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Citrus plant protection guide 2024

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Citrus plant protection guide 2024

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Contents

What's new

This 6th edition of the *Citrus plant protection guide* provides up-to-date information on all aspects of managing pests and diseases in a citrus orchard. The guide can be downloaded from the Department of Primary Industries and Regional Development (NSW DPIRD) website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/manuals-guides).

This edition includes updates on NSW DPIRD citrus projects, some of which are funded through the citrus levy. There is a revised article on Asian citrus psyllid, the devastating citrus disease Huanglongbing (HLB) and an update on the current Australian Centre for International Agricultural Research (ACIAR) project associated with managing HLB. There are also updates on the Hort Innovation-funded projects on Afourer canopy management, citrus IDPM and citrus tree intensification. This year's guide also has articles on managing resistance in postharvest fungicides and how growers can prevent this from occurring.

Pesticides

Under the pesticide registration system that the Australian Pesticides and Veterinary Medicines Authority (APVMA) administers, individual products are registered for use in or on specific crops for specific pests, diseases or weeds. There can be variations in use recommendations between states for the same crop, even differences in times of application or treatment intervals. Using examples of common chemical names in the guide is intended to simplify the advice, not as a recommendation. It also means that at least one product containing that active ingredient is registered for the purpose given. Pesticide use is under constant scrutiny through residue surveys and reviews. The onus is on the user to ensure their product use is consistent with the label or a permit issued by the APVMA (https://portal.apvma.gov.au/pubcris).

Acknowledgements

We thank Aphrika Gregson and Trevor Klein, Farm Chemicals Officers, who have undertaken our chemical review of the guide. Agricultural companies have provided information on their products and helpful suggestions and we thank them for their involvement and interest.

Citrus intensification

Dave Monks, Mahmud Kare, Steven Falivene, Andrew Creek, Nerida Donovan and Grant Chambers, NSW DPIRD

NSW DPIRD's Citrus tree crop intensification project aims to develop robust information and tools and make them available to growers to improve production decisions. To achieve this, we are modifying citrus tree canopies with dwarfing viroids, planting densities, pruning, and cultural practices to understand their effect on the relationships between fruit density, canopy volume and saleable fruit. A wide range of citrus varieties have been surveyed to determine the physical traits promoting fruit density and, in turn, suitability for production intensification. The program includes experimenting with high-density management and trellis production, assessing different dwarfing viroids for their effect on canopy size and productivity, and monitoring the growth and productivity of a range of citrus varieties to identify architectural features limiting crop production. Growers with experience in high-density technology support the program through case studies.

The work on mechanisms influencing fruit production helps develop tools and information for growers to use when selecting an appropriate production system. A series of pruning videos and a fact sheet have been published on the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus). These resources introduce pruning practices and explain the different pruning styles, which is an excellent way for farm staff to understand pruning basics so they can meet growers' requirements.

The trellis experiment is progressing well and some fruit was produced this season. The trial used existing trees, stumping them and directing the regrowth onto a trellis. The purpose of the trial is to get as much canopy growing as quickly as possible to fill the trellis and assess the yield potential of a mature trellis structure. The trees are spaced at 4.9 m, providing them with maximum light. If the trellis does not perform in these ideal conditions, then it is possible it could perform at closer spacing. The trellis is also an excellent resource to study the most appropriate pruning strategies for trellised trees. The current trellis orchard will also be used to assess semi-autonomous (platform picking, Figure 1 and Figure 2) and automated (harvest robots) harvesting machinery as it is being developed. While the current trellis trial provides an opportunity to learn about managing mature trellis orchards, developing a trellis trial from planting will provide long-term productivity results.

This project is part of the Hort Frontiers AS18000 National Tree Crop Intensification in Horticulture program, which includes similar work in almonds, avocados, macadamias and mangos. This project is funded through the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from NSW Department of Primary Industries and Regional Development and contributions from the Australian Government.

Figure 1. A prototype picking platform developed by Gary Nielson.

Figure 2. An Italian-manufactured Revo Piuma picking platform from GV Crop Protection.

Afourer canopy management

Steven Falivene, NSW DPIRD

This Hort Innovation Australia-funded project led by NSW DPIRD aims to develop best-practice canopy management techniques in Afourer mandarins.

The intended outcomes of the project are to improve long-term yields and minimise alternate bearing (the tendency to produce a greater than average crop one year, and a lower than average crop the following year) in Afourer mandarins. These are known for producing high yields (60–90 t/ha) in the first 8–10 years, but as the trees mature, their yield declines and alternate bearing becomes more prominent. Some growers with mature trees have reported average yields of 35–40 t/ha in 'off' years. Using different pruning strategies in replicated trials and demonstrations, we aim to find the ideal pruning regime to minimise vigour and water shoots, improve long-term yields, and reduce alternate bearing.

In November 2022, a tour group visited many orchards in Spain and an orchard in Morocco. The focus was to learn about canopy management strategies to maintain consistent production. The tour participants were Steven Falivene and Mahmud Kare (NSW DPIRD), Ryan Arnold (citrus grower) and John Chavarria (packing house consultant).

The key points learned from the tour include:

- intensive pruning is a common practice in most Afourer orchards
- key reasons to prune include:
  - tree height needs to be maintained below 3 m as pickers are not allowed to use tall ladders in Spain (Figure 3 and Figure 4)
  - trees with an open structure dry quicker, reducing fungal infections
  - if the trees are not pruned, yields decline
- pruning takes about 5 to 10 minutes per tree depending on tree size ($4–$10 AUD/tree); labour cost is about $18/h Australian equivalent
- an orchard in Morocco was trying to manage trees by allowing water shoots to grow. However, yields have started to decline in their mature orchards, and they need to change their strategy
- Spain has been in drought for a couple of seasons, with some growers receiving as low as 50% of their water allocation, and in Murcia, they also have high salinity water (3–5 dS/m). The growers recognise the value of good irrigation monitoring and practices.

Eighteen videos of the study tour (one for each farm visited) are available from the NSW DPIRD citrus website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus); videos range from 2 to 10 minutes. A companion three-page summary from each farm visit is also available.

Acknowledgements

This project is funded by Hort Innovation, using the citrus research and development levy and contributions from the Australian Government and co-investment from NSW Department of Primary Industries and Regional Development.

Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

We thank Afourer grower project members for providing their time and trial blocks in-kind. Special thank you to Nutrano, Southern Cross, KW Orchards, Costas Orchards and Mick Cuzzillo for collaborating in replicated trials.

Figure 3. Ryan Arnold (citrus grower, PYAP Produce) showing that most trees are pruned to about 2 m so fruit can be harvested from the ground.

Figure 4. Spanish citrus grower Rafael Cano (Eurosemillas) demonstrates how managing young trees through pruning and limb bending is very important to set the trees up for long-term productivity.

Citrus industry integrated pest and disease management extension program

Andrew Creek, NSW DPIRD

Increasing growers' knowledge of integrated pest and disease management (IPDM) is a focus of the current extension program for the citrus industry. NSW Department of Primary Industries and Regional Development (NSW DPIRD), Queensland Department of Agriculture and Fisheries (QDAF) and Western Australian Department of Primary Industries and Regional Development (DPIRD) are collaborating with experienced IPDM specialists to deliver a Hort Innovation-funded citrus IPDM extension program (CT19011).

Pest and disease management is an important aspect of citrus growing. Australian consumers and export markets demand high-quality citrus that is produced with reduced environmental impact. Adopting an IPDM program is a sustainable way to manage citrus pests and diseases. IPDM can work well in citrus as it is a perennial horticultural crop, and there is often an inter-row sod that can be managed to support beneficial insects.

