maculigerum)*.

Chemical: horticultural mineral oil sprays help to reduce whiteflies.

Figure 32. Australian citrus whitefly adults and eggs.

Figure 33. Australian citrus whitefly nymphs and pupae on the underside of a leaf.

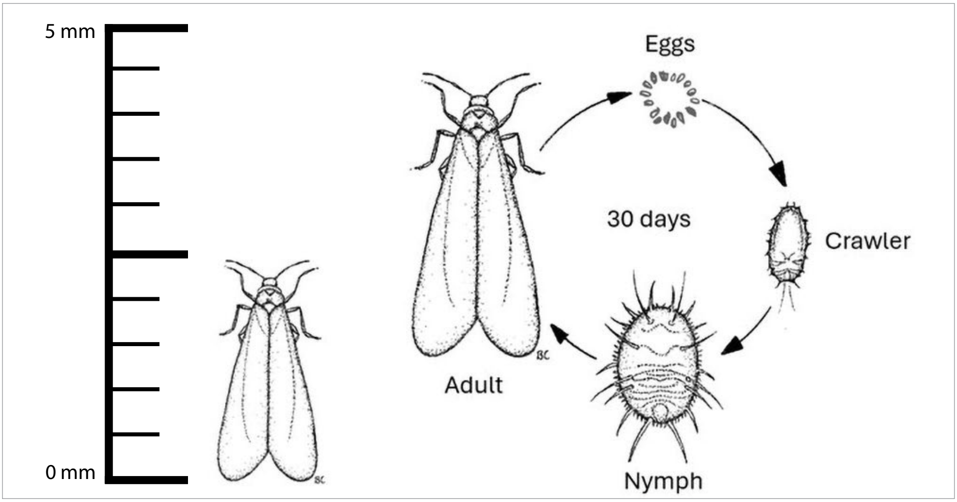


Figure 34. Australian citrus whitefly life cycle. Adapted from Goodwin (2002, p 21).

Figure 35. Chlorotic spots from whitefly feeding on the underside of leaves.

Figure 36. Sooty mould growing on whitefly honeydew secretions on mature fruit.

Scales

Citricola scale (*Coccus pseudomagnoliarum*)

Description

Eggs: yellow, oval, and remain under the female before hatching.

Immatures: flat and transparent when young, changing to a mottled grey–brown and darkening as they age (Figure 37). They are elongated, oval (Figure 38), and mobile.

Adults: up to 7 mm long, dark grey, oval (Figure 39), wingless and immobile (Figure 40).

Similar to black scale and soft brown scale.

Damage: they suck the sap from leaves and twigs of all citrus varieties and excrete honeydew, promoting sooty mould growth (Figure 41).

Risk period: October to November and March to April.

Management

Cultural: minimise dust and harvest mature fruit. Ants farm scale insects for their honeydew secretions, helping them to move to other locations. Large ant populations require control.

Biological: parasitoid wasps (*Coccophagus* spp.), lacewings (*Micromus tasmaniae* and *Mallada* spp.) and ladybird beetles (e.g. *Rhyzobius lophanthae*, *Cryptolaemus montrouzieri* and *Diomus notescens*) are common natural enemies.

Chemical: insecticides are best used to target young growth stages.

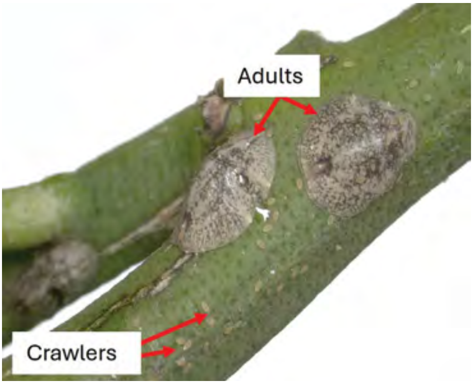


Figure 37. Citricola scale adult and crawler stages.

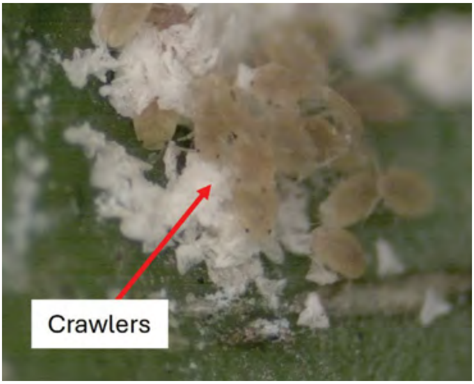


Figure 38. Citricola scale crawlers are oval and mobile.

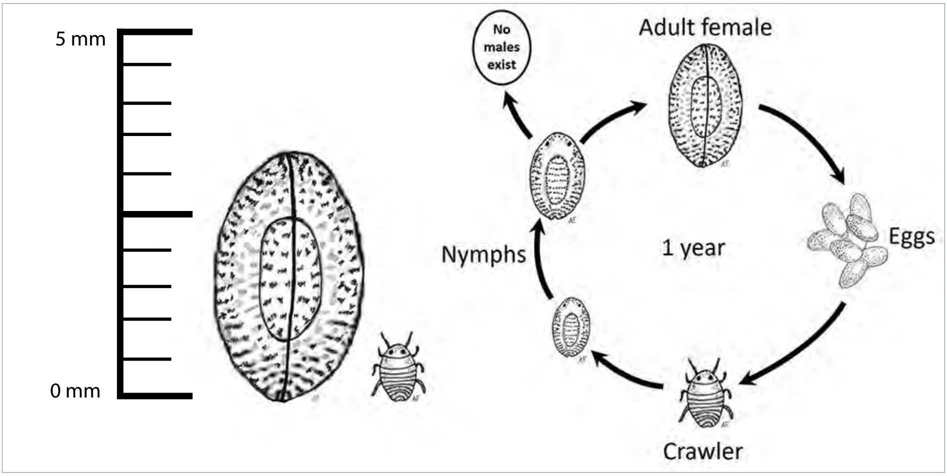


Figure 39. Citricola scale life cycle.

Figure 40. Citricola scale adult.

Figure 41. Citricola scale on a citrus flush, with sooty mould growth on leaves.

Cottony cushion scale (*Icerya purchasi*)

Description

Eggs: bright orange eggs in a fluted white cotton elongated egg sac, about 10–15 mm long.

Immatures: nymphs are bright red with dark antennae and thin brown legs (Figure 42). They are mobile, feeding on leaves and twigs.

Adults: females are wingless, bright orange–red or brown with a white wax covering (Figure 43). Adult females are 5 mm long, but their egg sac increases their length to 10–15 mm (Figure 44 and Figure 45). Winged males have a dark red body and dark antennae.

Similar to cottony citrus scale.

Damage: they suck the sap from leaves and twigs (Figure 46) of all citrus varieties and excrete honeydew (Figure 47), promoting sooty mould growth.

Risk period: February to March.

Management

Cultural: minimise dust and harvest mature fruit.

Biological: predators include lacewings (*Micromus tasmaniae*, *Mallada signatus*) and ladybird beetles (*Novius cardinalis*, *Novius koebeli*, *Cryptolaemus montrouzieri*). Parasites include *Cryptochaetid* spp. flies (*Cryptochaetum iceryae*) and parasitoid wasps (*Ophlosia* spp.).

Chemical: insecticides are best used targeting young growth stages. Ants protect cottony cushion scale for their honeydew secretions (Figure 48) by attacking their natural enemies. Large ant populations require control.

Figure 42. Cottony cushion scale crawlers emerge from the egg sac.

Figure 43. Cottony cushion scale females have a white wax coating.

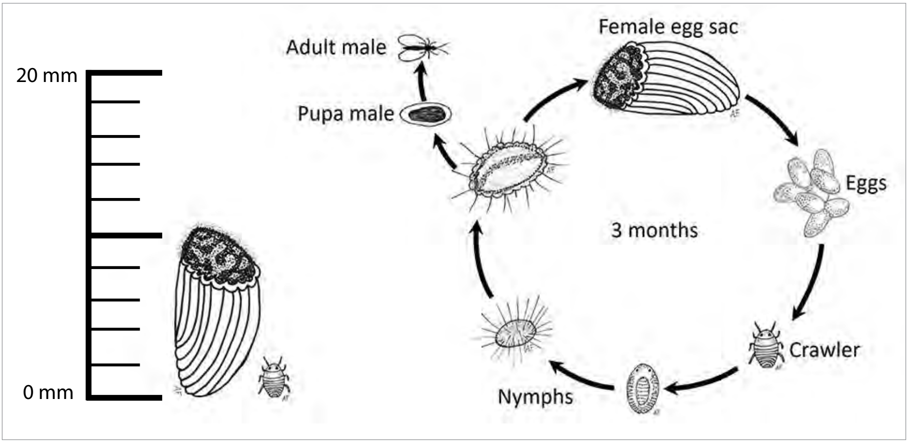


Figure 44. Cottony cushion scale life cycle.

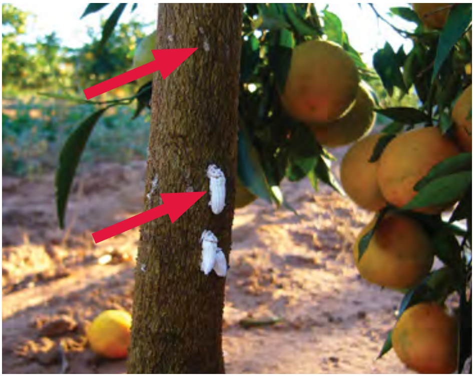


Figure 45. Cottony cushion scale with fluted cotton egg sacs attached to a citrus tree trunk (bottom) and adult without egg sacs (top).

Figure 46. A stem infested with cottony cushion scale.

Figure 47. A honeydew droplet secretion.

Figure 48. Ants feeding on honeydew and protecting the cottony cushion scale.

Soft brown scale (*Coccus hesperidum*)

Description

Eggs: the female deposits live crawlers (Figure 49); there is no egg stage.

Immatures: nymphs have legs and can move. They moult twice.

Adults: a soft yellow–brown mottled scale becoming darker with age (Figure 50). They are flat, oval and up to 4 mm long (Figure 51).

Similar to citricola scale.

Damage: soft brown scale can infest citrus leaves, stems (Figure 52) and fruit. The presence of scale promotes sooty mould growth (Figure 53), downgrading fruit. Large populations can cause leaf drop.

Risk period: October to November and February to March.

Management

Cultural: provide trees with good growing conditions, particularly irrigation, to enhance their resistance to scale damage. In areas with a hot summer, pruning to open canopies reduces scale populations due to exposure to heat and natural enemies.

Biological: predatory ladybird beetles (e.g. *Rhyzobius lophanthae*, *Cryptolaemus montrouzieri* and *Diomus notescens*), brown lacewings (*Micromus* spp.) and caterpillars (*Catoblemma dubia*) feed on soft brown scale. Several parasitoid wasps (e.g. *Metaphycus* spp., *Coccophagus* spp., *Microterys flavus,* and *Diversinervus elegans*) attack soft brown scale (Figure 54).

Chemical: mineral oil provides adequate control of soft brown scale crawler stages. Ants protect soft brown scale (Figure 55) for their honeydew secretions by attacking their natural enemies. Large ant populations require control.

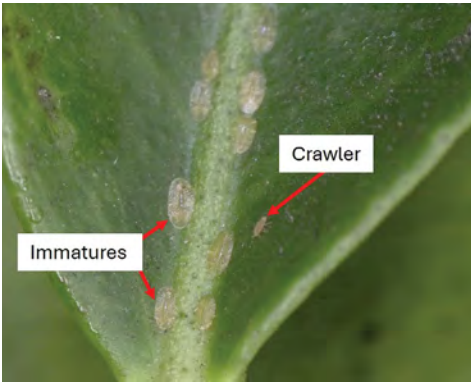


Figure 49. Soft brown scale immature and crawler stages on a citrus leaf.

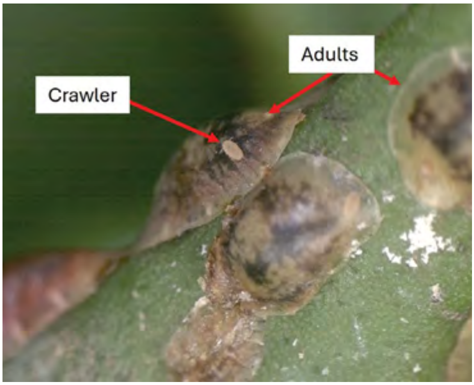


Figure 50. Soft brown scale adult and crawler stages.

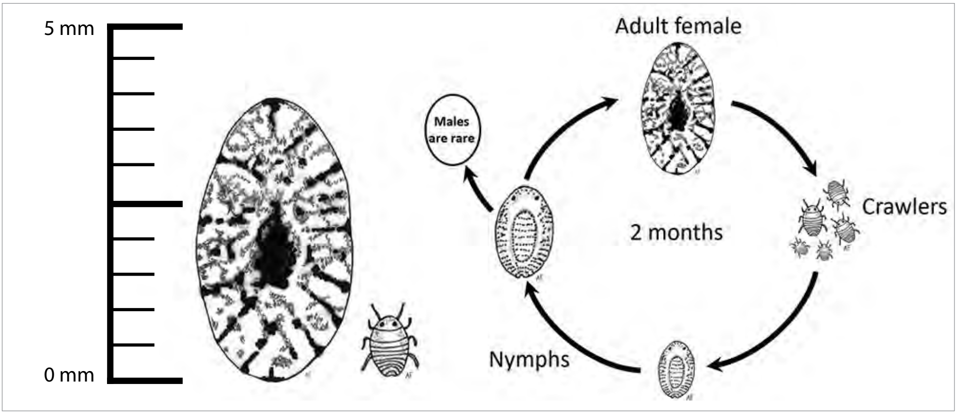


Figure 51. Soft brown scale life cycle.

Figure 52. Soft brown scale on citrus shoots.

Figure 53. Soft brown scale promotes sooty mould growth.

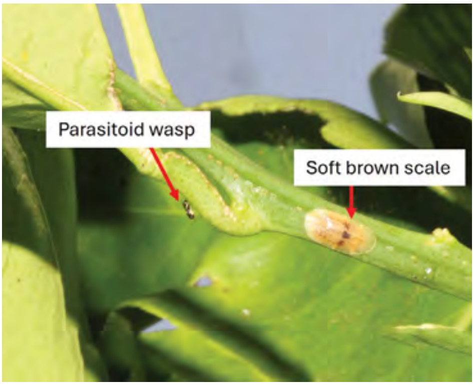


Figure 54. Parasitoid wasps are natural enemies of soft brown scale.

Figure 55. Ants protect soft brown scale.

Red scale (*Aonidiella aurantii*)

Description

Crawlers and white caps: pale yellow crawlers are mobile and fix themselves to surfaces as white caps (Figure 56).

Immatures: females are circular and smaller than adults. Males are oval and paler. Moulting occurs, creating a red scale cover in both sexes (Figure 57).

Adults: mature female scale covers are about 2 mm in diameter and reddish-brown. Mature males are small yellow wasps with a black band on the shoulders (Figure 58).

Similar to circular black scale and yellow scale.

Damage: young fruit might become pitted from feeding damage (Figure 59). Mature scale are usually on fruit that are fully developed or ready for harvest (Figure 60). Heavy infestations (Figure 61) can cause leaves to go yellow (Figure 62) and might result in premature leaf drop and twig dieback.

Risk period: November to April.

Management

Cultural: minimise dust and harvest mature fruit.

Biological: parasitoid wasps include *Aphytis* spp. and *Comperiella bifasciata*. Predators include *Rhyzobius lophanthae*, *Chilocorus circumdatus* (ladybird beetles), and green lacewings (*Mallada signatus*). Mating disruption (Figure 63) and natural enemies can sustainably manage red scale.

Chemical: insecticides are best used targeting young growth stages of red scale.

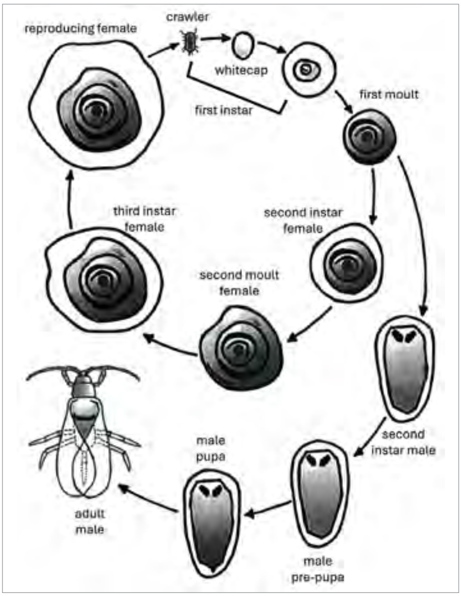


Figure 56. Red scale life cycle. Source: Forster et al. (1995).

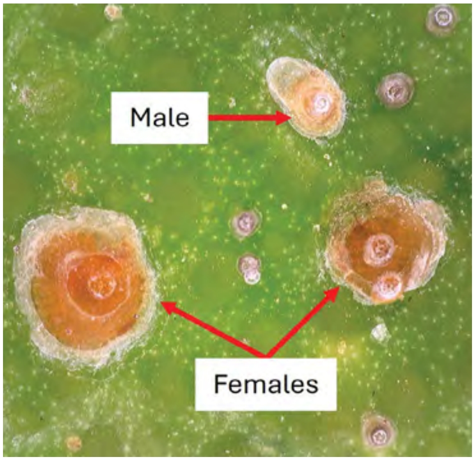


Figure 57. Male and female red scale.

Figure 58. Red scale adult male. Photo: JK Clark, University of California, Regents.

Figure 59. Red scale causes pitting on young fruit.

Figure 60. Red scale on fruit.

Figure 61. A heavy infestation of red scale.

Figure 62. Heavily infested leaves can turn yellow.

Figure 63. A mating disruption tab for red scale.

Mealybugs

Citrophilous mealybug (*Pseudococcus calceolariae*)

Description

Eggs: laid in cottony egg sacs attached to leaves, fruit, bark or branches.

Immatures: early-stage nymphs are tiny, pink and mobile. The later instars appear similar to adults (Figure 64).

Adults: slow-moving, oval, up to 4 mm long and have a dark claret-coloured body covered in white wax (Figure 65). Posterior filaments are one-third of the body length (Figure 66).

Similar to citrus mealybug and long-tailed mealybug.

Damage: mealybugs live in sheltered places where fruit touch. They secrete large amounts of honeydew, promoting sooty mould growth on fruit and leaves.