Some grower collaborators that host our research trials have said 'they sprayed more than their fathers ever did'. In the 1980s and 1990s, half-rate chlorpyrifos and oil, releasing *Aphytis* and an autumn copper spray, were the mainstay for growing oranges in the Riverina.

To remain profitable, the Australian citrus industry expanded into new export markets, which meant managing quarantine pests of concern, and many new insecticides became available. Some insecticides control a wide range of pests and are efficiently applied through drip irrigation systems.

The best market returns for a citrus grower are from well-sized, unblemished fruit. These factors have contributed to reduced IPDM and a greater reliance on chemicals. In 2022, the IPDM extension program surveyed growers; almost a third 'no longer' release beneficial insects, and another third had never done so.

The citrus IPDM extension program aims to:

1. understand how the citrus industry is currently managing pests and diseases
2. increase growers' knowledge of citrus pests, diseases and beneficials
3. establish IPDM demonstration sites to try sustainable pest management options.

Introduction to integrated pest and disease management

An IPDM strategy draws upon a range of management tools (Figure 5), with the goal being to use the least ecologically disruptive methods to manage pests and diseases. The focus is on cultural control options, with chemical controls playing a supportive role.

In an IPDM system, pests are managed to economically acceptable levels using a combination of biological, cultural and chemical control options.

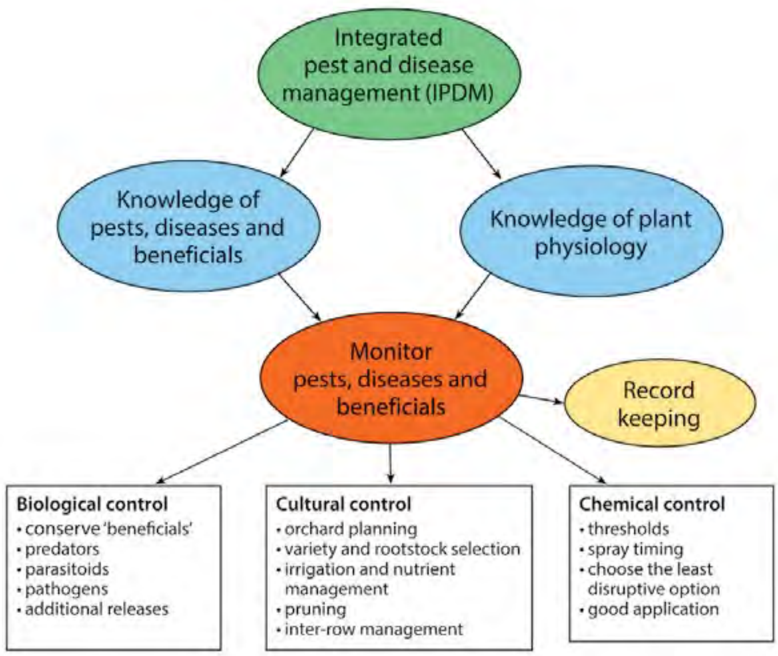

Figure 5. Factors to consider when using an integrated pest and disease management (IPDM) strategy.

'Beneficials' or natural enemies of pests are encouraged in the orchard by careful insecticide choices. Alternate row slashing or leaving grasses long provides habitat and a pollen food source for predatory insects and mites. Beneficial insect releases can assist in managing some pests, e.g. parasitic *Aphytis* spp. wasps for red scale (*Aonidella aurantia*).

Monitoring regularly for beneficials, pests, and diseases is an important aspect of IPDM. Using IPDM does not exclude chemical use, but encourages a preference for using 'softer' or selective insecticides that do not disrupt natural predators. Using broad-spectrum chemistry usually leads to secondary pest problems in citrus orchards and the need for further chemical application.

Citrus IPDM extension program activities

IPDM practice survey

The project team surveyed growers in 2022 to identify key pests and diseases for each region and current management practices (Figure 6). Results revealed there is a diverse approach to managing pests and diseases in Australian citrus. A report is also published on the NSW DPIRD citrus website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus).

Figure 6. A screenshot of the citrus pest and disease benchmarking site.

IPDM workshops and field walks

NSW DPIRD staff facilitated workshops and seasonal farm walks in the Riverina, Sunraysia and Riverland regions (Figure 7). QDAF staff held events at Mareeba (FNQ), while DPIRD staff held events at Moora and Harvey in WA.

Figure 7. Left: Gary Jolly (Grand View Orchards) and Brad Bowes (NSW DPIRD) assist Andrew Creek (NSW DPIRD) and Megan Bennett (Manness Entomology) in preparing lacewing larvae for release. Right: some participants at the Yanco seasonal farm walk. Image by Robert Hoddle, Gunnible, Gunnedah, NSW.

Publications

Program outputs are being published on the NSW DPIRD citrus website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus, Figure 8, left), including the IPDM practice survey report, fact sheets, webinars and short videos.

The IPDM practice survey data identified 30 priority pests for fact sheets. The fact sheets for the highest-priority pests were printed as handouts for seasonal farm walks. The cultural, biological and chemical control options are explained for each pest and QR codes provide quick access to additional information (Figure 8, right).

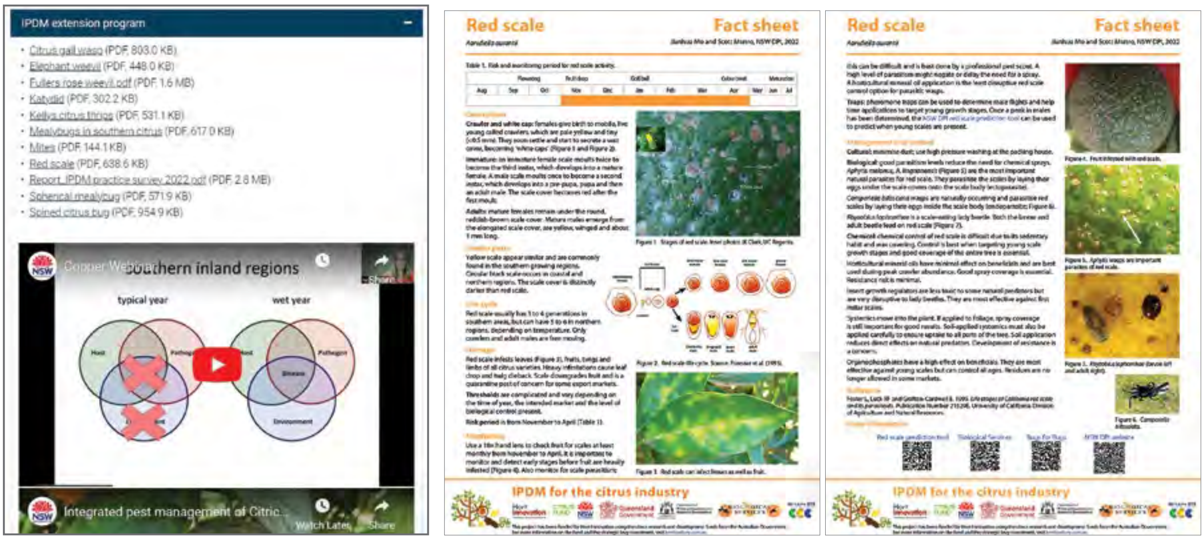

Figure 8. Left: the Citrus IPDM extension program. The webpage will host 30 fact sheets, 4 webinars and 8 YouTube videos. Right: front and reverse side of the red scale seasonal farm walk handout.

The extension program is hosting an annual webinar with a citrus researcher. These will focus on either a key pest or disease, providing on-farm practical application of the research work and an opportunity for Australian citrus growers to speak with the researcher. The webinar on citrus diseases and copper fungicide application is now published on the NSW DPIRD citrus website with chapter titles so viewers can go to specific sections of the presentation. e.g. 'copper phytotoxicity' or 'septoria spot'.

NSW DPIRD staff are working on a field guide called *Citrus pests, beneficials, diseases and disorders*. WA and QDAF collaborators will also assist with the field guide.

Figure 9. The parasitic wasp (*Megastigmus brevivalvus*).

Regional on-farm demonstration sites

The IPDM extension program has established demonstration sites in different citrus production regions. Red scale (*Aonidella aurantia*), citrus gall wasp (*Bruchophagus fellis*) and oriental spider mite (*Eutetranychus orientalis*) are some of the pests for which alternative management systems are being investigated. In the gall wasp site, hedge pruning and kaolin clay (Surround®) are being used in direct comparison to whole orchard treatment with systemic neonicotinoid insecticides. Parasitic wasps (*Megastigmus brevivalvus*, Figure 9) were released (Figure 10 and Figure 11) to a single row of untreated Valencia trees to provide a repository to build up further parasitic wasps. The parasitic wasps lay their eggs inside a citrus gall wasp egg, reducing gall wasp numbers over the longer term.

Figure 10. Parasitic wasps (*Megastigmus brevivalvus)* emerge from galls hanging in nets.

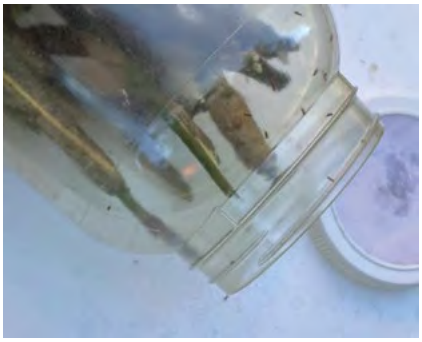

Figure 11. Parasitic wasps (*Megastigmus brevivalvus)* emerge from galls in jars.

To learn more about extension program activities, contact a team member in your region:

- NSW (Riverina), Andrew Creek, andrew.creek@dpi.nsw.gov.au
- NSW/VIC/SA (Riverland and Sunraysia), Steven Falivene, steven.falivene@dpi.nsw.gov.au
- QLD, Emily Pattison, emily.pattison@daf.qld.gov.au
- WA, Rachelle Johnstone, rachelle.johnstone@dpird.wa.gov.au

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 and Regional Development (NSW DPIRD), Queensland Department of Agriculture and Fisheries (QDAF) and the Agricultural Produce Commission. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Modern irrigation skills for profitable and sustainable orchards

Katie Dunne (formerly NSW DPIRD), Steven Falivene and Robert Hoogers (NSW DPIRD)

Climate change is predicted to increase the severity and frequency of droughts in Australia. During a drought, managing crops with the least amount of water enables growers to keep as much of the orchard as possible in production.

Drought resilience involves having an efficient and profitable orchard, which requires skill and experience. To help growers determine when and how much water to apply to maximise profitability, improve sustainability, and be better skilled and prepared for the next drought, advanced irrigation skills were provided to growers in the Riverina and Sunraysia over the past 2 years.

Irrigation masterclasses, held over 2 weeks, aimed to increase knowledge on foundational and advanced irrigation principles, modern irrigation practices, the latest irrigation 'agtech' (systems and sensors) and how to interpret soil water data. This will help growers improve their irrigation practices in non-drought years and to be in a stronger position to cope with drought conditions.

The first week concentrated on the basics of soil science and plant physiology. Growers learned how plants move water from the soil to the leaves and how this relates to climatic conditions and available soil moisture. There were practical demonstrations in the field where participants could observe root growth in excavated soil pits (Figure 12). This activity also showed how there can be several soil types in a block and how this can affect plant available water. Growers were shown how to calculate readily available water (the amount of easily extractable plant available water stored in the soil) and assess the soil texture on their farms (Figure 13). All growers were provided with the resources to apply this in their orchards and where to source soil testing kits.

Figure 12. A soil pit in a Cara Cara Navel orchard at Sunraysia.

Figure 13. Participants learning how to determine soil texture by rolling moist soil in their hands.

A key drought strategy is to provide only enough water to grow a profitable crop without waste. The second week focused on modern irrigation monitoring systems and sensors, which are used to help schedule irrigation and calculate how much water is required based on what the plants have used and are likely to need (predictive irrigation). This involves calculating evapotranspiration for a crop, accessing and interpreting weather data from the Internet, and knowing how water infiltrates the soil and whether this water is available to the plants or tightly held in the soil. Participants were provided with spreadsheet tools to estimate evapotranspiration, plant water use and the frequency and amount of irrigation. Participants put the theory into practice, testing the irrigation output in nearby orchards (Figure 14).

The latest agtech was discussed, including how the data are often presented on different platforms. There are many types of soil and plant monitoring sensors available. Some provide good historical data, while others provide more immediate information for daily irrigation scheduling. Sometimes the data platform can be overwhelming, leading to misinterpreted results. Understanding how the systems work and the type of information they provide helps participants interpret the results. The masterclasses helped growers understand the data, put them into perspective and improve their confidence in interpreting results. Orchard walks to inspect the mini agtech demonstration sites at the NSW DPIRD Griffith and Dareton research stations were also included. These sites validate using modern agtech with water savings of 0.6–2.2 ML/ha of water over the last 2 seasons.

The masterclasses also involved on-farm follow-up and some drought case study demonstrations. Each farm manager had an opportunity to share data from their orchard, discuss what happened in the block during the season and how irrigation scheduling could be tweaked for the following season. Feedback revealed that participants appreciated having someone look at their data and identify solutions.

These workshops were co-designed by NSW DPIRD and industry and are updated regularly based on grower feedback. Funding to develop and hold the workshops was provided by NSW DPIRD Climate Smart Pilots, part of the NSW DPIRD Climate Change Research Strategy. Additional funding was provided by the Southern NSW Drought Resilience Adoption and Innovation Hub.

Figure 14. Testing irrigation output and pressure and developing a uniformity assessment report for the block.

Climate vulnerability assessment of primary industries

Improving our understanding of climate change risks and effects on NSW primary industries

The Department of Primary Industries and Regional Development, through the Climate Change Research Strategy, has undertaken a comprehensive assessment of the vulnerability of key commodities to climate change in NSW. The assessment will fill gaps in our knowledge about the effects of climate change on the state's primary industries.

For horticulture and viticulture, the vulnerability assessment project has analysed climate change effects for citrus (Navel orange), cherry (Lapin), almond (Non-pareil), walnut (Chandler), blueberry (Southern highbush), macadamia and wine grapes (Chardonnay). In addition, the project is also currently integrating the effects of climate change on related pests and diseases, such as Queensland fruit fly.

This work will help to provide a clearer picture of potential climate change effects on the horticulture and viticulture sectors in NSW, looking ahead to 2050. It will also help identify adaptation needs and priorities that can guide future research and development activities to increase the resilience of this critical sector to a changing climate.

We are close to finalising the vulnerability assessment for citrus, and the results will be released later this year. To access the report, please go to the NSW DPIRD Climate webpage (https://www.dpi.nsw.gov.au/dpi/climate/climate-change-and-primary-industries) or email (vulnerability.assessment@dpi.nsw.gov.au). We welcome the opportunity to share the findings with you and discuss the next phase of work to support your industry in adapting to climate changes in NSW.