Risk period: November to June.

Management

Cultural: control alternate hosts such as nightshade and caltrop.

Biological: parasitoid wasps (e.g. *Tetracnemoidea brevicornis*, *Anagyrus fusciventris*, *Coccophagus gurneyi*, *Allotropa* spp. and *Ophelosia* spp.), lacewing larvae (*Mallada* spp.), ladybird beetles (e.g. *Rhyzobius ruficollis* and *Cryptolaemus montrouzieri*) and the cecid fly (*Diadiplosis koebelei*) are natural predators of citrophilous mealybug.

Chemical: horticultural mineral oils are effective on young nymphal stages.

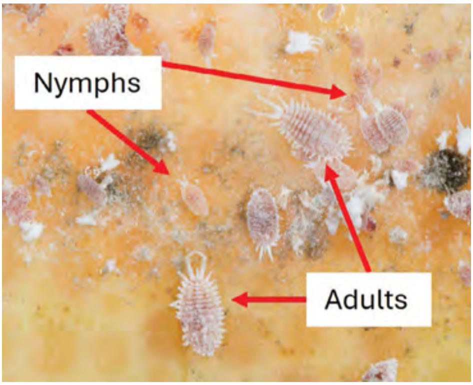


Figure 64. Citrophilous mealybug adults and early-stage nymphs.

Figure 65. Citrophilous mealybugs shelter where citrus fruit touch.

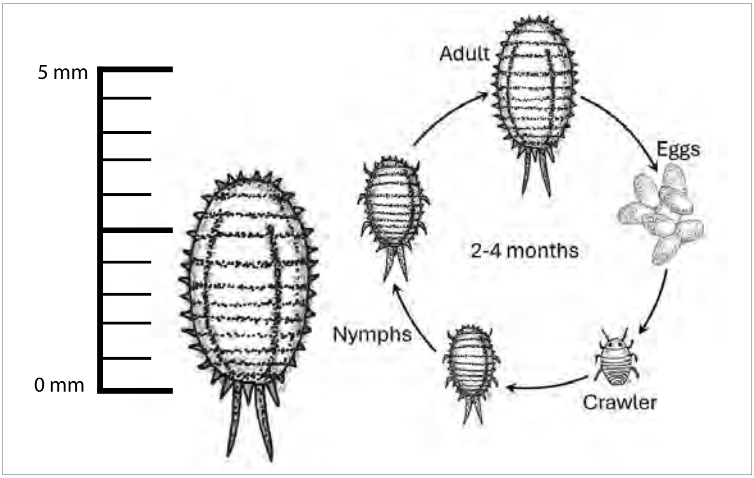


Figure 66. Citrophilous mealybug life cycle.

Long-tailed mealybug (*Pseudococcus longispinus*)

Description

Eggs: the female deposits live nymphs under her body; there is no egg stage.

Immatures: early-stage nymphs are tiny, pink, have legs and are faster-moving than adults. Late-stage nymphs have the characteristic white waxy coating of adult mealybugs. Nymphs go through 3 to 4 growth stages.

Adults: have long-tailed filaments that are longer than their body (Figure 67 and Figure 68), are slow-moving, oval, up to 4 mm long (Figure 69) and covered in white wax.

Similar to citrophilous mealybug, citrus mealybug and cryptolaemus ladybird beetle larvae (Figure 70).

Damage: mealybugs live in sheltered places (Figure 71) such as inside the navel and under the fruit calyx (Figure 72). Excreted honeydew promotes sooty mould growth on fruit (Figure 73) and leaves, which spoils the fruit's appearance. Other fungi can grow on the honeydew and cause the fruit to rot.

Risk period: November to June.

Management

Cultural: use alternate row slashing to provide habitat for natural enemies. Manage ant colonies, as ants will actively defend mealybugs for their honeydew from natural predators.

Biological: mealybugs can be managed by natural predators such as lacewing larvae (*Mallada* spp.), a ladybird beetle (*Cryptolaemus montrouzieri*) and the minute two-spotted ladybird beetle (*Diomus notescens*). Long-tailed mealybugs are also attacked by several parasitoid wasp species. Natural enemies are very effective as they can get inside the tree canopy and tight places where mealybugs reside.

Chemical: mealybugs are difficult insects to manage using pesticides alone. Make considered chemical choices to conserve natural enemies.

Figure 67. Long-tailed mealybug has long tail filaments.

Figure 68. Long-tailed mealybug adult.

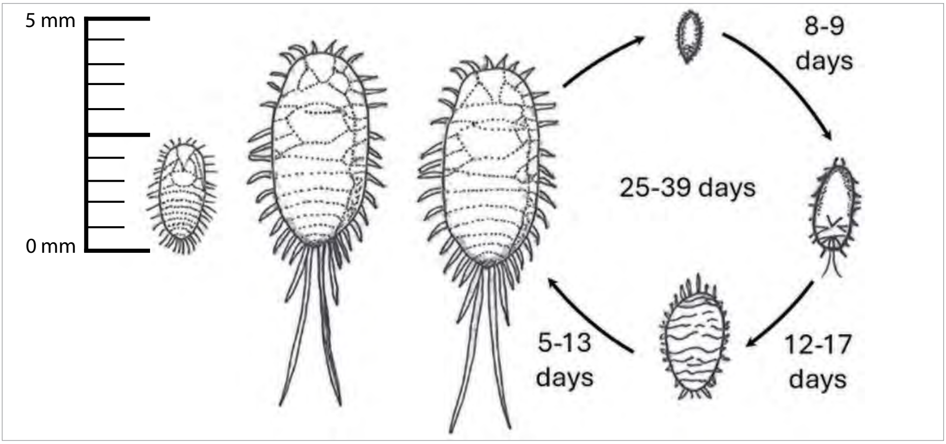


Figure 69. Long-tailed mealybug life cycle. Source: McDougall et al. (2013, p 42) ACIAR Monograph 157.

Figure 70. The predatory cryptolaemus ladybird beetle larvae resemble a mealybug.

Figure 71. Mealybugs sheltering on the inward-facing side of the fruit.

Figure 72. Mealybugs live in sheltered places such as inside the navel and under the calyx.

Figure 73. Mealybug infestation causes sooty mould growth.

Pests

Crusader bug

Mictis profana

Description

Eggs: laid in clusters on leaves (Figure 74), twigs or fruit. The eggs are brown, elongated and have a domed lid.

Immatures: smaller than the adult and have different colourings and markings. Nymphs are brown or black (Figure 75), while older nymphs have 2 orange spots in the centre of their back (Figure 76).

Adults: brown with a yellow cross on their back (Figure 77). They are 20–25 mm long (Figure 78) with long legs and long antennae with orange tips. When disturbed, they spray an unpleasant odour.

Similar to bronze orange bug and citrus blossom bug.

Damage: crusader bugs pierce and suck on young plant shoots, causing wilting, browning and dieback to older stems and death of flower heads. All citrus varieties are susceptible.

Risk period: October to April.

Management

Biological: many natural enemies control crusader bugs including birds, spiders, assassin bugs (*Pristhesancus plagipennis*), praying mantises (*Mantidae* spp.) and parasitoid wasps.

Chemical: control of crusader bugs is rarely required; if needed, spot-spray with a registered insecticide.

Figure 74. Crusader bug eggs.

Figure 75. Crusader bug early-stage nymph.

Figure 76. Crusader bug late-stage nymph.

Figure 77. Crusader bug adult.

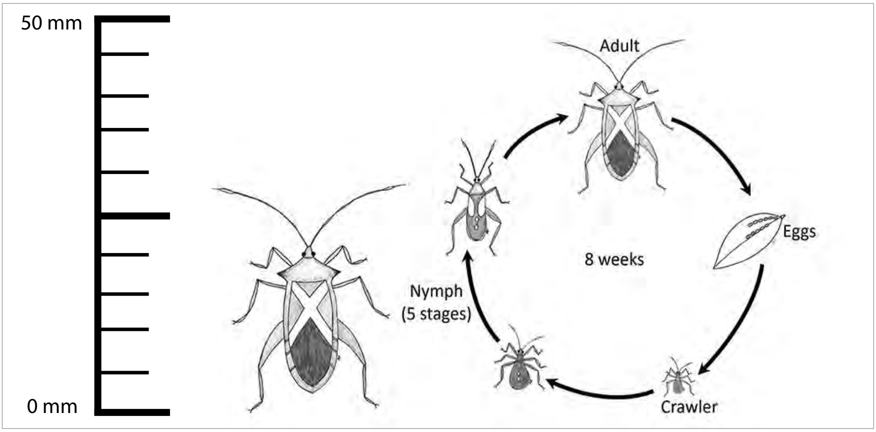


Figure 78. Crusader bug life cycle.

Spined citrus bug

Biprorulus bibax

Description

Eggs: sphere-shaped, 1 mm long and laid in rafts (Figure 79). They begin white and develop black and red markings closer to hatching.

Immatures: early-stage nymphs have yellow and black or orange and black markings. Late-stage nymphs have green and black markings (Figure 80).

Adults: 15–20 mm long (Figure 81), shield-shaped, and green with a black spine at each shoulder (Figure 82 and Figure 83). There are 3 generations per year (spring, summer and autumn) in NSW, Vic and SA and 4 generations in Qld (Figure 81).

Similar to green vegetable bug.

Damage: nymph and adult feeding cause skin gumming and lesions that blemish the fruit. It can also cause browning and staining (Figure 84), and internal dry patches, resulting in premature fruit drop. Spined citrus bug favours lemons and mandarins; damage in oranges is less common.

Risk period: October to March.

Management

Cultural: monitor regularly to detect spined citrus bug early in the growing season.

Biological: parasitoid wasps (*Trissolcus oenone, Trissolcus ogyges* and *Anastatus biproruli*) parasitise spined citrus bug eggs, while spiders, predatory bugs, praying mantises (*Mantidae* spp.) and assassin bugs (*Pristhesancus plagipennis*) prey on adults and nymphs. Ants and lacewing larvae also feed on spined citrus bug eggs.

Chemical: using broad-spectrum chemicals over entire blocks will kill the natural enemies of citrus pests. When pest pressure is high, trees with overwintering adult clusters can be spot-sprayed with a registered insecticide.

Figure 79. Spined citrus bug eggs.

Figure 80. Spined citrus bug late-stage nymphs.

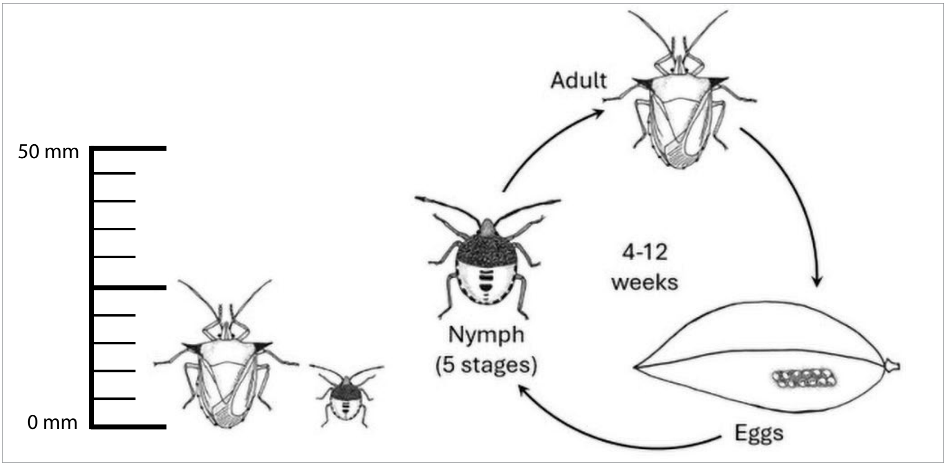
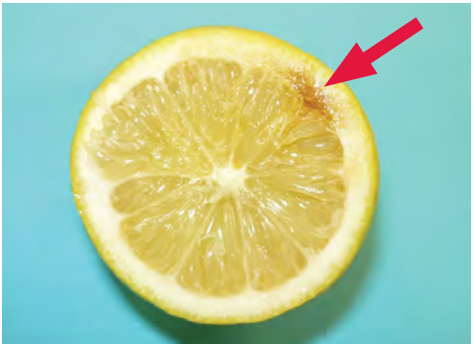


Figure 81. Spined citrus bug life cycle. Adapted from Smith et al. (1997, p 108).

Figure 82. Spined citrus bug adult and early-stage nymphs.

Figure 83. Spined citrus bug adult.



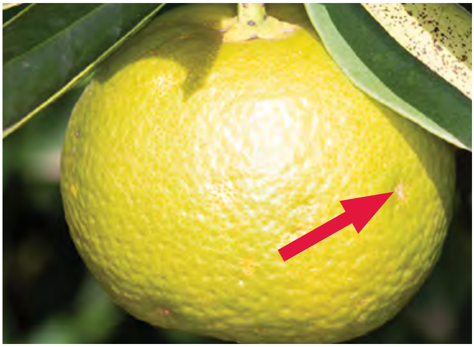


Figure 84. Internal (left) and external (right) damage to fruit from spined citrus bug feeding.

Kelly's citrus thrips

Pezothrips kellyanus

Description

Eggs: laid mainly in citrus flowers, with some also found on fruit and leaves.

Immatures: larvae develop through 2 instars (Figure 85), with the second mature instar pupating in the soil. They are pale yellow (Figure 86) to bright orange, up to 2 mm long and wingless. It is difficult to tell the difference between Kelly's citrus thrips larvae and the larvae of non-damaging thrips (e.g. plague thrips) without a microscope.

Adults: mainly black (Figure 87), 2–3 mm long with parallel wings. They emerge from the soil to feed and reproduce in the tree canopy.

Similar to greenhouse thrips, plague thrips, predatory thrips and tomato thrips.

Damage: rind scurfing appears as a ring (halo scarring) around the fruit calyx (Figure 88) and between touching fruit (Figure 89), which can look similar to light wind blemish (Figure 90 and Figure 91).

Risk period: mid-October to early December.

Management

Cultural: build up soil organic matter to support predatory mite populations.

Biological: predatory soil mites are an important natural predator of Kelly's citrus thrips' pupae. Other natural predators include spiders, lacewing larvae (*Micromus* spp. and *Mallada* spp.) and predatory thrips (e.g. *Haplothrips* spp.).

Chemical: avoid using broad-spectrum insecticides for other pests. Organophosphate foliar spray run-off reduces the abundance of soil-dwelling predatory mites that feed on Kelly's citrus thrips. Some resistance to this insecticide group (1B) has been reported. Several insecticides are available with varying effects on natural enemies.

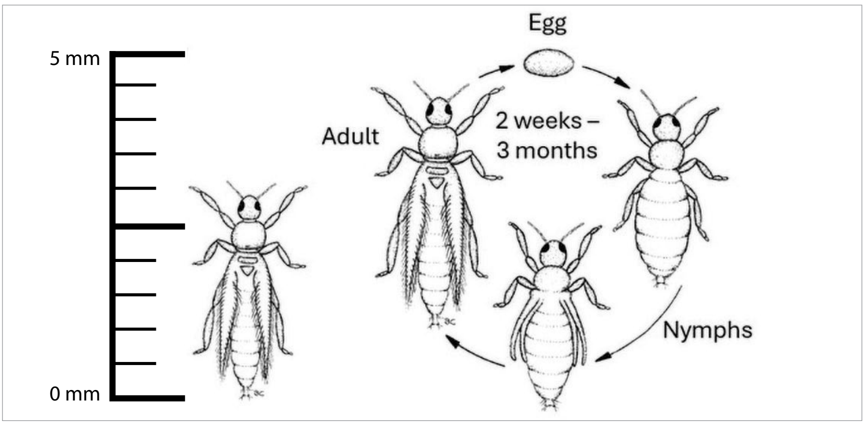


Figure 85. Kelly's citrus thrips life cycle. Source: Adapted from Goodwin (2002, p 25).

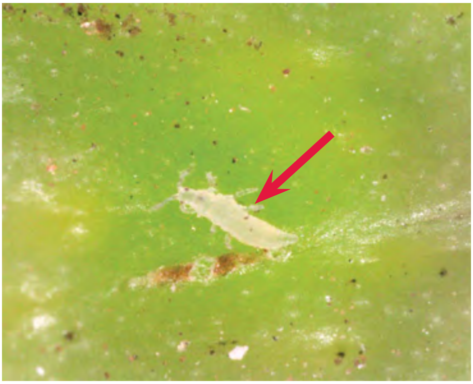


Figure 86. Kelly's citrus thrips larva.

Figure 87. Kelly’s citrus thrips adult.

Figure 88. Kelly’s citrus thrips scurfing blemish (halo scarring) around the fruit calyx.

Figure 89. Kelly's citrus thrips damage.

Figure 90. Kelly’s citrus thrips rind scurfing damage can resemble light wind blemishes.

Figure 91. Light wind blemish on an immature fruit appears similar to damage caused by Kelly's citrus thrips.

Citrus gall wasp

Bruchophagus fellis

Description

Eggs: opaque white, ovoid and less than 0.5 mm. They are laid under the bark of new-season citrus shoots (Figure 92 and Figure 93).

Immatures: larvae are legless and change from opaque white to off-white. Pupae go brown as they mature. They grow to 2 mm long and remain unseen inside the developing gall.

Adults: small black wasps about 2.5 mm long (Figure 94 and Figure 95). Adult wasps emerge from the gall to mate immediately. The females lay most of their eggs within the first 3 days after emerging. Adults are most abundant from late October to mid-November in southern Australia. After emergence, tree sap oozes from the galls (Figure 96).

Similar to parasitoid wasps.

Damage: branches have gall-like growths (Figure 97 and Figure 98) that disturb water and nutrient flow. If pest pressure is high, tree vigour, fruit size and yield will be reduced.

Risk period: October to December.

Management

Cultural: prune at least 2 months before they emerge in spring as adults to reduce pressure. Mulch any later-pruned material. Skirt pruning after egg laying can help reduce gall wasp pressure.

Biological: 2 parasitoid wasps (*Megastigmus brevivalvus* and *Megastigmus trisulcus*) are natural enemies of citrus gall wasps, but natural populations are usually too low to sufficiently control citrus gall wasps, and augmentative releases might be required. Parasitoid wasps will reduce gall density and size.

Chemical: systemic insecticides target larvae but have relatively long withholding periods. Chemicals applied to kill citrus gall wasps also kill the parasitoid wasps. Calcined kaolin is an effective repellent of citrus gall wasp when applied just before adult wasp emergence, however, it will disrupt the natural activity of parasitoid wasps.