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Selecting the right citrus rootstock for your orchard

Dr Tahir Khurshid, Steven Falivene and Andrew Creek, NSW DPIRD

This project has been funded by Hort Innovation, using the citrus research and development levy, and co-investment from New South Wales Department of Primary Industries and Regional Development. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

NSW DPIRD conducts extensive research on citrus rootstocks to maximise performance in citrus orchards. This update is to provide growers with a quick guide on rootstock selection. A more detailed fact sheet is on the NSW DPIRD citrus website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/rootstocks-varieties/rootstocks-articles/selecting-citrus-rootstocks).

Rootstock selection is one of the most important factors to consider when planning a citrus orchard, affecting yield, fruit size and quality. They also vary in their adaptability to different soil types, tolerance of adverse soil conditions, pests, diseases, and their suitability for use on re-planting sites. Some orchards use different rootstocks for the same variety to widen harvest (early and later fruit maturing rootstock).

The most appropriate rootstock will depend on:

- site characteristics
- the intended planting system
- the likelihood of specific pests, diseases or salinity problems
- the variety to be grown
- planned market outlets
- marketing strategies for the fruit.

The main rootstocks in Australia are *Citrus trifoliata* (syn. *Poncirus trifoliata*), Troyer citrange, Carrizo citrange, Swingle citrumelo, Cleopatra mandarin, rough lemon, sweet orange and Benton citrange. Different rootstock varieties are used in the major production areas because of different soil types and growing conditions. Trifoliate rootstocks are predominantly used in the Riverina, while South Australia and Murray Valley use Troyer and Carrizo citrange. In Queensland mandarin plantings, Troyer citrange is predominantly used. Benton citrange and Cox hybrid are the most widely planted rootstocks for lemons.

Before planting, obtain comprehensive soil surveys and profile descriptions of the proposed orchard sites, and use this information to select the most suitable rootstock.

The general characteristics and major limitations of the main rootstocks are summarised in Table 1. Effects on fruit quality and relative ranking for nematode, phytophthora, Citrus tristeza virus (CTV), salt and lime tolerance are shown in Table 2, further highlighting rootstock differences.

The main pest and disease considerations are citrus nematodes, phytophthora root and collar rots, and CTV. All rootstocks used in Australia should be CTV tolerant. Rootstocks for re-planting situations should also tolerate phytophthora and citrus nematode.

Compatibility also needs to be considered when selecting rootstocks. Results from a long-term research trial showed that Navelina orange is not recommended with C35 citrange rootstock. Concerns were also raised about reduced tree health and yields of Hockney Navel and Summer Gold Navel on C35 citrange rootstock (Sanderson and Skewes 2017). Navel oranges are generally compatible with Troyer and Carrizo citrange, Cleopatra mandarin and Trifoliate rootstocks. The known scion compatibilities for common rootstocks under Australian conditions are shown in Table 3.

Table 1. The advantages and disadvantages of the major citrus rootstocks used in Australia.

	Characteristics	Requirements	Major risk factors
Benton citrange	• Resistant to phytophthora root and collar rots. • Compatible with Eureka lemon, producing trees of intermediate size with good cropping efficiency.	• Exocortis-free budwood. • Not suitable for calcareous soil.	• Limited experience, still being evaluated. • Tolerance to nematodes unknown.
C35 (Figure 15)	• Resistant to phytophthora root and collar rots. • Citrus nematode and tristeza tolerant.	• Certified disease-free budwood or trees might be smaller in size.	• Incompatible with Eureka lemon, Navelina and possibly with varieties sourced as bud sport mutations from Navelina (e.g. FJ Navel and M7).
***Carrizo* and *Troyer* citranges** (Figure 16)	• Resistant to phytophthora. • Tristeza tolerant; infection by exocortis results in reduced tree size, but no butt scaling. • Mycorrhizal dependent. • Cold hardy. • Intermediate rooting depth; main lateral and fibrous root development can be poor in young trees. • Medium to large trees, usually very productive with good fruit quality.	• Exocortis-free budwood. • Adapted to a wide range of soil types, except highly calcareous soil.	• Incompatible with Imperial mandarin and Eureka lemon. • Very prone to micronutrient deficiencies, especially on calcareous soil. • Compatibility with some minor varieties unknown. • Prone to sudden death. • Not suited to clay loam soil, trees decline after 10 years.
Citrus macrophylla	• Large fruit size. • Lower °Brix and acidity when grown under standard practice. • If specialised water stress practices are used, internal quality can be improved.	• Routine de-suckering while trees are young is suggested to reduce feeding by aphids and infection with CTV.	• Susceptible to nematodes and tristeza, which can lead to tree decline.
Cleopatra mandarin	• Moderately susceptible to phytophthora root and collar rots. • Tristeza and exocortis tolerant. • Susceptible to citrus and burrowing nematodes. • Intermediate rooting depth; intensive fibrous root development. • Slow growing in the nursery. • Mature trees are large. • Early production is poor, satisfactory in mature trees. • Good fruit quality but small fruit size with some cultivars.	• Suited to virgin sites. • Only performs well on lighter soil. • Lime and salt tolerant.	• Tends to produce smaller fruit size. • Good drainage and precautions against root rot are essential. • Slow to come into bearing.
***Citrus trifoliata* (syn. *Poncirus trifoliata*)**	• Highly resistant to phytophthora, CTV and citrus nematode. • Intolerant of exocortis. • Cold hardy. • Shallow rooting depth but develops highly fibrous root density. • Requires more frequent irrigation than deeper-rooted rootstocks. • Tree size small to medium. • Generally, highly fruitful. • Fruit quality very good. • Suited to clay loam soil.	• Exocortis and tatter leaf-free budwood. • Will grow on a wide range of soil types but prefers loam; is intolerant of highly acidic and lime soil. • Poor drought tolerance.	• Incompatible with Eureka lemon, Imperial mandarin, Daisy mandarin and acid-less oranges. • Compatibility with some minor varieties unknown. • Despite accumulating high levels of chloride in leaf tissue, does not exhibit obvious toxicity symptoms. • Prone to sudden death.

Table 1. The advantages and disadvantages of the major citrus rootstocks used in Australia, page 2.

	Characteristics	Requirements	Major risk factors
Rough lemon (Citronelle)	• Susceptible to phytophthora root and collar rots, citrus nematode. • Tristeza and exocortis tolerant. • Mycorrhizal dependent. • Extensive lateral and vertical root development. • Highly drought tolerant. • Produces large trees. • Yields are high, good fruit size, but poor quality. • Promotes early maturity.	• Best on deep virgin sandy soil.	• Does not tolerate poorly drained soil. • Tends to accumulate excessive chloride, leading to leaf drop. • Unsuitable for some mandarins e.g. Satsuma and Ellendale tangor.
Sweet orange	• Very susceptible to phytophthora root and collar rots; susceptible to citrus nematode. • Tristeza and exocortis tolerant. • Mycorrhizal dependent. • Intermediate rooting depth. • Produces large trees on well-drained soil in inland areas. • High yielding with good fruit quality.	• Best on deep sandy soil. • Sensitive to dry conditions but tolerates calcareous soil.	• Does not tolerate excessive soil moisture.
Swingle citrumelo	• Phytophthora and tristeza tolerant. • Nematode resistant. • More salt tolerant than other *Citrus trifoliata* (syn. *Poncirus trifoliata*) hybrids. • Good fruit quality.	• Not suited to clay or highly calcareous soil.	• Sensitive to overwatering. • Incompatible with Eureka lemon and some orange and mandarin cultivars. • Overgrows orange varieties. • Fruit more prone to creasing.
Citrus volkameriana	• Susceptible to phytophthora root and collar rots.	• Suitable for virgin sites only.	• Less °Brix and acid to downgrade fruit quality.

Table 2. The general effects of rootstocks on citrus fruit quality.

	C35	Carrizo and Troyer citranges	Cleopatra mandarin	*Citrus macrophylla*	*Citrus trifoliata* (syn. *Poncirus trifoliata*)	Rough lemon	Sweet orange	Swingle citrumelo	*Citrus* volkamariana
Acidity	high	medium–high	high	low	high	low	medium	medium	low
Fruit size	medium	medium	small–medium	large	medium	large	medium	medium–large	large
Juice content	high	high	medium	low	high	low–medium	medium	high	low
Maturity	mid–late	mid	mid	early	mid–late	early	mid	mid	early
Rind texture	smooth	smooth	medium	coarse	smooth	coarse	medium	smooth	coarse
Rind thickness	thin	thin	thin	thick	thin	thick	medium	thin	thick
TSS	high	high	medium	low	high	low	medium	high	low

Rootstocks

Table 3. Rootstock compatibility.

	Benton citrange	C35	*Carrizo Troyer* citranges	Cleopatra mandarin	*Citrus trifoliata* (syn. *Poncirus trifoliata*)	Rough lemon	Sweet orange	Swingle citrumelo	Citrus volkamariana
Afourer	✓	!	✓	✓	Y	✓	✓	×	✓
Eureka lemon	✓	×	×	?	×	✓	✓	×	✓
Imperial mandarin	✓	?	×	✓	×	✓	✓	?	✓
Late Navels	?	✓	✓	✓	✓	✓	✓	✓	✓
Lisbon lemon	✓	✓	✓	?	✓	✓	✓	✓	✓
Murcott mandarin	✓	?	✓	✓	✓	✓	✓	×	✓
Navelina	?	×	✓	✓	✓	✓	✓	×	✓
Washington Navel	?	✓	✓	✓	✓	✓	✓	✓	✓

✓ = compatible, ! = suspicion of incompatibility, × = incompatible, ? = unknown, Y = young trees show no incompatibility to date.

Figure 15. C35 rootstock.

Figure 16. *Carrizo* citrange.

Conclusions

Growers need to understand compatibility and its effects on yield before purchasing rootstock for an orchard. The tables in this summary are a guide only. Actual horticultural performance under commercial conditions will depend on management inputs.

Reference

Sanderson G and Skewes M (2017) 'C35 citrange rootstock – a complicated story'. *Australian Citrus News*, winter edition.

Key citrus growth stages and cultural practices

Steven Falivene, Andrew Creek, Tahir Khurshid, Nerida Donovan and Jianhua Mo, NSW DPIRD

1. Bud initiation

(late May–June)

- Apply gibberellic acid (GA) to reduce flowering and increase the ratio of leafy to leafless inflorescence

2. Bud break

(late July–early August)

- GA to reduce flowering (narrow window)
- Start applying ground fertiliser

3. Young shoot growth and white bud

(August)

- Micronutrient sprays at 2/3 shoot expansion, earlier applications can start at 1/3 expansion
- Adding macronutrients to mixture is optional

Bud initiation → Bud break → Shoot growth

Maturity ← **Colour break** ← **Cell expansion/high fruit growth**

11. Fruit maturity and harvest

(May–July)

- Ensure Australian Citrus Quality Standards are met
- Prune trees after harvest

10. Colour break

(April)

- Colour change from dark green to light green–yellow
- GA to delay rind development
- Autumn copper sprays
- Cling sprays in following months
- Red scale chemical control if required
- Stop fertiliser program

9. Golf ball

(early January)

- 40–45 mm fruit diameter
- 20 ppm GA to reduce albedo breakdown
- Start taking monthly fruit diameter measurements
- Hand thinning mandarins
- Mealybug: assess parasitism, control option in February
- January–February: oil spray if required for scale control

4. Start of bloom
(late September–early October)

- 5% of flowers are open
- Record the date

5. Full bloom

- (early October)
- 50% of flowers fully open
- Thrips: presence indicates possible future problem, but it is not recommended to spray for thrips during flowering
- Light brown apple moth (LBAM): check for presence

6. End of petal fall
(mid–late October)

- 80–90% of petals fallen
- Fruit set spray
- Early thrips action if larvae thresholds exceeded
- Check for presence of young katydid and LBAM as indicators of future problems

Flowering

Fruit drop and cell division

Start of cell expansion

7. First fruit drop
(early November)

- Heavy fruitlet drop (a mat can help)
- 5–15 mm fruit diameter
- Assess crop load with counting frame at 12–15 mm fruit diameter (near end of drop) for possible chemical thinning
- Optional fruit size plant growth regulator (PGR) sprays after drop
- Sporadic drop will continue to December
- Katydid, LBAM and thrips are usually the most common pests for the next 6 weeks

8. End of cell division/start of cell expansion
(early–mid December)

- 30–36 mm fruit diameter
- Fruit in cell division sink in water, those in cell expansion float
- Peak fruit potassium (K) uptake starts; K foliar sprays can help boost tree reserves
- No more calcium (Ca) uptake into the rind
- Red scale monitoring and control throughout summer, start Fuller's rose weevil management

Insect pests

Jianhua Mo and Steven Falivene, NSW DPIRD

Citrus gall wasp

Description

Size and appearance: adult citrus gall wasps (*Bruchophagus fellis*) are 2.5 mm long and shiny black.

Life cycle: one generation a year; 4 larval stages, 2 pupal stages and an adult stage. In the first 3 days after wasp emergence, most eggs are laid under the bark of new season shoots (Figure 17). Adult citrus gall wasps (CGW) live for 3–14 days depending on temperature. Each female can lay about 100 eggs. Larvae hatch in 14–28 days and feed inside individually constructed cells.

Habit: most of a wasp's life is spent within the gall of a branch as a larva. Adult wasps emerge between October and November, depending on location.

Integrated pest management (IPM)

Damage and risk period: heavily infested trees are weakened and appear spindly, with reduced fruit size and productivity. Heavily infested rootstock trees gradually decline and die.

Adult wasps and young larvae are the most vulnerable stages. In the southern citrus production regions, the best time to actively control them is from mid October to December (Table 4).

Table 4. Risk and control periods for citrus gall wasp activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
		Emergence									
		Control									

Monitoring: check for galls in the low to middle canopies. Scattered small galls (<10 mm long) are indications of recent infestations, whereas large galls (>50 mm long) are indications of earlier infestations.

Threshold: CGW infestations are expanding in the southern citrus regions. In orchards where CGW is first found, galls should be cut off during winter. Where CGW infestation is well established (e.g. large galls present), chemical intervention might be needed. Discuss management strategies with your pest consultant.

Biological control: 2 parasitic wasps, *Megastigmus brevivalvus* and *M. trisulcus,* parasitise CGW eggs. Parasitic wasps will not eliminate the gall wasps but will reduce the density and size of galls. Where the parasitic wasp populations have not yet established, consider releasing them (see page 54).

Management

Pruning and burning current-season galls can control CGW. Use repellents to reduce egg-laying and apply systemic insecticides to kill the larvae.

Systemic insecticides have long residue periods and should not be used outside the recommended periods stated on the labels. Do not use systemic insecticides during flowering.