Figure 92. Scarring damage to a spring flush shoot after citrus gall wasp egg-laying (top) and a normal spring flush shoot (bottom).

Figure 93. Citrus gall wasp females lay eggs in new season citrus shoots.

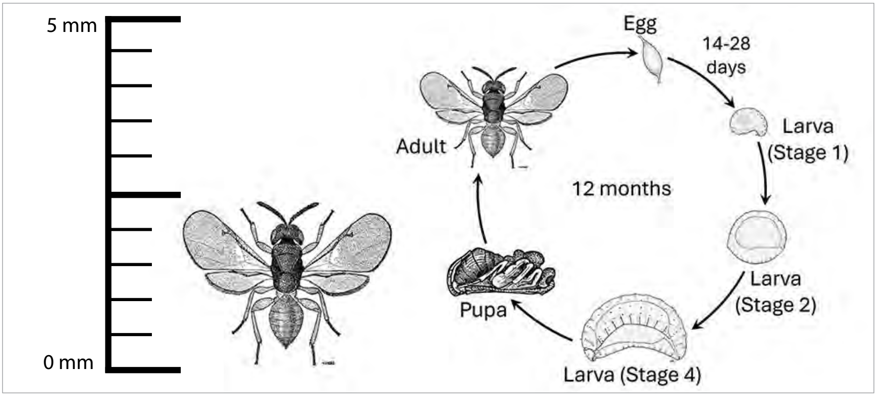


Figure 94. Citrus gall wasp life cycle. Adapted from Noble (1936).

Figure 95. Citrus gall wasp female in a citrus tree canopy.

Figure 96. Citrus gall wasp exit holes on mature citrus galls, with sap oozing from the openings.

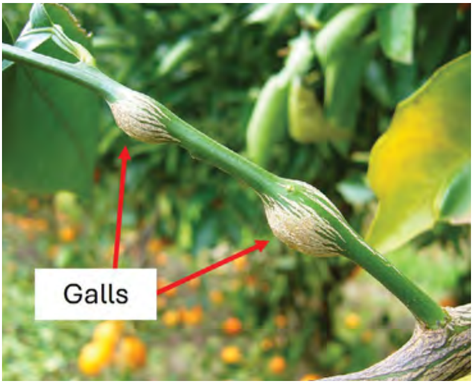


Figure 97. New season galls on a shoot.

Figure 98. A gall with bark removed and citrus gall wasps ready to emerge.

Citrus leaf-miner

Phyllocnistis citrella

Description

Eggs: very small, 0.3 mm long, translucent, oval and deposited singly along the midrib of young leaves.

Immatures: larvae are 3 mm long (Figure 99) and translucent to pale green. Pupae are yellow-brown. The larval stage is found inside silver mines in leaves, where it feeds, leaving a trail of dark frass behind (Figure 100).

Adults: moths are silvery-white and their hindwings are fringed with long hairs. They can grow up to about 2 mm long.

Similar to other leaf-miners (larvae) or small flies (adults).

Damage: young foliage is 'mined' as larvae feed, causing silvery trails and distorted and curled leaves (Figure 101). Older leaves are not attacked. Severe infestations can slow young tree growth in the first few years. Although leaf-miner infestations look bad in mature trees, shoots continue to photosynthesise and economic damage is unlikely. All citrus varieties are susceptible.

Risk period: January to May.

Management

Cultural: limit the production of leaf flushes when leaf-miner numbers are highest. Avoid hedging in summer and autumn. Do not over-water or over-fertilise in late summer and autumn. Fertilise in late winter to promote spring growth when leaf-miner populations are low.

Biological: predators are lacewings (*Micromus tasmaniae*, *Mallada signatus*). Parasitoids include a native wasp (*Semielacher petiolatus*) and 2 introduced wasps (*Cirrospilus quadristriatus* and *Ageniaspis citricola*).

Chemical: control with contact insecticides is difficult as larvae are shielded in their mines. Horticultural mineral oil sprays reduce egg laying as females are deterred from laying on sprayed surfaces. Relatively low oil rates and 2 or more applications are required for suppression from January to mid-March.

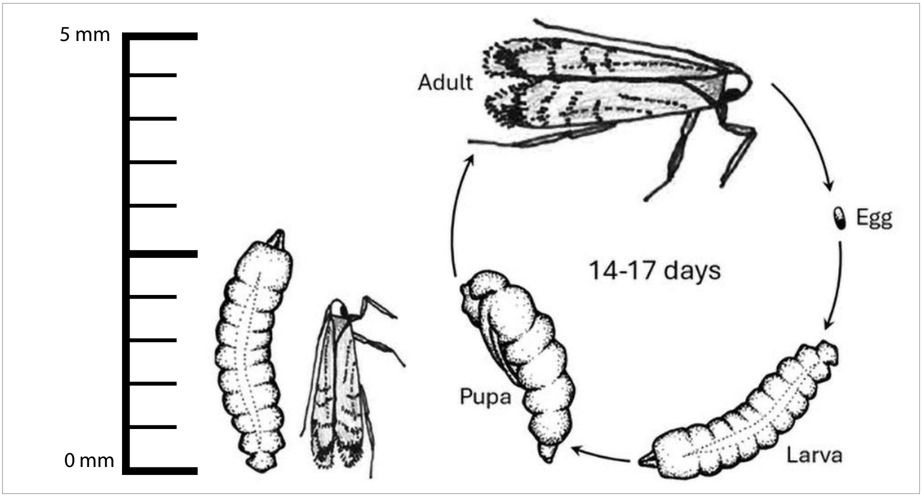


Figure 99. Citrus leaf-miner life cycle. Adapted from McDougall et al. (2017, p 45) and Smith et al. (1997, p 119).

Figure 100. Larva leaf-mining with a trail of dark frass.

Figure 101. Leaf-miner feeding distorts the new flush.

Light brown apple moth

Epiphyas postvittana

Description

Eggs: pale green and laid in flat overlapping masses that resemble fish scales (Figure 102) on leaves, stems and fruit.

Immatures: young larvae are pale yellow–green, while mature larvae are pale green with a brown head (Figure 103) and grow to about 18 mm long. They reside in a silk webbing, usually within a rolled-up leaf (Figure 104) or in flower debris, before pupating.

Adults: pale brown bell-shaped moth (Figure 105) with a wingspan up to 18 mm (Figure 106).

Similar to citrus leaf-roller and citrus rind-borer.

Damage: larvae feed beneath the calyx (Figure 107) and on young fruit (<25 mm in diameter), leaving a halo-like scar (Figure 108), causing packed fruit to be downgraded. Larvae can also bore into mature fruit, causing it to drop.

Risk period: October to mid-December (high risk) and April to July (moderate risk).

Management

Cultural: limit autumn leaf flush production as larvae prefer young foliage. Do not over-water or over-fertilise in late summer and autumn. Having grasses in the inter-row reduces host broadleaf weeds, minimising overwintering sites.

Biological: parasitoid wasps (*Trichogramma* spp.) lay eggs in moth eggs. A predatory bug (*Oechalia shellenbergii*), lacewing larvae and spiders feed on light brown apple moth larvae. A bacterial pathogen (*Bacillus thuringiensis*) and a virus (nuclear polyhedrosis virus, NPV) both affect light brown apple moth larvae. Pheromone ties can be used in larger blocks with moderate to high infestation as a mating disruption tool, reducing the need for insecticide application.

Chemical: consider spraying only if monitoring indicates an unacceptable number of larvae. Selective chemical options that preserve the natural enemies of pests in citrus are preferable. Some broad-spectrum insecticides can be used if monitoring indicates other pests require treatment.

Figure 102. Light brown apple moth egg masses resemble fish scales.

Figure 103. Light brown apple moth larvae.

Figure 104. Light brown apple moth webbing on a citrus leaf.

Figure 105. Light brown apple moth adult female (left) and male (right).

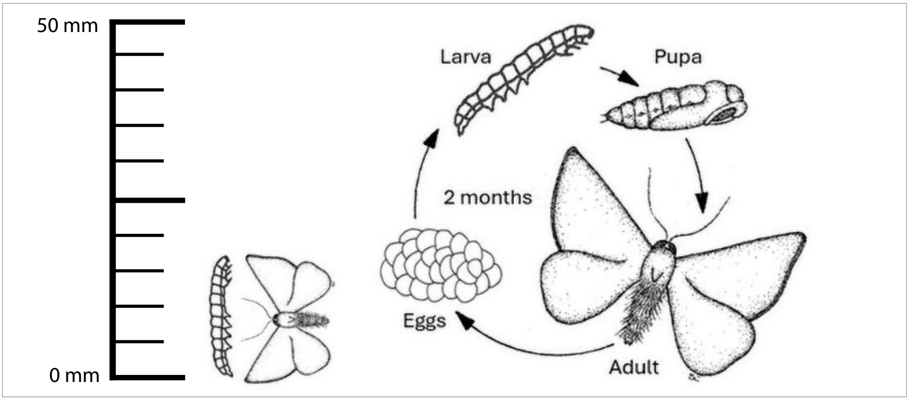


Figure 106. Light brown apple moth life cycle. Adapted from McDougall et al. (2017, p 29).

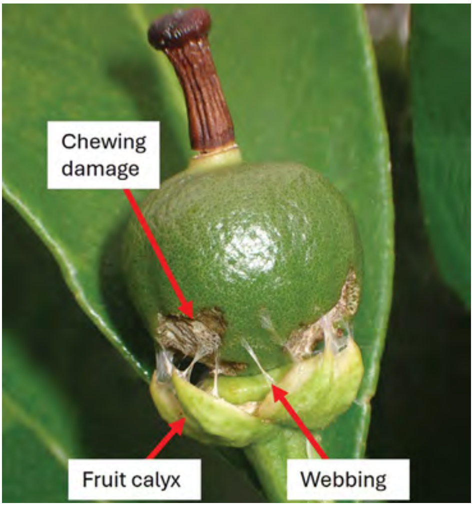


Figure 107. Light brown apple moth larvae feeding damage.

Figure 108. Light brown apple moth larvae feeding causes fruit halo scarring.

Loopers

Chrysodeixis spp.

Description

Eggs: hemispherical and slightly flattened. They are laid either singly or in loose clusters under leaves. They are yellow-green to pale green and 0.6 mm in diameter.

Immatures: young larvae are white or green with hairs that become shorter as they age. Mature larvae are up to 40 mm long (Figure 109), smooth, slender and green with a white stripe on both sides. They arch the middle of their body when resting and display a distinct 'looping' motion when moving (Figure 110). They pupate under leaves in a loose silk cocoon. Pupae begin green, then turn dark brown as they age, growing up to 20 mm long.

Adults: moths have a 30–40 mm wingspan and are dark brown with a silver pattern on the forewings. The hindwings are brown with a metallic sheen. They have a tuft of hair behind the head.

Similar to other caterpillars.

Damage: larvae feed on new growth flushes (Figure 111), flowers and young fruit (Figure 112). Chewed leaves will have large holes and can be completely eaten by mature larvae. Mature fruit will be scarred (Figure 113).

Risk period: September to October.

Management

Cultural: control weeds to minimise pest populations.

Biological: *Trichogramma* spp. wasps parasitise looper eggs. Other natural enemies include lacewings, jumping spiders and predatory bugs (damsel bugs, shield bugs and assassin bugs).

Chemical: loopers are susceptible to insecticides used for other caterpillar pests. When possible, use an insecticide product with minimal effect on the natural enemies of citrus pests.

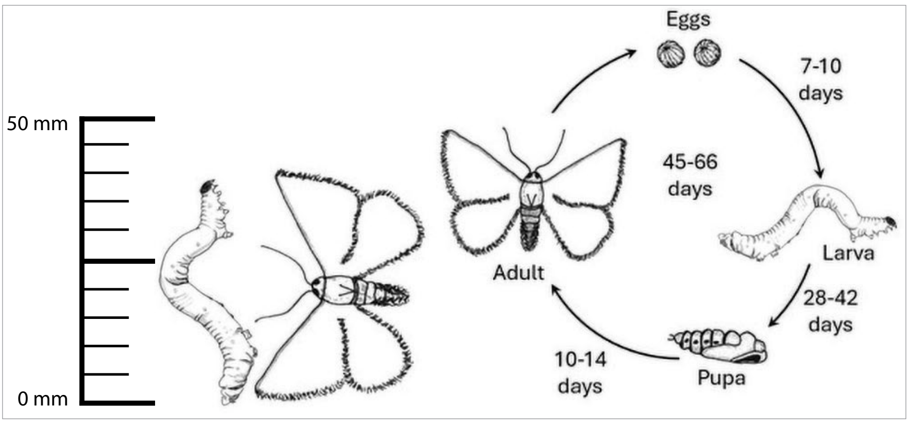


Figure 109. Looper life cycle. Adapted from McDougall et al. (2017, p 37).

Figure 110. Looper caterpillars move with a distinct looping motion.

Figure 111. Looper feeding damage to citrus leaves.

Figure 112. Looper feeding damage to young fruit.

Figure 113. Looper scarring on mature fruit.

Elephant weevil

Orthorhinus cylindrirostris

Description

Eggs: laid underneath the bark on branches throughout spring and summer.

Immatures: legless larvae are soft, creamy-yellow and 20 mm long.

Adults: black, grey or brown, 8–20 mm long (Figure 114) and covered in scales. Their front legs are longer than the other 2 pairs. Their clubbed antennae form an L-shape with a distinct elbow. The adult's long 'snout' (rostrum) is the most distinguishing feature (Figure 115). Adults have wings and can spread reasonable distances. Most adult beetles emerge during September and October.

Similar to citrus fruit weevil and citrus leaf-eating weevil.

Damage: both establishing and mature trees can be hosts, however, damage is reported more frequently in older trees. Adults chew twigs (Figure 116 and Figure 117), branches and leaves, while larvae tunnel throughout the lower tree trunk (Figure 118 and Figure 119) and roots.

Risk period: September to February.

Management

Cultural: keep trees healthy and avoid stressing them (e.g. waterlogging and drought). Commonly the trees in the rows closest to Casuarina windbreaks will be infested (Figure 120).

Biological: entomopathogenic fungi (*Beauveria bassiana*).

Chemical: there are currently no registered chemicals for elephant weevil in citrus.

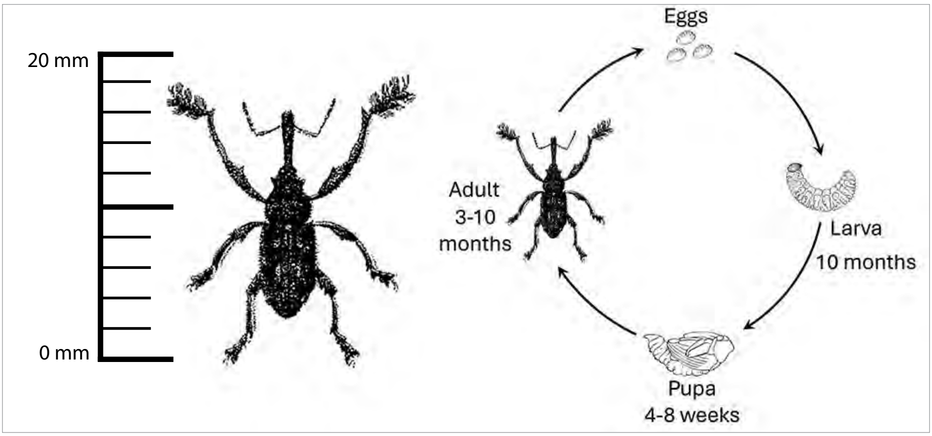


Figure 114. Elephant weevil size and life cycle. Adapted from Olliff (1890, p 279).

Figure 115. Elephant weevil adult.

Figure 116. Elephant weevil feeding damage to a graft stick.

Figure 117. Elephant weevil feeding on a young citrus branch.

Figure 118. Elephant weevil damage to a field nursery tree.

Figure 119. Adult elephant weevil exit holes in a citrus trunk.

Figure 120. Elephant weevils often infest citrus trees closest to Casuarina windbreaks.

Fuller's rose weevil

Asynonychus cervinus

Description

Eggs: laid and glued together in papery groups under fruit calyces (Figure 121 and Figure 122) and in bark fissures, however, they are sometimes between touching leaves and fruit. They are cylindrical, yellow and 1 mm long.

Immatures: the yellow, legless, plump larvae are 6 mm long. They fall to the ground after hatching and live in the soil.

Adults: 8 mm long (Figure 123), grey-brown (Figure 124), wingless and reproduce without mating.

Similar to other weevils.

Damage: while adults feed on citrus leaves, leaving a serrated edge (Figure 125), and larvae feed on citrus roots, Fuller's rose weevil causes little economic damage. However, it is currently a pest of quarantine concern in some export markets that have zero tolerance to the presence of viable eggs on exported fruit.

Risk period: December to August.

Management

Cultural: skirting citrus trees and controlling weeds reduces pathways to tree canopies.

Biological: platygastrid parasitoid wasp (*Fidiobia citri*), assassin bugs, praying mantis, ants, parasitic nematodes (*Heterorhabditis* spp.) and entomopathogenic fungi (*Beauveria bassiana*).

Chemical: regular trunk band spraying can cause secondary pest infestations.

Figure 121. Fuller's rose weevil eggs are usually laid in papery groups hidden under fruit calyces.

Figure 122. Close-up of Fuller's rose weevil eggs laid under the calyx with the calyx removed.

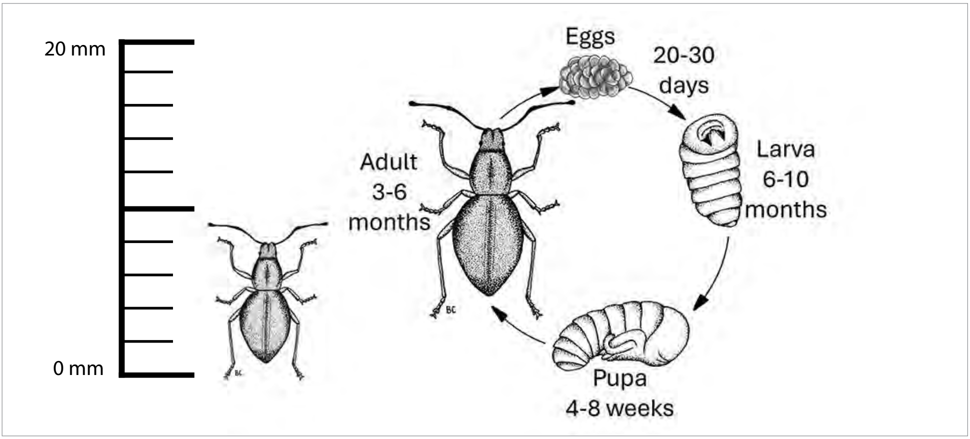


Figure 123. Fuller’s rose weevil life cycle. Adapted from Napier et al. (2009, p 21).