For further information, see Citrus gall wasp: future population trends on page 37 and Primefact 2010, *Citrus gall wasp in Southern Australia*.

The chemical control for CGW is listed in Table 18 on page 58.

Figure 17. Adult citrus gall wasps laying eggs.

Elephant weevil

Description

Elephant weevils (*Orthorhinus cylindrirostris*) are native to Australia.

Figure 18. Adult elephant weevil.

Size and appearance: immature larvae are soft and creamy–yellow. They are legless, approximately 20 mm long and curl up to form a C-shape. Pupae start transparent, becoming darker brown as they develop. Adults are black, grey or brown and between 8 mm and 20 mm long. The body is densely covered with scales (Figure 18). The front legs are longer than the other 2 pairs. Clubbed antennae form an L-shape with a distinct elbow. The adult's long snout (rostrum) is the most distinguishing feature. Adults have wings and can spread reasonable distances.

Life cycle: females lay up to 80 eggs during their lifetime, underneath and in gaps in the tree bark. Egg laying occurs from October to November. Larvae tunnel downwards for 10 months, feeding on the wood, tightly packing tunnels with fine fibrous material that looks like sawdust. When fully grown, they move back up the tunnel to pupate. Pupation occurs up to 1 m above ground level within the trunk in cells at the end of these tunnels. The pupal stage lasts for 2 months. The adults emerge by boring a round hole directly to the trunk exterior. A complete life cycle takes about one year. Adults emerge from September to February, peaking in December. They are strong fliers and feed on the bark of woody plants.

IPM

Figure 19. Elephant weevil damage to young (left) and old (right) trees.

Damage and risk period: adult elephant weevil attacks young and old trees (Figure 19); however, damage is reported more frequently in older trees. The adult weevil damages young plants by eating leaves and stems and scalloping the foliage. They can also ring-bark young branches. Adult exit holes are 5–6 mm in diameter, located mostly in the lower trunk and rootstock. There can be multiple exit holes on one tree trunk.

The larvae are wood borers, tunnelling in the trunk and roots. Most damage is done by tunnelling larvae.

Fruit size and tree health might be reduced on heavily infested trees. Severe infestation might cause branch/tree dieback. Healthy trees are unlikely to have significant elephant weevil damage.

Risk period: September to February (Table 5).

Table 5. Risk and monitoring period for elephant weevil activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

Monitoring: check blocks for adult emergence holes in the lower trunk and branches, particularly on unhealthy trees. Cutting across a branch or tree trunk will reveal tunnels filled with frass that look like sawdust (Figure 20). Freshly chewed bark on twigs might indicate elephant weevil presence (Figure 21).

Figure 20. Elephant weevil tunnels filled with sawdust in a young (left) and old (right) tree.

Figure 21. A young branch that has been chewed by an elephant weevil (left) and a larvae tunnel inside a young tree (right).

Management

Cultural: maintain healthy trees and avoid tree stress such as waterlogging and drought. Often, elephant weevils infest stressed trees closest to windbreaks. Keep weeds down and maintain healthy plants.

Biological: entomopathogenic fungi, e.g. *Beauveria bassiana* (Figure 22), can infect elephant weevil and could be part of an integrated control strategy.

Chemical: chemical control of elephant weevil is difficult. There are currently no registered chemicals for elephant weevil control in citrus.

Figure 22. An adult elephant weevil infected with an entomopathogen *(Beauveria bassiana)*. Photo: Murdoch (2010).

Fuller’s rose weevil

Description

Size and appearance: adult Fuller’s rose weevils (*Pantomorus cervinus*) are wingless, grey–brown (Figure 23) and about 8 mm long. Mature larvae are legless, yellow and about 6 mm long.

Life cycle: there is one generation a year. Fuller’s rose weevil (FRW) females produce 20–30 eggs glued together in yellowish, papery masses without mating. Eggs are laid under fruit calyces, in bark crevices or in micro-sprinklers under trees. After hatching, the larvae drop, burrow into the soil and feed on citrus roots. Adults emerge from the soil mostly between February and May (Table 6), but can be found all year round.

Figure 23. Adult Fuller’s rose weevil.

Table 6. Risk and monitoring period for Fuller’s rose weevil activity.

	Flowering		Fruit drop	Golf ball				Colour break	Maturation		
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

Habit: the adults chew leaf margins, leaving a serrated edge. Foliage near the trunk or touching the ground is most likely to be damaged.

IPM

Damage and risk period: having FRW eggs on fruit is a major quarantine pest of concern to many Asian markets. While the months just before harvest are the highest risk for FRW (Table 6), it should be managed all year round.

Monitoring: actively monitor from December to May. Shake the foliage of selected trees over a 1 m² light-coloured mat and look for any adults. Leaves showing serrated edge damage on the lower portion of trees could be a sign of adults feeding.

Threshold: FRW is not a major concern for domestic or non-quarantine export countries, but there is zero tolerance for quarantine export countries.

Natural predators: platygastrid parasitoid wasp (*Fidiobia citri*), assassin bug (*Pristhesancus* spp.), praying mantis (*Mantidae* spp.) and parasitic nematodes.

Management

Skirting trees and good weed control help to reduce pathways for the adult to move into trees.

Trunk band spraying is effective in reducing populations in conjunction with skirting and weed control. However, it can cause outbreaks of secondary pests such as mites and scale insects. Careful monitoring and early intervention of the secondary pests are recommended. Check label recommendations for trunk band spraying for weevils.

The chemical controls for FRW are listed in Table 18 on page 58. Some chemical control options are not suitable for trunk spraying; always check the label.

Orchards registered in the Korea, China and Thailand export program should obtain a copy of the *Australian citrus to Korea, China and Thailand Integrated Pest Management and packing house controls* document from the Citrus Australia website (https://citrusaustralia.com.au/latest-news/2020/04/important-information-on-export-accreditation-for-china-korea-and-thailand-2020/) and contact their packer in spring to discuss their management program.

For more detail, see Managing Fuller's rose weevil on page 39.

Katydids

Description

Size and appearance: there are several katydid species (*Caedicia* spp.), all with long antennae and large hind legs. Adults are 40–50 mm long. Nymphs resemble the adults but with shorter wings. Adult citrus katydids and inland katydids are green (Figure 24). Adult spotted katydids are olive green and brown with dark-brown markings on the wings and body.

Life cycle: one generation a year. The nymphs hatch in early spring and begin feeding on newly-set fruit from mid October to November (Table 7).

Habit: katydids live in young citrus foliage, flowers and fruit, and plants in bushland next to orchards. Adults fly from tree to tree, resulting in patchy infestations.

Table 7. Risk and monitoring period for katydid activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

IPM

Damage and risk period: katydids feed on small fruit up to 30 mm in diameter (petal fall to mid December), causing large scars on fruit (Figure 25 and Figure 26). They can also cause fruit to drop.

Monitoring: check fruit according to monitoring protocols (page 56) for signs of damage and scan the foliage for insects.

Natural predators: assassin bugs, praying mantis and birds all feed on katydids but generally do not provide effective control.

Management

There are no registered chemical controls for katydids. Discuss IPM rates and strategies with your pest consultant. Timely control is essential as small numbers of katydids can quickly cause considerable damage.

Figure 24. Adult citrus katydid.

Figure 25. Katydid damage to developing fruit.

Figure 26. Katydid damage to mature fruit.