Figure 124. Fuller's rose weevil adult.

Figure 125. Fuller's rose weevil feeding causes serrated leaves.

Pests

Katydids

Citrus katydid (*Caedicia* spp.)

Inland katydid (*Caedicia simplex*)

Spotted katydid (*Ephippitytha trigintiduoguttata*)

Description

Eggs: disc-shaped, 5 mm long and laid in rafts glued together on branches from January to April. Katydids overwinter in egg stages.

Immatures: nymphs hatch in early spring and develop through 5 instars (Figure 126). They look similar to adults but are smaller and wingless (Figure 127).

Adults: resemble grasshoppers, have strong hind legs, are winged but have much longer antennae than grasshoppers. Citrus katydid and inland katydid (Figure 128) are green. Adult spotted katydids are olive green and brown with dark brown markings on the wings and body. The adult stage is reached during December and January.

Similar to grasshoppers and crickets.

Damage: katydids feed on citrus leaves, flowers and young fruit. Fruit larger than golf ball size is not eaten. Fruit feeding causes fruitlet drop and deep scar damage on the sides of developing fruit (Figure 129 and Figure 130).

Risk period: mid-October to mid-December.

Management

Cultural: skirting citrus trees and controlling weeds.

Biological: natural enemies include birds, praying mantis, assassin bugs, spiders and predatory wasps. Tachinid flies and parasitoid wasps parasitise citrus katydids. However, adequate control is difficult to achieve with natural enemies.

Chemical: katydids are susceptible to some insecticides registered for other citrus pests.

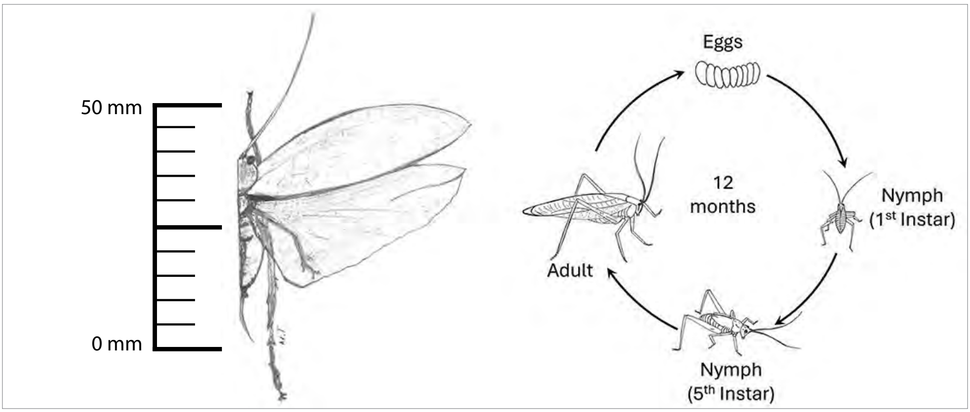


Figure 126. Katydid life cycle.

Figure 127. Katydid nymph.

Figure 128. Inland katydid adult.

Figure 129. Katydid damage at early fruit set.

Figure 130. Katydid damage caused in early spring has calloused by harvest.

European earwig

Forficula auricularia

Description

Eggs: ovoid, white to pale yellow, 1 mm long, and laid in clutches of 20–80 in bark crevices or soil burrows.

Immatures: nymphs resemble adults but are smaller (Figure 131), paler, and have wing buds and undeveloped forceps. Nymphs stay in the burrow.

Adults: brown, 13–16 mm long, have short, equal-sized legs, long, thin antennae, chewing mouthparts, flight wings hidden on their back and a flattened, segmented abdomen with 2 forceps on the end. Males have inwardly curved forceps, while females have straighter forceps (Figure 132). The forceps are used to catch and carry prey and for defence.

Similar to native common brown earwigs (*Labidura truncate*).

Damage: young trees (Figure 133) are more susceptible to European earwigs than mature trees. Feeding damages buds, flowers, leaves, young shoots and rind of young fruit (Figure 134). Earwigs consume developing buds, preventing new foliage from growing. Bud damage looks similar to frost damage. Leaf edges become scalloped and fruit will be scarred. Mature foliage is rarely chewed. Severe infestations prevent flowering and fruit development, promoting alternate bearing and out-of-season fruit.

Risk period: June to November.

Management

Cultural: tilling soil and reducing vegetation, particularly in early June, can help reduce and destroy nesting sites. Prune the skirts of trees to prevent earwig access and remove tree guards to discourage sheltering sites.

Biological: natural enemies include birds, spiders, reptiles, frogs, centipedes, assassin bugs, entomopathogenic fungi and nematodes. The European earwig is also a predator and can be beneficial at low densities. Native common brown earwigs (larger with an orange triangle on their back; Figure 135) are beneficial in the orchard, predating on many insects, including caterpillars, pupae and eggs.

Chemical: there are currently no registered chemicals for European earwig in citrus.

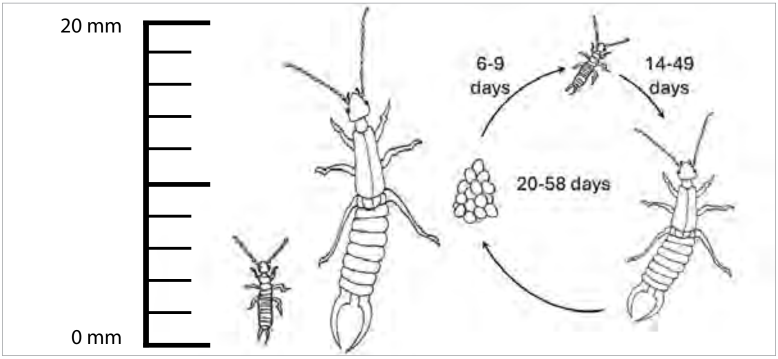


Figure 131. European earwig life cycle.

Figure 132. European earwig adult female (left) and male (right).

Figure 133. European earwig adult on citrus foliage.

Figure 134. European earwig chewing damage on young fruit.

Figure 135. The native common brown earwig has an orange triangle on its thorax.

Snails

Common garden snail (*Helix aspersa*)

Common white snail (*Cernuella virgata*)

Pointed snail (*Cochlicella acuta*)

Small brown snail (*Microxeromagna vestita*)

White Italian snail (*Theba pisana*)

Description

Eggs: soft-shelled, white, sphere-shaped and around 3 mm in diameter and laid 20–40 mm deep in moist soil.

Immatures: small versions of the adult.

Adults: reach up to 40 mm in diameter with a hard shell. The soft, slimy, grey body has a head with 2 large and 2 small antennae (Figure 136). The flat muscular 'foot' is used for sliding movement, aided by releasing mucus to reduce surface friction. The mucous leaves a slimy trail. When threatened, the snail's body retracts into the shell. They are hermaphrodites, having both female and male reproductive organs. During hot, dry periods, snails retract into their shell, sealing the opening with a membrane and becoming dormant (aestivate) in protected places such as tree crotches (Figure 137). Snails are identified according to their shell characteristics:

- **Common garden snails** (*Helix aspersa*) have a 25–40 mm diameter hard coiled shell with a characteristic tortoiseshell striped pattern and no umbilicus (Figure 138).
- **Common white snails** (*Cernuella virgata*) have a 10–20 mm diameter coiled white shell with a brown band around the spiral and a round, open umbilicus (Figure 139).
- **Pointed snails** (*Cochlicella acuta*) have an 18 mm long hard shell with a length-to-diameter shell ratio >2, fawn, grey or brown (Figure 140).
- **Small brown snails** (*Microxeromagna vestita*) have a 7 mm diameter hard brown to honey-coloured shell with a wide, round umbilicus (Figure 141).
- **White Italian snails** (*Theba pisana*) have 10–30 mm diameter coiled hard shells, a brown band around the spiral, and a semi-circular umbilicus that is partially closed (Figure 142).

Similar to other snails.

Damage: feeding on fruit scars the rind (Figure 143), and holes are chewed through to the flesh. Leaves are damaged with large, chewed areas along the margins (Figure 144). Both leaves and twigs can become skeletonised. Most feeding occurs at night and after rain. All citrus varieties are susceptible.

Risk period: March to October.

Management

Cultural: skirt trees to reduce access, manage weeds and mow inter-rows to reduce shelter and food sources. Use good orchard hygiene by removing rubbish that can shelter snails.

Biological: birds, lizards, frogs, and beetles.

Chemical: reduce populations with baiting and deter snails by spraying trunks or foliage with copper.

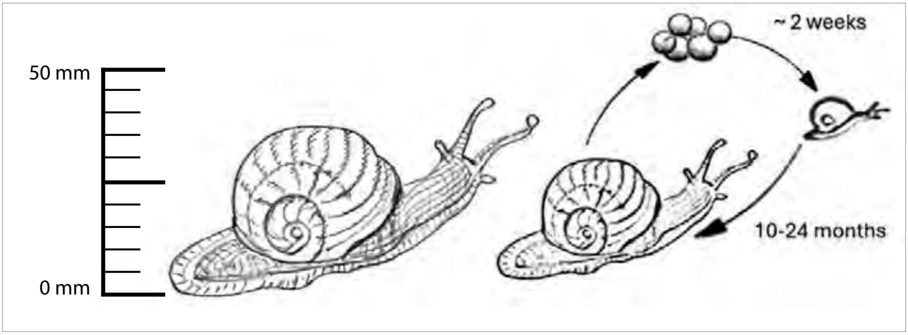


Figure 136. Common garden snail life cycle. Adapted from McDougall et al. (2017, p 55).

Figure 137. Snails can aestivate in tree crotches during summer.

Figure 138. Common garden snail.

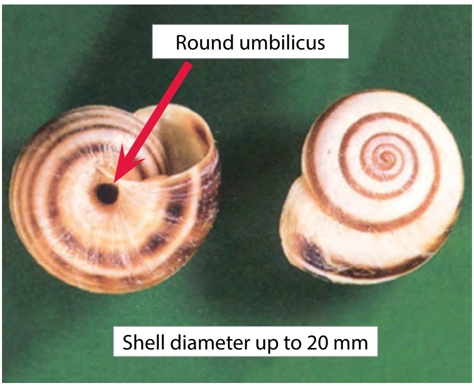


Figure 139. Common white snail. Photo: SARDI.

Figure 140. Pointed snail. Photo: SARDI.

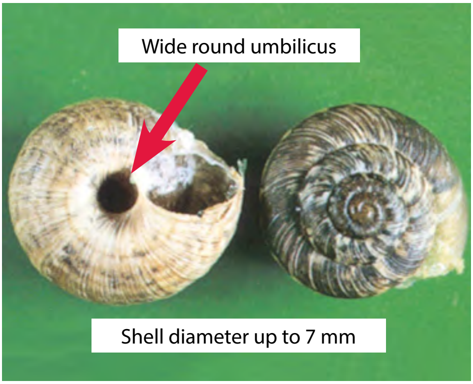


Figure 141. Small brown snail. Photo: SARDI.

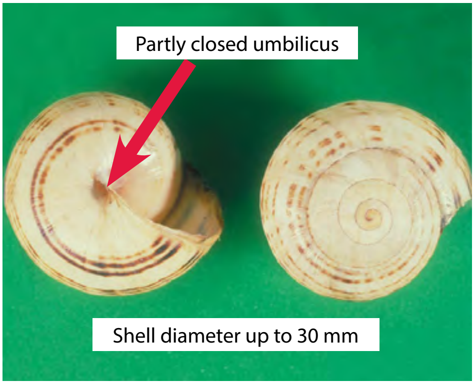


Figure 142. White Italian snail. Photo: SARDI.

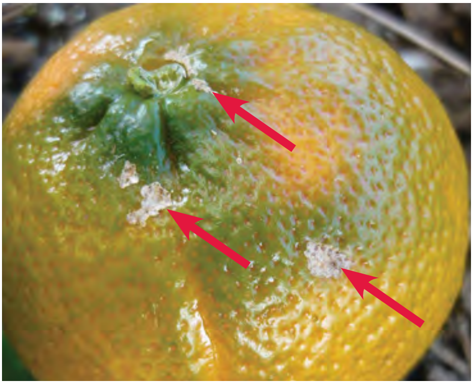
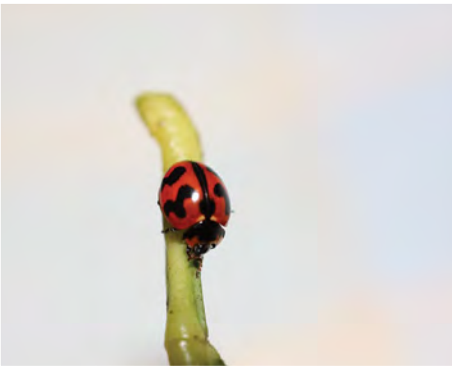


Figure 143. Fruit rind scarring from common garden snail feeding.

Figure 144. Citrus leaves chewed to the margins by snails. Photo: David Rosen, University of California.

Natural enemies (beneficials)






Predatory bugs

Assassin bug (*Pristhesancus* spp.)

Damsel bug (*Nabis kinbergii*)

Predatory shield bug (*Oechalia* spp.)

Pests attacked: aphids, crusader bug, Fuller's rose weevil, spined citrus bug, and caterpillars (e.g. light brown apple moth larvae, loopers).

Description

Eggs: barrel-shaped, laid in tight, upright clusters of rows on bark, leaves or stems. Damsel bug eggs are laid into soft plant tissue, making them difficult to find.

Immatures: nymphs are mobile and look similar to adults but are smaller, wingless and can be coloured differently (Figure 145) from adults (Figure 146).

Adults: assassin bugs are yellowish–brown to red, grow up to 30 mm long (Figure 147), with a long, narrow body, elongated head, raised eyes, and long, piercing-sucking mouthparts. They have transparent wings and slender antennae. The hind legs are long and the front legs are large, enabling them to catch prey. Damsel bug adults appear similar to assassin bugs but tend to be slimmer (Figure 148), darker brown and can move rapidly if disturbed or when hunting prey.

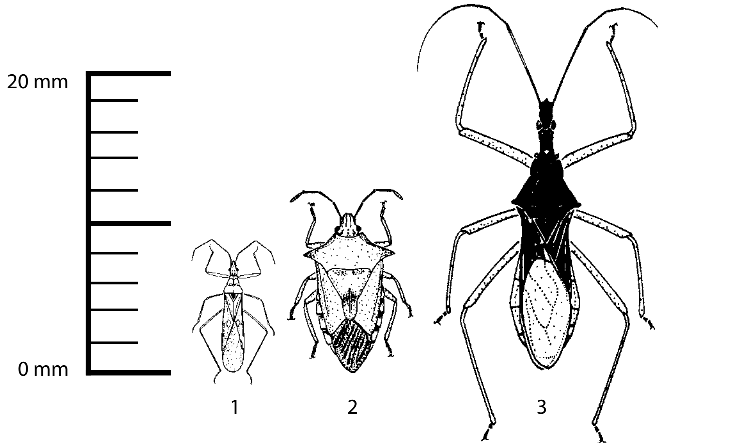
Similar to spined citrus bug.

Predatory activity

- They are generalist predators, ambushing prey and stabbing it with their piercing mouthpart that injects digestive enzymes to dissolve body tissues, which are then sucked dry.
- They are active hunters, catching prey both smaller and larger than themselves (Figure 149).
- Damsel bug nymphs and adults can survive on nectar and cannibalise each other when prey is scarce.

Figure 145. Predatory shield bug nymph.

Figure 146. Predatory shield bug adult.



1 = *Nabis kinbergii*, 2 = *Oechalia* spp., 3 = *Pristhesancus* spp.

Figure 147. Scale diagram of predatory bugs. Adapted from McDougall (2003, p 53).

Figure 148. Damsel bug adult.

Figure 149. Assassin bug attacking a caterpillar.

Lacewings

Brown lacewing (*Micromus tasmaniae*)

Green lacewing (*Mallada signatus*)

Pests attacked: aphids, mealybugs, mites, moth eggs, psyllids, scale insects, small caterpillars, thrips, and whiteflies.

Description

Eggs: laid in batches or singly on thin white stalks (green lacewing; Figure 150) or non-stalked on the back of leaves (brown lacewing; Figure 151). Depending on the species, eggs can be oval and white or cream.

Immatures: larvae grow up to 8 mm long (Figure 152), are soft-bodied and pale. Green lacewings camouflage themselves by carrying the remains of their prey on their back (Figure 153). Both species have a large pair of hollow jaws they use to grasp and suck out the body fluids of their prey. After 3 moults, they pupate inside a thin silk cocoon.

Adults: brown or green, long and slender, and have large, finely veined or 'lacey' wings (Figure 154 and Figure 155). Green lacewings will grow to around 15 mm, and brown lacewings are smaller.

Similar to mayflies.

Predatory activity

- Larvae are generalist predators that prey on various insects (Figure 156).
- Green lacewing adults are non-predacious, only feeding on nectar and pollen, while brown lacewing adults are predacious.
- Lacewings are active in a wide range of weather conditions.
- Green lacewings are commercially available in Australia for augmentative release.
- Establishing a breeding population can help with managing target pests.

Figure 150. A green lacewing egg laid on the end of a long stalk.

Figure 151. Brown lacewing eggs.

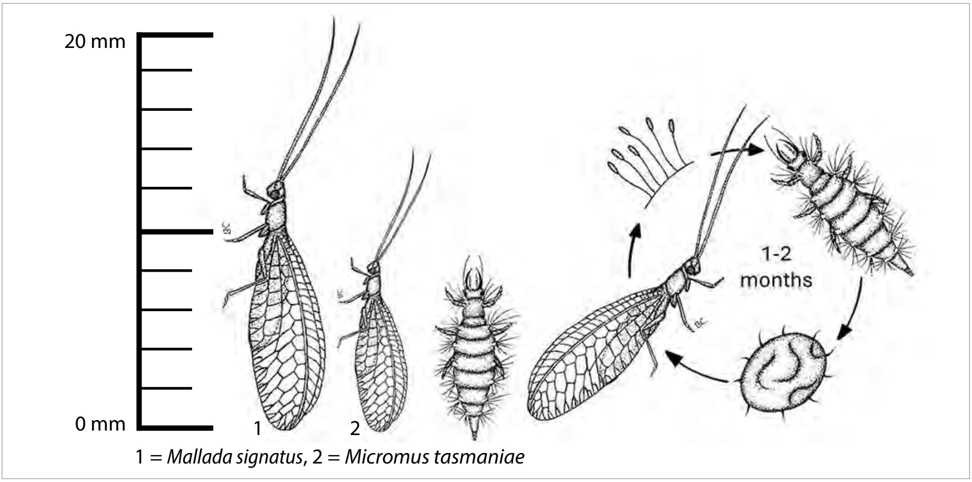


Figure 152. Lacewing life cycle. Adapted from Goodwin (2002, p 61).

Figure 153. Green lacewing larva carrying the remains of prey on its back for camouflage.

Figure 154. Green lacewing adult.

Figure 155. Brown lacewing adult.

Figure 156. Brown lacewing larva feeding on an aphid.

Ladybird beetles

Citrus whitefly ladybird (*Serangium maculigerum*)

Mealybug ladybird (*Cryptolaemus montrouzieri*)

Minute two-spotted ladybird (*Diomus notescens*)

Rhyzobius ladybird (*Rhyzobius forestieri*, *Rhyzobius lophanthae*)

Spotted amber ladybird (*Hippodamia variegata*)

Stethorus spp.

Striped ladybird (*Micraspis frenata*)

Transverse ladybird (*Coccinella transversalis*)

Vedalia ladybird (*Novius cardinalis*)

Pests attacked: aphids, mealybugs, mites, moth eggs and small larvae, red scale, soft scale, and thrips.

Description

Eggs: yellow to orange eggs are laid in clusters (Figure 157) near suitable prey. They are football-shaped and sit upright with the rear end glued to the leaf surface (Figure 158).

Immatures: larvae have 6 legs (Figure 159), chewing mouthparts, soft bodies with segmented, tapered abdomens covered in small spines, and are grey–black with orange markings. Pupae are oval, black and orange and segmented (Figure 160).

Adults: dome-shaped, six-legged, oval, shiny beetles; usually orange, red, yellow or black with spots or striped patterns (Figure 161). Some are only 1.5 mm and black.

Similar to mealybugs (*Cryptolaemus montrouzieri* larvae resemble mealybugs but have chewing mouthparts, are faster moving, and are twice the size when mature). Green lacewing larvae camouflage themselves with the bodies of their prey (e.g. mealybugs) and are often confused with the *C. montrouzieri* ladybird larvae as they resemble mealybugs.

Predatory activity:

- Both adults and larvae are active generalist predators, catching and feeding on a variety of insects (Figure 162).
- *Rhyzobius* spp. (Figure 163) are important predators of red scale and soft brown scale.
- *Cryptolaemus* larvae can be confused with their mealybug prey due to their similar appearance (Figure 164). This can be used as camouflage. *Cryptolaemus montrouzieri* adults (Figure 165) are active predators that feed on mealybugs and soft scales.
- Adults can fly when searching for prey, while larvae provide efficient hotspot control.
- *Novius cardinalis* (previously known as *Rodolia cardinalis;* Figure 166 and Figure 167) feed specifically on cottony cushion scale.

- *Diomus notescens* (Figure 168 and Figure 169) feed on aphids, thrips and mites.
- *Stethorus* spp. (Figure 170) feed on mites.
- *Serangium maculigerum* (Figure 171) feed on Australian citrus whitefly.
- *Micraspis frenata* (Figure 172) feed on hard wax scale and aphids.
- *Cryptolaemus montrouzieri* and *Rhyzobius lophanthae* are commercially available in Australia for augmentative release.

Figure 157. Ladybird eggs.

Figure 158. Ladybird eggs glued to leaves.

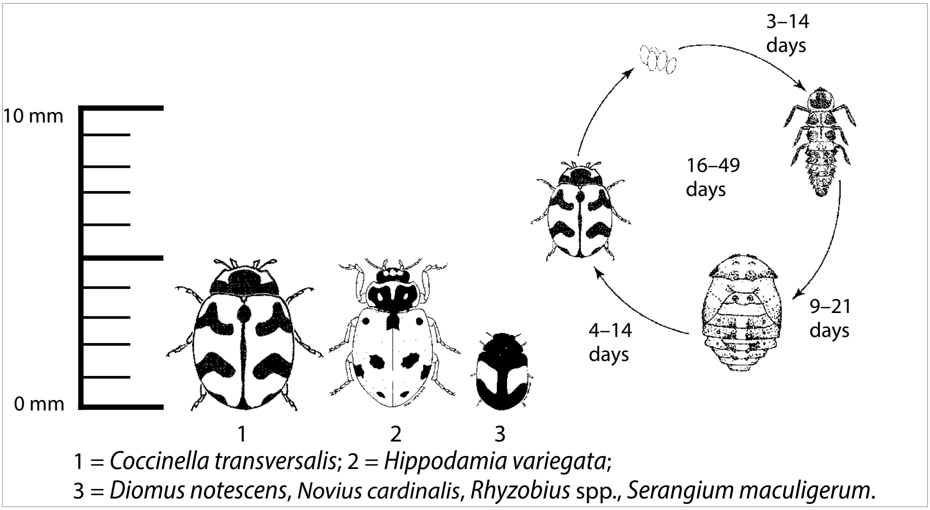


Figure 159. Ladybird beetle life cycle. Source: McDougall (2003, p 47).

Figure 160. Transverse ladybird beetle (*Coccinella transversalis*) pupa.

Figure 161. Transverse ladybird beetle (*Coccinella transversalis*) adult.

Figure 162. *Hippodamia variegata* adult and larva feeding on aphids.

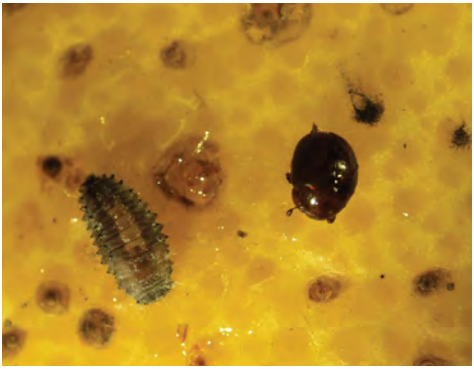


Figure 163. *Rhyzobius lophanthae* larvae (left) and adult (right).

Figure 164. *Cryptolaemus montrouzieri* larvae resemble mealybugs. Photo: Rob Weppler, Riverina IPM.

Figure 165. *Cryptolaemus montrouzieri* adult. Photos: Rob Weppler, Riverina IPM.

Figure 166. Vedalia (*Novius cardinalis*) larvae feeding on cottony cushion scale. Photo: Vito Mancini, Redbelly Citrus.

Figure 167. Vedalia (*Novius cardinalis*) ladybird beetle adult. Photo: Rob Weppler, Riverina IPM.

Figure 168. Minute two-spotted ladybird beetle (*Diomus notescens*) adult.

Figure 169. Minute two-spotted ladybird beetle larva catching an aphid.

Figure 170. *Stethorus* spp. ladybird beetle.

Figure 171. Australian citrus whitefly (*Serangium maculigerum*) ladybird beetle.

Figure 172. Striped ladybird beetle (*Micraspis frenata*).

Predatory mites

Amblyseius spp.

Anystis spp.

Bdellid mites

Euseius spp.

Gallendromus occidentalis

Neoseiulus californicus

Neoseiulus cucumeris

Phytoseiulus persimilis

Saniosulus nudus

Pests attacked: aphids, Australian citrus whiteflies, broad mites, red scale, rust mites, spider mites, thrips, and two-spotted mites.

Description

Eggs: white, oval-shaped, very small (0.05–0.1 mm) and laid on soil or leaf surfaces.

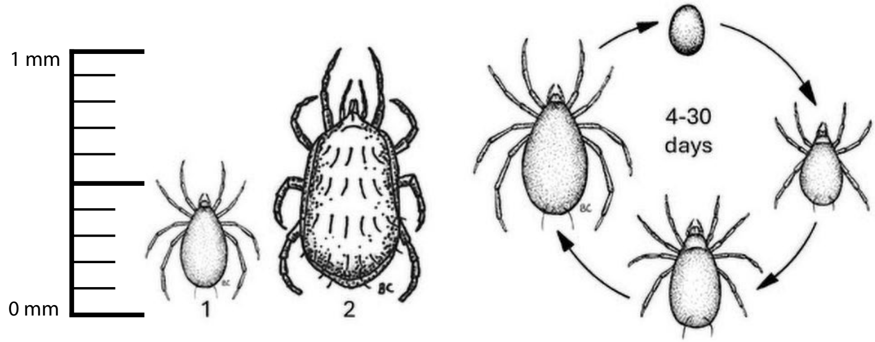
Immatures: resemble adult mites but only have 6 legs in the early growth stages (Figure 173).

Adults: range from cream to red to orange (Figure 174), are pear-shaped, 8-legged and move quickly.

Similar to other mites.

Predatory activity

- Some predatory mites are active predators that pursue and capture prey (Figure 175). Some are generalist predators that feed on a variety of prey. Different species of predatory mites target different pests.
- Soil predatory mites (Figure 176) feed on all stages of spider mites and are usually found with colonies of spider mites on the underside of leaves and the soil surface.
- Some species include pollen in their diet and are found in flowers. Flowering inter-row grasses or other pollen sources help to support predatory activity.
- Alternate-row slashing increases predatory mite populations compared with entire orchard inter-row slashing or bare earth.
- *Neoseiulus californicus* (Figure 177) can tolerate a range of climatic conditions from low to high temperatures and low humidity. Other predatory mites find survival in these conditions difficult.
- Use insecticides and miticides that have the least effect on predatory mites.
- Some predatory mites are commercially available in Australia for augmentative release.



1 = *Euseius* spp., *Neoseiulus californicus, Neoseiulus cucumeris, Phytoseiulus persimilis;*
2 = *Anystis* spp., *Bdellid* spp.

Figure 173. Predatory mite life cycle. Adapted from Goodwin (2002, pp 63 and 67).

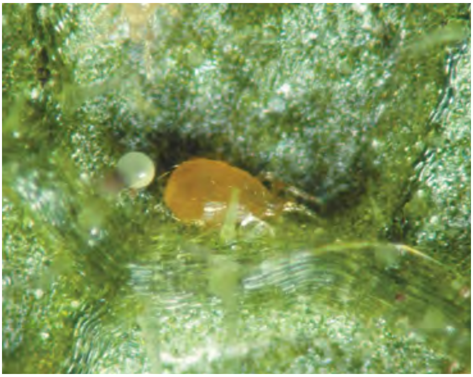


Figure 174. *Neoseiulus cucumeris* adult (centre) and egg (left).

Figure 175. *Phytoseiulus persimilis* adult feeding on two-spotted mite.

Figure 176. Soil predatory mite.

Figure 177. *Neoseiulus californicus* adult feeding on two-spotted mite. Photo: James Altmann, Biological Services.

Spiders

Jumping spiders (Saltidae)

Wolf spiders (Lycosidae)

Orb-weaving spiders (Araneidae)

Pests attacked: most insects (beetles, bugs, caterpillars, flies, katydids, leaf-hoppers, mites, moths, and thrips).

Description

Eggs: these are usually wrapped within a protective white egg sac constructed from silk. The number of eggs laid can range from a few to thousands, depending on the species.

Immatures: spiderlings resemble adults but are smaller. They can moult 5–10 times (depending on species) before reaching adulthood.

Adults: consist of a thorax and abdomen with 8 legs, 6–8 eyes, mouthparts and fangs. Depending on the species, they can range from 5–20 mm long.

Similar to harvestmen (class: Arachnida, order: Opilionida).

Predatory activity

- Spiders are generalist predators, eating a wide variety of insect pests.
- Spiders are active predators that hunt and capture any prey small enough to over-power. They use powerful venom to kill their prey and/or silk wrapping once captured in a web.
- Active hunting spiders prey on slow-moving targets (e.g. caterpillars, bugs and eggs; Figure 178 to Figure 181). Web-spinners catch flying prey (e.g. fruit flies, moths and katydids; Figure 182 and Figure 183).
- Spiders are in citrus orchards all year.
- Not all spiders are beneficial, as they can reduce the effectiveness of natural enemies e.g. parasitoid wasps can get trapped in webbing.

Figure 178. A spider waiting for prey in citrus foliage.

Figure 179. A jumping spider eating an insect.

Figure 180. Huntsman spider feeding on captured prey.

Figure 181. Bird-dropping spider.

Figure 182. Golden orb-weaving spider waiting to capture prey in its web.

Figure 183. Spider with captured katydid nymph in webbing.

Praying mantises

Pests attacked: aphids, beetles, caterpillars, crusader bugs, Fuller's rose weevil, katydids, moths, and spined citrus bugs.

Description

Eggs: laid inside white papery egg cases that are attached to twigs or branches (Figure 184 and Figure 185).

Immatures: nymphs appear similar to adults but are smaller and wingless (Figure 186).

Adults: large insects (Figure 187) with 2 hooked front legs that resemble a praying position to catch prey (Figure 188). Its head can turn 180 degrees to look directly behind it to hunt and eat live prey. Green and brown are the usual colours (Figure 189 and Figure 190).

Similar to stick insects and katydids.

Predatory activity

- Praying mantises are generalist predators. The type and size of prey change as it grows, feeding on larger insects as it develops. Freshly hatched praying mantises feed on small insects, including other newly hatched praying mantises.
- Mantids camouflage by remaining still and hidden while hunting (Figure 191). When prey comes close, they quickly grab it and eat it head-first.

Figure 184. Praying mantis egg mass.

Figure 185. Praying mantis egg mass with emergence holes.

Figure 186. Praying mantis nymph.

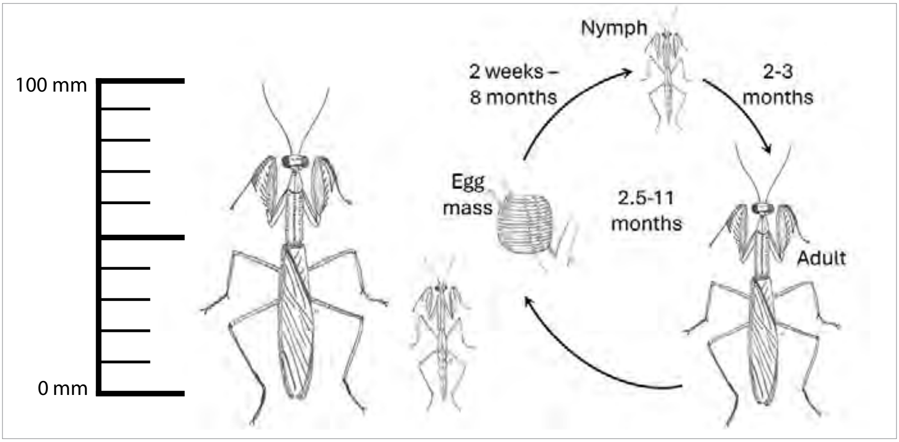


Figure 187. Praying mantis life cycle. Adapted from McDougall et al. (2017, p 80).

Figure 188. Praying mantis adult in a 'praying' position.

Figure 189. Brown praying mantis adult.

Figure 190. Green praying mantis adult.

Figure 191. Praying mantis adult camouflaged in citrus foliage.

Parasitoid wasps

Aphelinus spp.

Aphidius spp.

Pests attacked: aphids.

Description

Eggs: microscopically small and are laid inside the aphid body.

Immatures: the larvae appear grub-like.

Adults: about 3 mm long (Figure 192), small brown to black wasps (Figure 193).

Similar to many small parasitoid wasps.

Parasitoid activity

- *Aphelinus* spp. and *Aphidius* spp. wasps are an important natural control option for aphids.
- Larval stages feed on aphid body fluids; the aphid stops feeding and becomes swollen (Figure 194).
- Parasitised aphids turn black (*Aphelinus* spp.) or grey or tan (*Aphidius* spp.) and are called 'mummies'.
- The adult wasp chews a hole in the abdomen of the aphid shell to emerge.

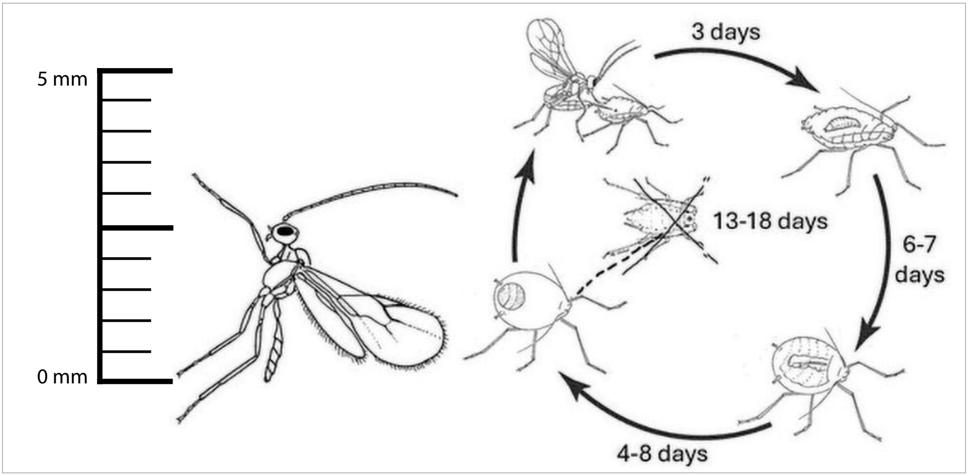


Figure 192. Aphid parasitoid life cycle. Source: McDougall et al. (2017, p 70).

Figure 193. *Aphidius* spp. wasp adult.

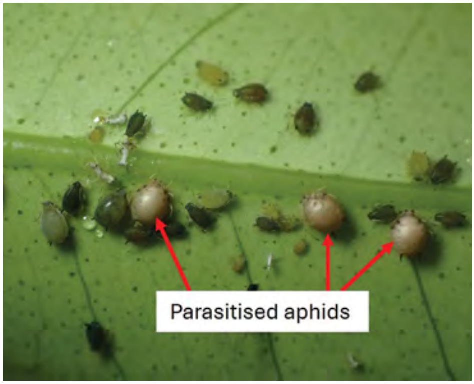


Figure 194. Parasitised aphid bodies appear swollen.