Kelly's citrus thrips

Description

Size and appearance: adults are black (Figure 27), up to 3 mm long, with a small clear band and parallel wings. Larvae are pale yellow (Figure 27) to bright orange and up to 2 mm long. It is difficult to tell the difference between Kelly's citrus thrips (*Pezothrips kellyanus*) larvae and the larvae of non-damaging thrips (e.g. plague thrips) without a microscope. Orchard history and the presence of adult Kelly's citrus thrips (KCT) at flowering will provide valuable information about the potential risk of a KCT infestation.

Life cycle: KCT prefers to lay its eggs in citrus flowers but they can also be laid on fruit or leaves. There are 2 larval instar stages that feed on developing fruit. The second instar pupates in the upper 20 mm of soil. A generation is completed in about 2 weeks in mid summer and up to 3 months in winter.

Habit: KCT is seen in flowers from petal fall to December (Table 8). Larvae scrape the fruit rind under the calyx and where fruit touch.

Table 8. Risk and monitoring period for Kelly's citrus thrips activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

IPM

Damage and risk period: scurfing (surface wind-rub-like blemish; Figure 28) will appear around the calyx (halo scarring) or where fruit touch. The critical period for monitoring and control is petal fall (mid October) through to calyx closure (mid–late November), but damage can occur through to December.

Monitoring: inspecting flowers for adult KCT will indicate a possible problem but will not indicate the presence of their larvae. Most of the scurfing damage is caused by the larval stages during the first 4–5 weeks after petal fall. Monitor for larvae from petal fall to calyx closure and up to December.

Threshold: 5% or more of fruit infested with larvae. Use a 10× hand lens and, for monitoring purposes, all larvae should be assumed to be KCT, especially if there is a history of KCT damage.

Natural predators: predatory thrips, predatory soil mites (attack pupae), predatory bugs and spiders.

Figure 27. Kelly's citrus thrips adult (black) and various larval stages. Photo: South Australian Research and Development Institute (SARDI).

Management

The key spray period is after petal fall and before calyx closure (3–4 week window). Several insecticides are registered for thrips control (Table 18 on page 58), but they have varying degrees of efficacy and effects on beneficial insects. Excessive use of organophosphate (e.g. chlorpyrifos) insecticides could exacerbate thrips problems because the chemicals interfere with predatory mites in the soil. There have also been reports of thrips resistance to organophosphates. Talk to your pest consultant about insecticide options.

Figure 28. The scurfing blemish left by Kelly's citrus thrips.

Light brown apple moth

Description

Size and appearance: young larvae (caterpillars) are pale yellow–green, and mature larvae are pale green and grow up to 18 mm long. Eggs are pale green and laid in flat, overlapping masses up to 12 mm long. Pupae are red–brown and 10–12 mm long. Adult light brown apple moths (*Epiphyas postvittana*) are up to 12 mm long, light brown and bell-shaped (difficult to see in the orchard).

Life cycle: after hatching, the larvae pass through 6 stages before pupating.

Habit: leaves are the preferred egg-laying site in citrus, although eggs can be found on fruit and young stems. Larvae of all ages construct silken shelters at the feeding site (Figure 29 and Figure 30). When disturbed, the larvae will wriggle vigorously backwards. Larvae can also be found on fallen fruit and some broadleaf weeds.

Figure 29. A mature light brown apple moth larva on a leaf with webbing. Inset: an early instar on a young fruit with calyx removed.

Figure 30. Light brown apple moth damage to a fruitlet.

Figure 31. Halo scarring from light brown apple moth damage.

IPM

Damage and risk period: light brown apple moth (LBAM) is a cool-climate pest, more commonly found in spring (Table 9) and occasionally in early autumn and winter. Halo scarring (Figure 31) in small fruit can appear in spring and winter. Larvae can bore into mature fruit.

Monitoring: check fruit according to monitoring protocols (page 56) for signs of damage. Use pheromone traps to monitor moth flights to better time control sprays.

Natural predators: *Trichogramma* wasps parasitise moth eggs; other parasitic wasps and flies parasitise moth larvae. Important predators include the predatory bug, *Oechalia shellenbergii*, lacewing larvae and spiders. Nuclear polyhedrosis virus (NPV) can also infect larvae, which are susceptible to the bacterial pathogen *Bacillus thuringiensis* (Bt).

Management

In most situations, LBAM is kept under natural control and does not require chemical intervention. Commercial pheromone mating-disruption products are available for area-wide LBAM management (see Table 18 on page 58).

Table 9. Risk and monitoring period for light brown apple moth activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
		High risk						Moderate risk			

Long-tailed mealybug

Description

Size and appearance: adult long-tailed mealybugs (*Pseudococcus longispinus*) are 3–4 mm long with a mealy wax cover and long tail filaments that are as long as, or longer than, the body (Figure 32). When squashed, the body fluids are pale yellow.

Life cycle: there are 3–4 generations a year. Each female produces around 200 live young that she deposits under her body over 2–3 weeks.

Habit: spring generations settle onto fruit in late November and early December (Table 10). They generally settle in sheltered sites such as the fruit calyx or inside the navel (Figure 33) and between touching fruit and leaves. Mealybugs can overwinter as adults.

Figure 32. Mature long-tailed mealybug. Photo: QLD Government's Department of Agriculture and Fisheries.

Figure 33. Long-tailed mealybugs on a Navel orange.

Table 10. Risk and monitoring period for long-tailed mealybug activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

IPM

Damage and risk period: long-tailed mealybug is a quarantine pest of concern for some export markets and it also causes sooty mould (Figure 34), which downgrades fruit.

Monitoring: check fruit according to monitoring protocols (page 56) for signs of infestation.

Threshold: 10% of fruit infested, but lower for export markets where mealybug is a pest of concern.

Natural predators: parasitic wasps, lady beetles and lacewings.

Management

Controlling moderate spring infestations might not be warranted because heat, parasitism and predation can significantly reduce numbers over summer. Late February is a key time to assess mealybug numbers and parasitism.

Insecticide mixed with oil can provide effective control in medium level infestations (see Table 18 on page 58). Discuss IPM rates and strategies with your pest consultant.

Figure 34. Sooty mould caused by long-tailed mealybugs.

Queensland fruit fly

Description

Figure 35. Dorsal view of adult Queensland fruit fly.

Size and appearance: adult Queensland fruit fly (QFF) are about 6–8 mm long and reddish-brown with yellow markings (Figure 35). QFF are most active in warm humid conditions and after rain. Adult flies might be seen walking on the undersides of leaves or on maturing fruit, but will readily take flight if disturbed.

Life cycle: in early spring, over-wintering adult flies become active and the females lay eggs in suitably mature fruit. Eggs hatch in about 2 days and larvae develop in the fruit. The larvae leave the fruit in 7 days (summer) to 40 (winter) days and pupate in the soil. Pupation lasts for about 10–20 days and then adults emerge. The female fly actively feeds on protein and can lay eggs after 7–10 days. A life cycle in summer is 30–35 days.

Habit: adults are active when temperatures are above 17 °C. They often do not fly more than 500 m from their pupation site.

IPM

Damage and risk period: although green immature fruit can be stung, fruit from the early stages of maturation (colouring) up to harvest are most likely to be damaged (Table 11). Valencias are higher risk than Navels because fruit maturation occurs in the warmer months (spring and summer) when fruit flies are most active.

Table 11. Risk and monitoring period for Queensland fruit fly activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

Monitoring: hang male lure traps at head height on a 400 m grid or every 10–20 ha. Target higher risk areas such as fruit trees around buildings and gardens. Sometimes neighbouring properties can be high-risk areas, so monitoring boundaries with traps is good practice. Male lure traps attract flies from a greater distance (>100 m downwind) than female traps (10 m).