Aphytis spp.

Pests attacked: armoured scale insects (e.g. red scale).

Description

Eggs: *Aphytis melinus*, *A. lingnanensis* and *A. chrysomphali* eggs are microscopically small and are laid on the host body beneath the scale cover. Each *Aphytis* spp. female can lay around 100 eggs during her 2-week life span. Two or three *Aphytis melinus* might develop on one scale.

Immatures: the larvae are pale, ovoid and have distinct segments. Dark brown faecal pellets can be seen around the pupae under exposed scale covers (Figure 195 and Figure 196).

Adults: small yellow wasp (Figure 197), about 1 mm long. They are weak flyers and require manual distribution throughout the orchard for an effective augmentative release.

Similar to adult male red scales but they have yellow bodies. Many small parasitoid wasps and citrus gall wasps are similar in size.

Parasitoid activity

- *Aphytis* spp. wasps are an important natural enemy to help manage red scale (Figure 198).
- *Aphytis* spp. larvae feeding kills the host. The host scale gradually shrinks and dies, appearing as a flat, dehydrated scale body.
- Pupae mature, eat their way out of the scale and emerge as adults.
- Adult wasps also feed directly on the host scale.
- There can be 2 *Aphytis* spp. generations per generation of scales.
- *Aphytis* spp. wasps can move to parts of the tree where insecticide sprays often do not reach.
- Evidence of parasitoid presence is difficult with some *Aphytis* spp. due to the emerging adults causing dead scales' remains to fall off the plant.
- *Aphytis* spp. wasps are susceptible to a lack of humidity. Do not release wasps in very hot weather, e.g. when temperatures are over 40 °C.
- Natural populations of *Aphytis* spp. are quite effective and adult movement is wind-assisted.
- *Encarsia citrina* and *E. perniciosi* are other small parasitoid wasps of red scale. They attack younger stages of red scale than *Aphytis*, making them a complementary natural enemy of red scale.
- *Aphytis* spp. are commercially available in Australia for augmentative release, which works well with mating disruption tabs to manage red scale.
- Only use insecticides that have the least effect on parasitoid wasps.

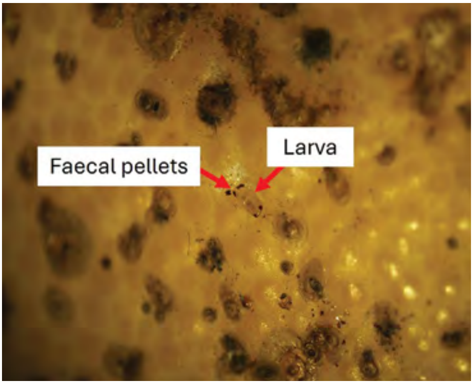


Figure 195. *Aphytis* spp. larva with brown faecal pellets.

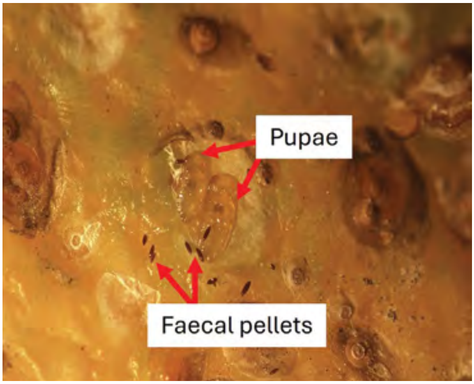


Figure 196. *Aphytis* spp. pupae with brown faecal pellets.

Figure 197. *Aphytis* spp. wasp adult.

Figure 198. *Aphytis* spp. wasp adult feeding on red scale.

Comperiella spp.

Pests attacked: armoured scale insects (e.g. red scale and yellow scale).

Description

Eggs: each female wasp lays one microscopically small egg and within the scale body.

Immatures: larvae are elongated and pale white to translucent, while the oblong pupae are black. Dark faecal pellets are excreted but remain inside the scale body. The larvae develop and pupate while hidden within the scale body.

Adults: 1.5 mm long, black with 2 white stripes on the head and black and white areas on the wings (Figure 199).

Similar to citrus gall wasps, *Encarsia* wasps and *Trissolcus* wasps.

Parasitoid activity

- The legless larvae hatch and feed on the host scale, depleting it of its bodily fluids. The host scale gradually dies, appearing as a dry, bloated scale body containing dark excrement pellets. The adults emerge by chewing a jagged hole in the armoured covering of the dead scale.
- *Comperiella bifasciata* is an important red scale parasitoid and naturally occurs in many southern citrus orchards using selective insecticide chemistry.
- *Encarsia citrina* and *E. perniciosi* are other small parasitoid wasps of red scale. They attack younger stages of red scale than *Comperiella*, making them a complementary natural enemy of red scale.

Figure 199. *Comperiella bifasciata* adult surrounded by red scale. Photo: Rob Weppler, Riverina IPM.

Megastigmus spp.

Pests attacked: citrus gall wasp eggs.

Description

Eggs: microscopically small and are laid within the host egg inside young twigs, hatching after the host egg hatches.

Immatures: grow inside citrus gall wasp larvae.

Adults: small wasps, about 2.5 mm long. Females are honey-coloured with red eyes, while males are black on top and brown underneath.

Similar to many small parasitoid wasps, citrus gall wasps.

Parasitoid activity

- *Megastigmus* spp. wasps are important naturally occurring parasitoids of citrus gall wasp (*Bruchophagus fellis*). Eggs are laid within gall wasp eggs, and the parasitoid larvae develop inside the gall wasp larvae, eventually destroying them.
- *Megastigmus brevivalvus* (Figure 200 and Figure 201) and *M. trisulcus* (Figure 202 and Figure 203) are established in the southern citrus regions.
- *Megastigmus* spp. wasps are susceptible to lack of humidity and very hot weather.
- Insecticides applied for citrus gall wasps will also affect *Megastigmus* spp. Use an insecticide that has the least effect on parasitoid wasps.

Figure 200. *Megastigmus brevivalvus* wasp adult female.

Figure 201. *Megastigmus brevivalvus* adult male looks similar to a citrus gall wasp.

Figure 202. *Megastigmus trisulcus* adult female.

Figure 203. *Megastigmus trisulcus* adult male.

Trichogramma spp.

Pests attacked: light brown apple moth eggs, looper eggs.

Description

Eggs: ovoid and 0.1 mm long.

Immatures: larvae are pouch-shaped. Pupae develop appendages that are folded against their bodies.

Adults: tiny wasps up to 1 mm long (Figure 204), orange to yellowish–brown, short antennae, bulging red eyes (Figure 205), and clear wings edged with tiny hairs.

Similar to citrus gall wasps, *Encarsia* wasps and *Trissolcus* wasps.

Parasitoid activity

- Wasp eggs are laid into moth eggs and wasp larvae develop inside the egg (Figure 206).
- Adults emerge from parasitised moth eggs (Figure 207 and Figure 208).
- *Trichogramma* spp. wasps can be naturally occurring in southern orchards. Choose insecticides that have the least effect on wasps to support their population and parasitism levels.
- *Trichogramma* spp. wasps are commercially available in Australia for augmentative release.

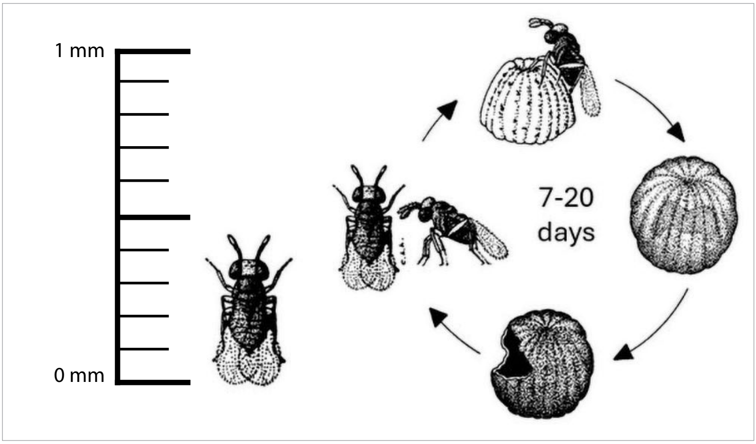


Figure 204. *Trichogramma* spp. life cycle. Source: McDougall (2003, p 61).

Figure 205. *Trichogramma pretiosum* adult.

Figure 206. Parasitised moth eggs turn black.

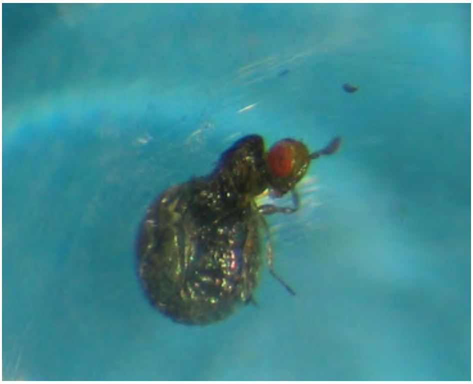


Figure 207. *Trichogramma pretiosum* adult wasp emerging from a parasitised egg.

Figure 208. *Trichogramma carverae* adult male (left) and female (right) on light brown apple moth eggs.

Trissolcus spp.

Pests attacked: shield bug eggs (including spined citrus bug eggs).

Description

Eggs: laid inside host eggs. Parasitised bug eggs darken or exhibit a dark ring near the top of the eggshell. Usually one egg is laid in each host egg; if more than one egg is laid, the strongest larva will survive.

Immatures: larvae hatch inside the egg, consuming the developing host and pupate within the eggshell. Once fully developed, they emerge by chewing through the eggshell (Figure 209).

Adults: black with a large head and thorax but a small, flattened abdomen. Their antennae are brown and bent. They are up to 1.5 mm long with red-brown legs. The 2 pairs of clear wings are longer than the abdomen.

Similar to citrus gall wasp.

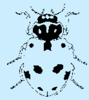
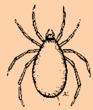
Parasitoid activity

- *Trissolcus* spp. parasitise Australian shield bug eggs (e.g. spined citrus bug, green vegetable bug). Once an egg mass is parasitised, the female rubs a chemical over the eggs so other *Trissolcus* spp. avoid them.
- Female and male wasps guard eggs by chasing away other parasitoid wasps.
- Multiple overlapping generations are produced per year.
- *Trissolcus* spp. wasps are an important biological control of shield bugs infesting citrus trees.
- Ants predate on the *Trissolcus* spp. wasp, so large numbers of ants might need to be controlled.
- Having flowering plants provides adult wasps with food (nectar and pollen) and sustains parasitoid numbers.

Figure 209. *Trissolcus* spp. emerging from spined citrus bug eggs. Photo: Rob Weppler, Riverina IPM.

Pesticide toxicity to natural enemies (beneficials)

Table 1. Pesticide toxicity ratings to natural enemies in the orchard.
0 = no toxicity, 1 = very low, 2 = low, 3 = medium, 4 = high, and 5 = very high toxicity to beneficials.

Group and subgroup	Parasitoid wasps 	Lacewings 	Ladybird beetles 	Predatory mites 
Insecticides				
1A Carbamates	5	4	5	5
1A Carbamates (pirimicarb)	3	1	1	1
1B Organophosphates	5	5	5	5
3A Synthetic pyrethroids	5	5	5	5
3A Natural pyrethrins	3	3	3	3
4A Neonicotinoids (soil-applied)	2	2	2	3
4A Neonicotinoids (foliar-applied)	4	3	4	3
4C Sulfoximine	4	4	3	1
5 Spinosyns	4	3	1	3
7C Pyriproxyfen	2	2	4	0
11 Biological (e.g. *Bacillus thuringiensis, Bt*)	0	0	0	0
16 Buprofezin	2	4	1	1
18 Diacylhdrazines	1	1	1	1
23 Tetronic + tetramic acids	1	2	1	4
28 Diamides	2	3	0	2
30 Isoxazolines	5	3	5	5
Adjuvant Horticultural mineral oils	1	1	1	2
Miticides				
6 Avermectins	4	3	3	4
10A Clofentezine	1	1	1	1
10B Etoxazole	1	1	1	4
12A Diafenthiuron	1	1	2	2
M2 Sulfur	3	1	2	3

Disclaimer: individual species vary in their susceptibility to pesticides. For this publication, the toxicity effects are of a general nature for each active ingredient listed.

Insect pathogens

Family: Bacillaceae

Bacillus thuringiensis (bacteria)

Pests attacked: light brown apple moth larvae, looper larvae and heliothis larvae.

Description

Bacillus thuringiensis (Bt) is a naturally occurring entomopathogenic bacterial disease of insects. Strains of the bacteria are specific against different insect groups. Several strains have been commercialised as insecticides. Larvae must eat a lethal dose from contaminated foliage to be affected by the bacteria. Feeding usually stops immediately after ingestion. Infected caterpillars will become limp and the bacterial disease can take 2–5 days to kill them (Figure 210 and Figure 211). Bt products degrade in UV light. For best results, spray in the evening.

Pathogenic activity

- *Bacillus thuringiensis* reproduces by making spores that grow into new bacteria.
- *Bacillus thuringiensis* requires specific gut enzymes to activate the protein and release toxins. Bt-based insecticides do not affect natural enemies found in Australian citrus.
- When spores are eaten, the gut lining of insect larvae is damaged, causing death from starvation or a ruptured digestive system.
- Young insect larvae are most susceptible.
- Different Bt subspecies can be lethal to different insects. The Bt subspecies *aizawai* and *kurstaki* can affect many Lepidopteran larvae (caterpillars). Other Bt subspecies can affect Diptera (flies and mosquitoes) and Coleoptera (beetles).

Figure 210. Healthy *Heliothis* larva.

Figure 211. *Heliothis* larva killed by *Bacillus thuringiensis*. Photo: QDPI.

Family: Cordycipitaceae

Beauveria bassiana (fungus)

Pests attacked: aphids, beetles (elephant weevil, Fuller's rose weevil), bugs, katydids and thrips.

Description

Beauveria bassiana (Bb) is an entomopathogenic filamentous fungus that lives naturally in soil. Organic soil amendments increase soil organic matter to sustain a healthy balance of soil microflora, including *Beauveria bassiana*.

Pathogenic activity

- *Beauveria bassiana* causes white muscardine disease. When the fungal spores contact the external layer of the susceptible host insect, they germinate and penetrate, growing rapidly inside the host insect, feeding on nutrients, proliferating and producing a variety of toxins, causing death. Then a white mould develops externally (Figure 212 and Figure 213), producing new infective spores to restart the life cycle.
- *Beauveria bassiana* has non-toxic effects on non-target organisms, including animals and humans.

Figure 212. An elephant weevil infected with *Beauveria bassiana*. Photo: Murdoch (2010).

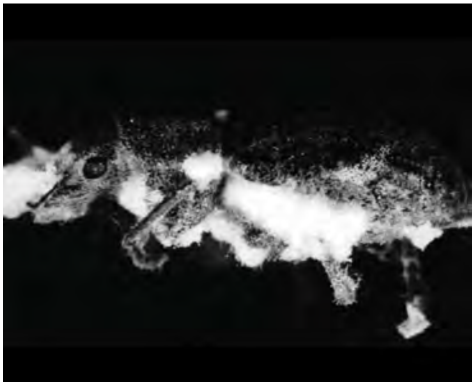


Figure 213. A Fuller's rose weevil adult infected with *Beauveria bassiana*.

Diseases




Fungal diseases

Anthracnose (*Colletotrichum* spp.)

Symptoms: rind blemish that can appear as firm, brown to black spots (Figure 214) or form a tear-staining pattern on the fruit rind (Figure 215). Symptoms can develop in the orchard or postharvest. Mid and late-season navel oranges are more prone to developing anthracnose symptoms than early-season varieties.

Figure 214. Anthracnose on the rind after cold weather.

Figure 215. Anthracnose can appear as a tear-staining pattern on the rind.

Cause: *Colletotrichum* spp. fungi are present throughout the orchard in deadwood (Figure 216). They commonly invade citrus rind but usually only cause decay when it is damaged by other factors, such as cold or sunburn. Foggy and moist conditions in winter are ideal for the fungi to grow. Fungal spores are spread by rain splash. Postharvest anthracnose can develop when fruit are harvested late (over-mature) or held too long in storage.

Management: annual pruning after harvest removes deadwood and reduces the risk of symptoms developing in the orchard. Applying a protective copper spray before autumn rain will reduce anthracnose in the orchard. Apply a second copper spray if the fruit are held for a later harvest.

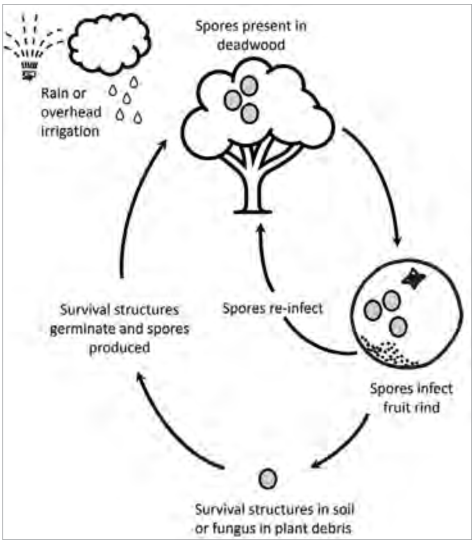


Figure 216. The Anthracnose disease cycle.

Black core rot (*Alternaria* spp.)

Symptoms: black decay develops inside the fruit (Figure 217) and a darkened blemish might be on the rind at the stylar end (Figure 218). Infection might not be noticed during packing and symptoms can develop later (Figure 219). This disease is most prevalent in southern citrus-growing areas. It mostly affects orange and mandarin varieties, particularly Imperial mandarin. It is also called alternaria core rot or centre rot. Infected fruit typically colour prematurely, drop and have an unpleasant taste.

Cause: *Alternaria* spp. fungal spores enter the fruit during early development or through wounds or imperfections.

Management: applying recommended registered fungicides early during fruit development can reduce disease incidence. Well-pruned trees have better air circulation and spray penetration, therefore, they have lower spore populations. Where practical, delay harvest to allow infected fruit to drop first (Figure 220).

Figure 217. Black core rot infection beginning from the stylar end.

Figure 218. External blemish at the stylar end indicates black core rot infection.

Figure 219. Black core rot in mandarins. Photo: Zali Mahony, University of Queensland.

Figure 220. Fruit infected with black core rot typically colour prematurely and drop.

Brown spot (*Alternaria alternata*)

Symptoms: brown to black spots appear on young leaves, shoots and fruit rind. Spots are usually circular and surrounded by a yellow halo (Figure 221 and Figure 222), although necrosis often extends along the leaf veins. Spots on older fruit might form eruptions that can fall off and leave a pockmark. Infected leaves and young fruit often drop and infected shoots die back. Symptoms often appear soon after infection. Brown spot occurs on mandarins, tangelos and tangors in humid, high-rainfall areas.

Figure 221. Brown spot lesions surrounded by yellow halos on fruit.

Figure 222. Brown spot lesions surrounded by yellow halos on leaves.

Cause: *Alternaria alternata* fungal spores are spread by wind and germinate in wet conditions, including heavy dew, leading to infection (Figure 223). Poor air circulation within the tree canopy can promote infection from early spring to autumn.

Management: pruned trees with good airflow have a lower risk of developing brown spot. A copper-based fungicide program to protect each growth flush is important, in addition to using a systemic fungicide before warm, wet conditions when disease pressure increases.

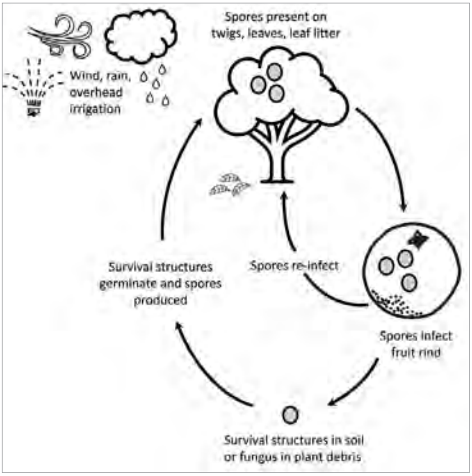


Figure 223. Brown spot disease cycle.

Black spot (*Phyllosticta citricarpa*)

Symptoms: fruit have 1–2 mm diameter red spots on the rind that develop into 3–10 mm circular, sunken, tan-grey lesions with reddish-brown to black margins (Figure 224 and Figure 225). Continued disease development later in the season can lead to large, brown to black, irregularly shaped, sunken lesions. Infected fruit and leaves might drop. Black spot occurs in humid summer rainfall areas, mainly on lemons and Valencia and navel oranges.

Figure 224. Black spot on fruit.

Figure 225. Black spot on foliage and fruit.

Cause: the *Phyllosticta citricarpa* fungus causes infection in moist conditions (Figure 226), but spores stay dormant and fruit symptoms do not appear until ripening, mainly during warm, wet weather.

Management: fruit should be harvested at maturity to avoid symptoms from developing in the field. Apply recommended registered fungicides at petal fall and 16–20 weeks later. Store fruit below 20 °C after harvest to suppress postharvest disease development.

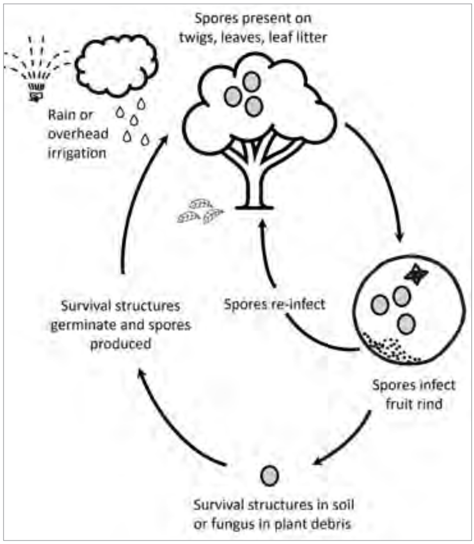


Figure 226. Black spot disease cycle.

Greasy spot (*Zasmidium citri-griseum*)

Symptoms: yellow spots appear on the upper leaf surface and matching, slightly raised, pale brown blisters form on the undersides of leaves (Figure 227) 2–3 months after infection. The lesions darken over time. Greasy spot is most common on grapefruit, lemon and early maturing orange varieties, but all citrus are susceptible.

Cause: infection by the fungus *Zasmidium citri-griseum* (formerly known as *Mycosphaerella citri*) is favoured by wet conditions, rainfall or dew in autumn or spring.

Management: copper-based fungicides in spring and autumn reduce disease incidence.

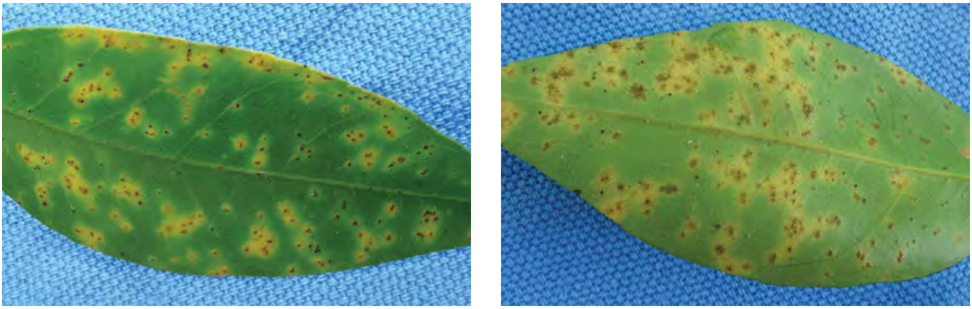


Figure 227. Greasy spot symptoms on the topside (left) and underside (right) of a leaf.

Diseases

Lemon scab (*Elsinoe fawcettii*)

Symptoms: raised, irregular, wart-like scab lesions form on leaves, twigs and fruit (Figure 228 and Figure 229). Leaf lesions can form on both the topside and underside, but do not penetrate through the leaf. Initially the lesions are grey to pink and darken over time. Affected growth is usually distorted. This affects lemons in coastal areas, causing young fruit to shed and rendering older fruit unmarketable.

Cause: the *Elsinoe fawcettii* fungus. Scab lesions produce spores in wet conditions (e.g. rain, dew, irrigation). Spores spread in water splash and infect immature tissue.

Management: apply copper sprays at 50% petal fall and again 4–6 weeks later for each lemon flowering. Timing is critical, as sprays at other times of the year are not effective.

Figure 228. Lemon scab symptoms on lemon leaves and fruit.

Figure 229. Wart-like scab lesions on lemon fruit.

Melanose (*Diaporthe citri*)

Symptoms: small, raised spots about 1 mm in diameter, usually dark brown to black on leaves (Figure 230), fruit and twigs in high-rainfall areas. Spots darken with copper sprays and can appear as streaks or tear stains. Early and severe infections result in masses of brown spots (Figure 231). As the fruit grows, cracks form in the brown masses; this symptom is called mud cake melanose (Figure 232 and Figure 233). Twig dieback and wood rot can also occur.

Cause: *Diaporthe citri* produces fungal spores on dead twigs during wet periods, which spread to young leaves and fruit by rain splash. Fruit are susceptible for 3–5 months after fruit set.

Management: pruning to remove dead wood reduces the spore load in affected trees. A copper fungicide at petal fall and again 6–9 weeks later provides effective control.

Figure 230. Melanose symptoms on citrus leaves.

Figure 231. Melanose symptoms on citrus fruit.

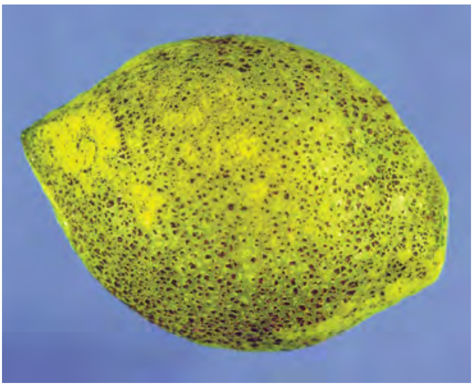


Figure 232. Mud cake melanose on a lemon.

Figure 233. Cracks form in the brown masses of mud cake melanose as the fruit grows.

Diseases

Septoria spot (*Septoria citri*)

Symptoms: start as small, light brown depressions on the rind (Figure 234). The spots can enlarge, merge and darken as the fruit ripens. Small black fruiting bodies can form in the sunken lesions (Figure 235). Navels and grapefruit are most affected, but all commercial citrus varieties are susceptible.

Figure 234. Initial septoria spot on citrus.

Figure 235. Progression of septoria spot to larger, sunken lesions.

Cause: *Septoria citri* produces fungal spores on twigs, leaves and leaf litter, which are spread to fresh tissue via water splash (Figure 236). Infection usually occurs during late summer or autumn when the fruit are still green. The disease remains latent for several months, with symptoms developing after cold weather as the fruit ripens.

Management: applying a copper-based fungicide before autumn rain and pruning trees to improve air circulation in the canopy can reduce disease incidence.

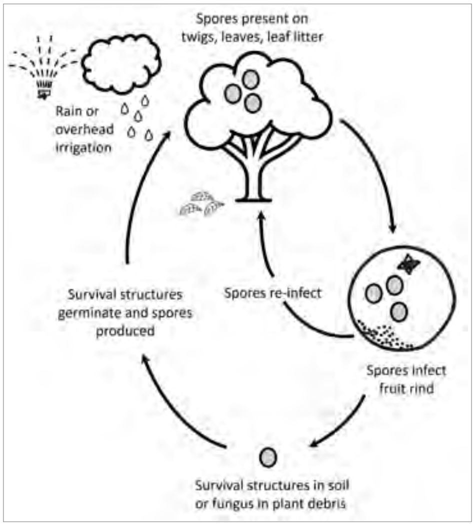


Figure 236. Septoria spot disease cycle.

Phytophthora root rot (*Phytophthora* spp.)

Symptoms: feeder roots on affected trees die off more quickly than they are replaced (Figure 237). Above the ground, citrus trees will show signs of stress, such as leaf yellowing and twig dieback (Figure 238), because their depleted root system cannot support the canopy.

Cause: waterlogged or poorly drained soil creates ideal conditions for phytophthora root rot.

Management: the disease is best managed using resistant or tolerant rootstocks, for example, *Citrus* (*Poncirus*) *trifoliata*, citrange hybrids or Swingle citrumelo. Sweet orange and rough lemon stocks are highly susceptible. Prevent root rot by ensuring adequate soil drainage and well-managed irrigation. Applying a registered systemic fungicide can help manage phytophthora.

Figure 237. Dead feeder roots on a seedling infected with phytophthora root rot (left) and healthy feeder roots (right).

Figure 238. Phytophthora root rot can cause leaves to turn yellow and drop from trees.

Brown rot (*Phytophthora* spp.)

Symptoms: leaf infections appear as dark brown, spreading blotches (Figure 239). Infected fruit develop a rapidly spreading, brown rind discolouration (Figure 240). Brown rot-infected fruit usually falls from the tree.

Cause: *Phytophthora* spp. fungal spores in water and soil are splashed onto leaves and fruit.

Management: skirting trees reduces the risk of soil splashing onto the tree canopy or low-hanging fruit. Applying copper-based fungicides in autumn helps to limit the disease. Organisms such as snails and ants can carry soil containing spores into the canopy and should be controlled.

Figure 239. Brown rot leaf symptoms (left) and fruit symptoms (right) from a lemon tree.

Figure 240. Brown rot on oranges.

Collar rot (*Phytophthora* spp.)

Symptoms: at the bottom of the tree trunk, just above soil level, gum will exude from the affected area, then the bark becomes discoloured (brown to black), soft and wet (Figure 241). When conditions are favourable for disease development, secondary lesions of phytophthora gummosis (Figure 242) can occur within the tree. Sap or gum exude from moist, softened bark, which is an early sign of collar rot. Over time, the wood dries out, re-hardens and cracks (Figure 243). The disease can cause ringbark and kill affected trees.

Cause: *Phytophthora* spp. spores can be splashed onto the trunk in soil and water. Ants can carry soil with the spores up inside tree guards to their nests.

Management: at planting, ensure the bud union is well above the soil level. Avoid trunk injuries and skirt trees to improve air circulation. Affected tissue can be scraped away and a protective barrier can be applied with fungicide-containing paint. Skirting or under-tree sprays (e.g. copper) can reduce infection. Manage ant colonies in the orchard to reduce spore movement into the canopy.

Figure 241. Gum exuding from a tree affected with collar rot.

Figure 242. Gummosis of the scion is a symptom of phytophthora infection.

Figure 243. Old symptoms of collar rot just above the soil level.

Sudden death

Symptoms: trees often wilt and rapidly decline with a crop of fruit (Figure 244). One or more main roots will be black and dead (Figure 245). The butt will be discoloured brown, but this does not go higher than the bud union (Figure 246). When the deadwood is heated, a putrid coconut oil odour is emitted. The rootstock is free of gumming and pitting. *Citrus trifoliata*, Carrizo and Troyer citrange rootstocks are most affected, as are trees 7 to 15 years old, but trees of all ages can succumb.

Cause: in Australia, no pathogen has been identified as the primary cause, but secondary invaders can exacerbate root decay. Incidence is more prevalent on heavier or poorly drained soil and where ammonia fertilisers are over-used.

Management: select sites with good surface and sub-surface drainage. Use mounding and/or drip irrigation to reduce waterlogging and poor aeration. Monitor and manage irrigation using moisture monitoring equipment to reduce excessive watering. Planting inter-row cover crops helps soil health.

Figure 244. Trees with sudden death begin to wilt and rapidly decline.

Figure 245. A blackened tree root.

Figure 246. *Citrus trifoliata* roots with discoloured wood up to the bud union.

Blue mould (*Penicillium italicum*)

Green mould (*Penicillium digitatum*)

Symptoms: fruit have white mycelia and blueish conidia (blue mould) or white mycelia and greenish conidia (green mould). Initially a soft water-soaked area develops on the peel of infected fruit. After a few days, a superficial spot of white mould grows on the area. Over time, the mould spreads over the rind surface, and the initial infection area becomes blueish or greenish (Figure 247 and Figure 248). The nearby tissues become soft, water-soaked and covered in white mycelia. The fruit quickly spoils and collapses into a rotten mass. Nearby fruit can be infected.

Figure 247. Green mould on oranges.

Figure 248. Blue mould on oranges.

Cause: fruit can be infected pre or postharvest with *Penicillium italicum* or *P. digitatum* fungal spores. Deadwood in trees can puncture fruit, and wounds can form during handling (e.g. picking, packaging, transporting) and storing, allowing fungal spores to enter the fruit. Enzymes are produced that break down fruit cells, causing shrinkage and soft, watery spots of rot. Some citrus varieties, e.g. Dekopon (Figure 249), are prone to infection in the orchard when disease conditions are favourable.

Management: avoid in-field and postharvest fruit damage. Removing deadwood in trees and wearing picking gloves minimises rind injury. An appropriately timed gibberellic acid treatment will reduce rind sensitivity to mechanical damage.

Figure 249. Advanced blue mould symptoms on a mandarin.

Diseases

Sour rot (*Geotrichum citri-aurantii*)

Symptoms: initial symptoms of soft, water-soaked lesions (Figure 250) appear on fruit, which begins to rot, becoming soft enough to easily put your finger through. In high humidity, the areas of rot become covered in white fungal fibres (Figure 251). A sour odour is emitted during advanced stages of the disease. Infected fruit degrade to a slimy, rotten mass.

Cause: *Geotrichum citri-aurantii* fungal spores in soil are spread by wind or water splash to the fruit surface within the tree canopy. Fruit are infected when fungal spores enter wounds caused by insects or postharvest handling (e.g. picking, packaging, transporting) and storage, with fruit becoming more susceptible as they mature. Sour rot occurs sporadically and is less common than blue mould or green mould.

Management: handle fruit gently during harvest. Wearing picking gloves minimises rind injury. An appropriately timed gibberellic acid treatment in the orchard will reduce rind sensitivity to mechanical damage. Avoid postharvest fruit damage. Ensure packing sheds follow best practice postharvest fruit management.

Figure 250. Soft, water-soaked lesion on a grapefruit.

Figure 251. Sour rot areas covered in white fungal fibres.

Viral and viroid diseases

Citrus cachexia viroid

Citrus exocortis viroid

Citrus psorosis virus

Citrus tristeza virus

Symptoms: affected trees can have stunted growth (Figure 252), reduced production and fruit quality, tree decline or death. Other symptoms can include stem pitting (Figure 253), gumming and bark peeling (Figure 254). Different viruses affect different citrus scions and rootstocks. Infected trees of tolerant varieties can be symptomless, but the virus can spread from these trees to susceptible varieties.

Cause: there are numerous viruses and viroids affecting citrus, including citrus cachexia viroid, citrus exocortis viroid, citrus psorosis virus and citrus tristeza virus. Viruses and viroids are spread by infected propagation material, cutting tools and root grafting between field trees. Some diseases can also be spread by vectors, such as citrus tristeza virus, which is spread by aphids.

Management: there is no cure for graft-transmissible diseases; prevention is the best management option. Always use budwood and rootstock seed from a tested source, and always disinfect cutting tools in a bleach solution (1.25% available chlorine).

Figure 252. Citrus exocortis viroid causes stunted tree growth (left).

Figure 253. Citrus tristeza virus stem pitting symptoms on grapefruit.

Figure 254. Citrus exocortis is sometimes referred to as 'scalybutt' due to the peeling bark at the base of the tree.

Exotic diseases

Citrus canker (*Xanthomonas citri* subsp. *citri*)

Symptoms: leaf lesions start as tan pinpoint spots, which change to brown-grey and become corky with a raised margin (Figure 255). The lesions will have a sunken centre or crater-like appearance, penetrating both sides of the leaf and surrounded by a yellow halo (Figure 256). The lesions become raised and corky (Figure 257 and Figure 258) with a water-soaked margin. Fruit lesions vary more in size because the rind is susceptible to infection for a longer time. The yellow halo is not visible on ripe fruit.

Cause: *Xanthomonas citri* subsp. *citri* bacteria are spread by wind-driven rain and water splash, and survive for months in lesions and plant debris.

Management: applying copper-based fungicides helps manage canker where the disease is present. Purchase nursery trees from a reputable supplier and keep records. Adopt biosecurity best practices to prevent the entry, establishment and spread of pests and diseases. At the time of writing, Australia is free from this exotic bacterial disease.

Figure 255. Citrus canker leaves with raised, corky lesions.

Figure 256. Citrus canker lesions surrounded by a yellow halo.

Figure 257. Citrus canker lesions on tangelo fruit.

Figure 258. Citrus canker raised and corky lesions on a citrus stem.

Huanglongbing (*Candidatus* Liberibacter asiaticus)

Symptoms: the first sign of huanglongbing (HLB) is progressive yellowing of the canopy. Leaves can have an asymmetric blotchy mottling where each side of the midrib has a different pattern of yellow and green (Figure 259) or symmetrical leaf patterns resembling nutrient deficiency. Fruit are smaller, lopsided (Figure 260) and bitter tasting. Seeded varieties can have small, brownish-black aborted seeds. The skin colour might stay partially green (Figure 261). HLB-affected trees gradually lose productivity (Figure 262) and die within a few years.

Cause: *Candidatus* Liberibacter asiaticus bacteria are transmitted by the Asiatic citrus psyllid (*Diaphorina citri*).

Management: long-distance spread of HLB occurs via moving infected citrus plant material and HLB-infected insects (e.g. Asiatic citrus psyllid, an exotic insect pest not currently in Australia). Only use propagation material of a known health status. Purchase nursery trees from a reputable supplier and keep records. Adopt biosecurity best practices to prevent the entry, establishment and spread of pests and diseases. At the time of writing, Australia is free from this exotic bacterial disease.

Figure 259. Huanglongbing causes an asymmetric blotchy mottle on leaves.

Figure 260. Huanglongbing causes lopsided fruit.

Figure 261. Huanglongbing can cause the fruit rind to remain partially green.

Figure 262. Huanglongbing causes advanced dieback in a citrus tree.

Disorders

Nutritional disorders

Zinc deficiency

Symptoms: first appear on young leaves as a bright creamy–yellow mottle, with chlorosis (yellowing) between the green veins (Figure 263 to Figure 265). Leaves might be small and narrow on shortened shoots. Symptoms are often described as 'little leaf', 'mottle leaf' and 'rosetting'. Leaf symptoms are most common on spring flush but can occur on any flush. Early-stage symptoms resemble those of manganese deficiency, but both can occur in combination. Fruit are small and of poor quality. Trees have reduced yield and vigour. Zinc (Zn) deficiency is a common nutritional disorder of citrus.

Cause: most prevalent on alkaline soil. Excessive phosphate fertiliser use can promote Zn deficiency. Wet soil and cool temperatures make the deficiency common in spring.

Management: apply Zn foliar sprays annually when spring flush leaves are one-third to two-thirds developed. In severe cases, more than one spray per season is required. Spray timing must include spring growth if applying more than one application. Old, hardened leaves do not readily absorb Zn foliar sprays and soil applications of Zn salts are ineffective.

Figure 263. Zinc deficiency causes chlorosis of leaves between the veins.

Figure 264. Typical zinc deficiency symptoms include chlorotic, small, narrow, upright leaves.

Figure 265. Citrus leaf with yellow mottled patches, often described as 'mottle leaf'.

Manganese deficiency

Symptoms: pale green mottling between the veins in young and mature leaves. Each side of the main leaf vein has a narrow green band (Figure 266). Symptoms are more noticeable on the southern side of the tree. Spring growth is affected but leaf size remains normal. Symptoms resemble those of zinc deficiency, and both can occur in combination.

Cause: manganese (Mn) is insoluble in slightly alkaline soil and leaches in strongly acidic soil, causing Mn deficiency; it is often associated with zinc, iron and copper deficiencies in alkaline soil.

Management: apply a Mn foliar spray when leaf flushes are one-third to two-thirds developed. Foliar sprays rectify the deficiency pattern on young leaves, but older leaves respond more slowly. Foliar Mn sprayed on Mn-deficient citrus increases fruit yield and improves juice quality. Manganese can also be applied as fertiliser to acidic soil.

Figure 266. Manganese deficiency in citrus.

Iron deficiency

Symptoms: leaf yellowing with the main veins staying green (Figure 267). Iron (Fe) does not move easily within the plant, so young leaves are the most severely affected, while older leaves remain green.

Cause: Fe is insoluble in alkaline calcareous soil, making it unavailable to the tree. Iron is required to produce chlorophyll, which is needed for photosynthesis. Wet conditions and low soil temperature worsen the deficiency.

Management: choose suitable rootstocks and scion varieties when planting in calcareous soil. Cleopatra mandarin is the most tolerant rootstock, while *Citrus trifoliata* is the least tolerant rootstock. Lemons are more prone to Fe chlorosis than oranges. Carefully monitor and manage irrigation to prevent over-watering and provide good drainage. Chelated iron applied to the soil can help reduce symptoms. Foliar sprays are ineffective.

Figure 267. Iron deficiency in citrus.

Magnesium deficiency

Symptoms: margins of older leaves will exhibit a distinctive yellowing, which gradually expands to the leaf apex. The leaf base will remain green in a triangular area (Figure 268). Magnesium deficiency is often associated with nutrient antagonism with very high levels of potassium application. A severe deficiency results in shoot dieback, leaf drop, smaller fruit size, lower fruit acid, reduced juice content and biennial fruit bearing. Deficiency symptoms are rarely seen in southern states of Australia.

Cause: deficiencies are common in coarse-textured (sandy) soil, especially in areas with high rainfall. Magnesium deficiencies begin to show at high (>8.5) and low soil pH (<5). Heavy potassium applications reduce magnesium (Mg) uptake. Nitrogen application can help amend Mg deficiency.

Management: apply a Mg foliar spray during late spring. Severe cases might need soil and foliar Mg applications. It can take several years to correct so regular monitoring is needed. Leaf Mg levels can return to normal in the first year but yields can take up to 4 years to respond.

Figure 268. Magnesium deficiency symptoms include yellowing at the leaf margins and a green triangular area at the base of the leaf.

Physiological disorders

Copper spray injury

Symptoms: usually the exposed (outward-facing) fruit surface shows signs such as stippling or darkening of existing blemishes (Figure 269 to Figure 271). Damaged leaves also display stippling (Figure 272).

Cause: spray injury can be caused by not following product label rates and recommendations. Injury can also occur when copper sprays are applied during hot weather or mixed with incompatible chemicals.

Management: do not apply copper fungicides with a complex tank mix of foliar fertilisers, particularly sulfate-based products. Some copper formulations should not be mixed with oil. Avoid phytotoxicity and the resulting injury by applying more frequent applications with lower rates of copper. Do not apply copper when fruit or leaf temperatures are high and humidity is low, or when the fruit are wet. Always follow label instructions.

Figure 269. Copper stippling and existing blemishes darken.

Figure 270. Fruit stippling caused by copper spray.

Figure 271. Darkened copper spray blemishes on the outward-facing side of the fruit.

Figure 272. Copper spray damage to citrus leaves.

Creasing (albedo breakdown)

Symptoms: fruit with albedo breakdown have a weak rind that is susceptible to cracking. Cracked rinds allow disease-causing microbes to enter and the fruit to decay. Fruit with creasing are more likely to split when packed (Figure 273). This is often a seasonal issue that can reduce fruit grade and increase the risk of fruit breakdown during transit.

Cause: creasing is where the underlying albedo layer collapses, giving the fruit rind a wrinkled appearance (Figure 274). The causes of creasing are not fully understood. The signs normally appear at the later stages of fruit maturity and are often worse on the inward-facing, shaded part of the fruit.

Management: applying preharvest gibberellic acid and calcium foliar sprays reduces creasing. Susceptibility differs between scion varieties and rootstocks. Pruned trees with filtered sunlight throughout the canopy and good spray penetration have less fruit with creasing. Over-mature fruit rinds are more prone to creasing (Figure 275).

Figure 273. Albedo breakdown causes rind separation.

Figure 274. Albedo breakdown causes fruit creasing.

Figure 275. Severe creasing in an over-mature mandarin.

Frost injury

Symptoms: frosted fruit can have rind scald (Figure 276 and Figure 277) and dry fruit sacs (Figure 278). Severely damaged fruit usually drop. Severe frost in spring can destroy flowers, reducing yield (Figure 279). Young, frost-damaged trees can have split bark and dead foliage. A succession of moderate frosts and cold winds can cause foliage to curl and bleach, appearing as brown blotches.

Cause: internal fruit damage can occur when the temperature is below –2 °C for more than 4 hours. There are varietal differences in susceptibility to frost damage. Mature fruit are less susceptible as the sugar acts as anti-freeze.

Management: do not plant trees in areas prone to severe frost. Frost fans increase airflow from the warmer inversion layer to delay frost formation.

Figure 276. Frost injury causes fruit rind scald.

Figure 277. Cold injury on grapefruit leaf and fruit.

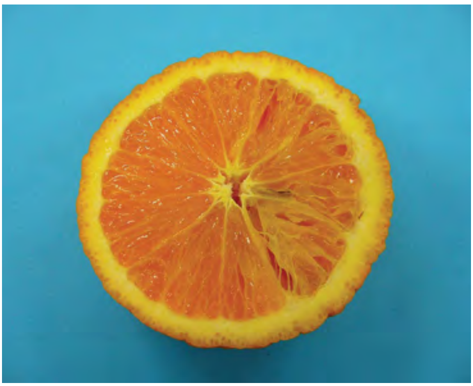


Figure 278. Frost injury causes dry fruit sacs in a navel orange.

Figure 279. Frost injury destroyed spring flush and flowers.

Incompatibility

Symptoms: incompatibility between the scion and rootstock is usually associated with declining tree health. Rootstock suckering will increase (Figure 280) and the rootstock can outgrow the scion (Figure 281). Trees can die prematurely (Figure 282).

Cause: some scions are incompatible with certain rootstocks. Known incompatibilities include Imperial mandarin on *Citrus trifoliata*, Eureka lemon on *C. trifoliata* and Navelina orange on C35 rootstock.

Management: use compatible stock and scion combinations (Figure 283) or separate incompatible varieties using an inter-stock.

Figure 280. Incompatibility between a Navelina scion and trifoliate rootstock results in rootstock suckering.

Figure 281. Incompatibility of Imperial mandarin on trifoliate rootstock.

Figure 282. Citrus tree death from incompatibility.

Figure 283. Compatible scion and rootstock combinations grow smoothly, allowing an unrestricted flow of carbohydrates between the scion and rootstock.

Disorders

Oleocellosis and watermarks

Symptoms: darkened spots on the fruit rind.

Cause: the phytotoxic action of peel oil released onto the rind causes oleocellosis. Foggy, wet conditions can cause the rind to become turgid (swollen) and more prone to rupturing oil glands during harvest. Turgid fruit suddenly exposed to low temperatures can cause peel oil to be released on unharvested fruit (Figure 284). Rough handling of fruit during harvest or postharvest can cause the oil cells to rupture (Figure 285 and Figure 286).

Management: an appropriately timed, orchard-applied gibberellic acid treatment will reduce rind sensitivity to mechanical damage. Carefully handle fruit at harvest. Pickers should wear gloves. Do not harvest after rain or early on winter mornings when the fruit are cool and wet.

Figure 284. On-tree oleocellosis.

Figure 285. Oleocellosis caused by handling.

Figure 286. Oleocellosis caused by rough handling can appear a few days after harvest.

Hail damage

Symptoms: damage varies with storm severity and the phenological stage and age of the tree. Hail can hit foliage, bark, branches, flowers and fruit (Figure 287 to Figure 290), with damage occurring mostly on the outer, storm-exposed side of the tree and fruit.

Cause: hailstorms.

Management: prune off severely damaged branches as soon as possible to stop disease-causing organisms from entering the wounds. A copper-based fungicide can help prevent disease. Replace young trees if the damage is too severe. If fruit are hard and green, hand thinning can selectively remove hail-damaged fruit to improve the yield and quality of the remaining fruit.

Figure 287. Typical fruit scarring from a moderate hailstorm.

Figure 288. Hail damage on immature fruit.

Figure 289. Severe hailstorm damage to a tree.

Figure 290. Severe hailstorm damage. Photo: Rohan Ashley, Mildura Fruit Company.

Wind blemish

Symptoms: shallow, discoloured scars on fruit rind (Figure 291), especially on the more exposed trees, such as those along boundaries. Fruit are more susceptible in the early stages of development.

Cause: wind knocking fruit against branches, dead twigs and thorns. Deadwood and long, spindly fruit-bearing wood (Figure 292) increase the amount of damage.

Management: pruning to remove deadwood and reduce the length of fruit-bearing wood also allows light into the tree, promoting fruitful buds and protecting the fruit. A sorghum × sudan forage hybrid planted every 2–4 inter-rows can be used as a short-term windbreak for young citrus trees (Figure 293). It can be mulched down and will re-shoot the following season. Once young trees are established, the windbreak can be removed by incorporation into the soil. Well-designed windbreaks reduce wind velocity over an orchard.

Figure 291. Wind damage causes shallow scars on fruit rind.

Figure 292. Deadwood increases the incidence of wind blemish on fruit.

Figure 293. A sorghum × sudan forage hybrid as a windbreak for newly planted citrus trees.

Sunburn

Symptoms: fruit and leaves have yellow to brown leathery patches on the sun-exposed areas (Figure 294 and Figure 295). Young trees are more susceptible to sunburn damage. Pruning mature trees heavily in hot weather exposes the lower trunk and limbs to sun scald. Affected bark becomes sunken, dies and peels off mostly on the north-western facing side (Figure 296 and Figure 297).

Cause: high levels of solar radiation (energy from the sun) on exposed surfaces. Damage is made worse by low soil moisture, reducing the cooling effect of transpiration. Sunburn is common after pruning that exposes previously shaded trunks or limbs to solar radiation.

Management: registered products are available for protecting tree canopies and fruit from the sun. Acrylic, flat white paint mixes are often applied to trunks when re-working citrus to protect them from sunburn. When trees are heavily hedged, paint mixes can be applied to the western side of lower trunks, particularly during hot weather, to prevent sunburn damage.

Figure 294. Sunburn damage to citrus fruit.

Figure 295. Sunburn damage to citrus foliage.

Figure 296. Sunburn damage to a tree trunk.

Figure 297. Callusing after sunburn damage.

Sooty mould *(Capnodium citri)*

Symptoms: black, superficial fungal growth on surfaces covered with sticky honeydew (Figure 298). Thick sooty mould reduces photosynthesis and spoils the appearance of the fruit.

Cause: sooty mould is a fungus that grows on the sugary excrement of sap-sucking insects. Sooty mould does not rot the fruit, but it can affect fruit development by reducing photosynthesis.

Management: control honeydew-producing insects (e.g. aphids, soft scale insects, mealybugs) and ants to reduce sooty mould. Ants are attracted to honeydew and actively defend sap-sucking pests from natural enemies, helping pests to move to other areas.

Figure 298. Sooty mould growing on honeydew secretions.

Salt toxicity

Symptoms: leaf burning, necrotic or dry leaf edges (Figure 299), yellowing, bronzing or browning of leaves and premature leaf drop (Figure 300 and Figure 301). Symptoms can resemble drought stress, such as stunted growth.

Cause: excess salts (e.g. chloride [Cl^-] and sodium [Na^+]) in the tree root zone. High Na levels in the soil reduce tree root water penetration and uptake. This can result from saline water, saline soil or the water table rising to the root zone. Problems are worse where drainage is poor and when fertilisers move into the root zone, particularly muriate of potash (potassium chloride) due to its high Cl^- content (50%).

Management: test the soil before planting to determine Cl^- and Na^+ levels. Minimise salt in the root zone by improving irrigation management and/or sub-surface drainage to reduce the depth of the water table. Maintain sub-surface drains to help salts leach from the root zone. Monitor irrigation water quality. Citrange rootstocks generally have moderate tolerance to salinity, while *Citrus trifoliata* is the least tolerant.

Figure 299. Leaf burning due to excess salt accumulation.

Figure 300. Excessive leaf drop and poor tree growth on a saline water table.

Figure 301. Severe leaf drop and poor tree health from excess salts in the root zone.

Disorders

Chemical disorder

Herbicide damage

Symptoms: differ depending on the mode of action group used.

- Lipid synthesis inhibitors (Group 1, e.g. clethodim) cause chlorosis and wilting of new leaves; severe exposure will cause tissue death and dieback.
- Hormone mimics (Group 4, e.g. 2,4-D and dicamba) deregulate growth by causing new shoots and leaves to be bent, with distorted and cupped leaves (Figure 302).
- Photosynthesis inhibitors (Group 5, e.g. simazine and bromacil) cause inter-veinal and whole leaf yellowing; severe exposure will cause shoot/twig dieback and distort new growth (Figure 303).
- Amino acid inhibitors (Group 9, e.g. glyphosate) cause leaves to turn yellow and fall over time; new leaf growth is small, narrow and needle-shaped; fruit will have rind damage (Figure 304) and can drop if severe.
- Nitrogen metabolism inhibitors (Group 10, e.g. glufosinate) cause wilting in the contact areas within days of application, followed by tissue death in weeks.
- Pigment inhibitors (Group 12, e.g. norflurazon) cause affected structures to become white or translucent and appear bleached.
- Cell membrane disruptors (Groups 14 and 22, e.g. flumioxazin and diquat) cause spots of dead tissue on the leaves (Figure 305) or other parts, including fruit.
- Cellulose synthesis inhibitors (Group 29, e.g. dichlobenil) cause foliage yellowing, especially at the tips of low-hanging branches.

Figure 302. 2,4-D causes distortion and cupping of leaves.

Figure 303. Herbicide damage distorts new growth.

Cause: herbicide movement by drift, volatilisation, run-off and root grafting due to improper herbicide use and practices, unfavourable weather conditions, product misapplication, tank contamination or herbicide carry over from a past application.

Management: appropriate chemical application. Strictly follow product label directions.

Figure 304. Sub-lethal doses of glyphosate drift causes rind damage to mature fruit (left) and small, narrow leaf development (right).

Figure 305. Contact, post-emergent, non-selective herbicide damage.

Disorders

Genetic disorder

Chimera

Symptoms: abnormally shaped, textured or coloured leaves and/or fruit (Figure 306 to Figure 310).

Cause: a chimera results from a genetic alteration or mutation of cells.

Management: prune to remove undesirable limb mutations. Many new varieties have originated from mutations or bud sports.

Figure 306. Chimera can cause abnormally textured fruit.

Figure 307. Chimera can cause striped fruit.

Figure 308. Chimera in a blood orange.

Figure 309. Chimera can cause fruit ridging.

Figure 310. Lemon leaves and fruit showing signs of chimera.

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Index

Pests, beneficials, diseases and disorders in citrus: a field identification guide

This field identification guide is a diagnostic tool to help citrus growers identify the main pests, beneficials, diseases and disorders found in citrus orchards. It provides descriptions, photographs and other information about pest status and management.

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