Monitor traps weekly from November to May and fortnightly from June to October. When doing so, empty the traps and record the number of QFF.

Threshold: observing data trends is important. One sporadic male fly might be a solitary traveller; be alert to spray bait in high-risk areas. Multiple male flies can indicate a local problem. An orchard-wide baiting program might be required.

Natural predators: QFF is susceptible to several natural predators including parasitic braconid wasps and assassin bugs. These predators will have some effect on established local QFF populations, but they are unlikely to significantly reduce QFF spread.

Management

Queensland fruit fly is best controlled with an integrated management strategy. See page 44 for more information on QFF and Table 18 on page 58 for control options.

Monitor and apply protein bait sprays and remove all mature fruit from trees. Male lure traps placed at monitoring densities do not control QFF, but they do indicate population trends. Protein bait sprays should be used to control QFF.

Relying on broad-spectrum systemic insecticides after much of the fruit is stung or dropping can result in economic loss as a secondary pest flare-up usually occurs after the spray is applied.

Red scale

Description

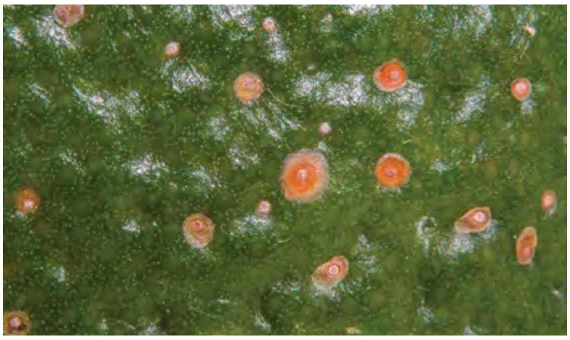

Figure 36. Various stages of red scale.

Size and appearance: the first stage starts as yellow crawlers, then whitecaps before turning reddish–brown and growing to 0.5–2.0 mm in diameter (Figure 36). Females are round and males are elongated. Adult males are yellow and have wings.

Life cycle: 2–5 generations a year in NSW.

Habit: red scale (*Aonidiella aurantii*) is usually immobile in trees except when crawlers hatch and winged adults emerge.

IPM

Damage and risk period: heavy infestations cause leaf drop and twig dieback. Scale downgrades fruit and is a quarantine pest of concern for Korean markets.

Monitoring: check fruit according to monitoring protocols (page 56) for scale from November to December (Table 12), then monthly until harvest. Before spraying, randomly collect 20 fruit from each block and examine the relatively large mature female scales for parasitism. Discuss IPM rates and strategies with your pest consultant.

Table 12. Risk and monitoring period for red scale activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

Traps: place one pheromone trap in each hectare block. Change the traps weekly and the pheromone lures every 4 weeks. The first post-winter peak of male flights will indicate when to spray the crawlers, which peak about 4–8 weeks after this first flight.

Threshold: usually 10–15% of red scale infested fruit, but lower thresholds can apply to quarantine export markets. Good parasitism levels should reduce the need for chemical sprays.

Natural predators: the most common are lacewing larvae and scale-eating lady beetles. The most common parasites are the *Aphytis* wasp and *Comperiella bifasciata* wasp (Figure 37). *Aphytis* wasps prefer to parasitise second instar scales; up to 80% of female scales can be parasitised.

Management

Figure 37. Adult *Comperiella* parasitic wasp. Photo: QLD Government's Department of Agriculture and Fisheries (QDAF).

Applying horticultural mineral oil (HMO) at high volumes is effective against red scale and relatively harmless to beneficial insects. HMO sprays are more effective against young scales (crawlers and whitecaps). Spraying when young scales are abundant achieves better control. Spraying HMO after February can affect colouring on Navel oranges and some mandarins.

HMO requires high volume application (e.g. medium-sized trees might need 5,000–8,000 L/ha). Medium-volume spray machines (i.e. air-blast) might not provide satisfactory results. Other chemical options (see Table 18 on page 58) could be applied with a medium-volume spray machine.

Early season (December) control is applied in high infestations or sites with a history of recurring scale. If red scale infestation is present and parasitism is low between October and March, consider releasing *Aphytis* wasps.

Soft brown scale

Description

Size and appearance: soft brown scales (*Coccus hesperidum*) are flat, oval, 3–4 mm long, yellow–green or yellow–brown (Figure 38) and often mottled with brown spots. Female scales darken with age.

Life cycle: there are 3–4 generations a year in the southern regions. One generation takes approximately 2 months in summer. Females can reproduce without mating, giving birth to around 200 live crawlers. Crawlers have functional legs and can move around until they are half-grown, then settle onto fruit and remain sedentary for the rest of their life.

Habit: soft brown scales are found on leaves, twigs (Figure 39) and occasionally fruit. Most infestations are found in young or recently reworked trees.

Figure 38. Mature soft brown scale.

Figure 39. Soft brown scale can infect entire shoots.

IPM

Damage and risk period: soft brown scale causes sooty mould, which downgrades fruit. Monitor trees in early summer and autumn (Table 13). Focus monitoring on boundary rows (dusty trees), young trees and recently reworked trees.

Monitoring: check fruit according to monitoring protocols (page 56) for signs of damage.

Threshold: 15% or more of green twigs infested.

Natural predators: numerous parasitic wasps.

Table 13. Risk and monitoring period for soft brown scale activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

Management

Horticultural mineral oil generally provides adequate control. Ant activity can exacerbate the problem and should therefore be controlled. See Table 18 on page 58 for control options.

Spined citrus bug

Description

Size and appearance: spined citrus bug eggs are laid in rafts on leaves, fruit or twigs. They are initially white, but become mottled with black and red as they develop. Early-stage nymphs (stages I–III) are marked with black, green, yellow, white and orange spots. Late-stage nymphs (stages IV–V) are mainly green with black markings (Figure 40). Adults are green, 15–20 mm long and have a prominent spine on each shoulder (Figure 41).

Life cycle: there are 3 generations a year. Each generation consists of an egg stage, 5 nymphal stages and an adult stage.

Habit: spined citrus bugs (*Biprorulus bibax*; SCB) mainly attack lemons and some mandarin varieties, but grapefruit and oranges can be affected. Both adults and nymphs tend to congregate in clumps. Adult males produce an aggregation pheromone to attract other males and females to new sites. Adults aggregate over winter in non-lemon citrus that are near lemons.

Figure 40. Spined citrus bug nymphs at various stages.

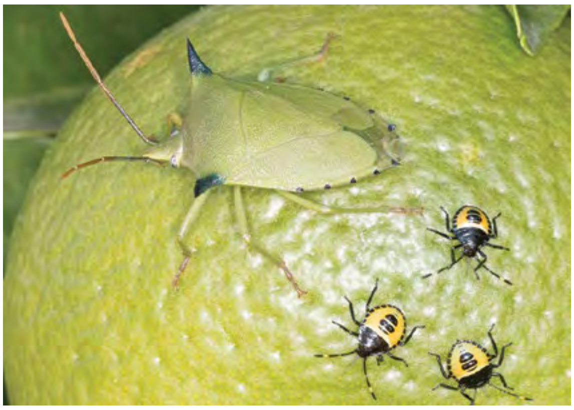

Figure 41. Spined citrus bug adult and nymphs.

IPM

Damage and risk period: November to harvest (Table 14). Adults and nymphs feed on fruit by sucking, causing rind lesions, dried out fruit segments and fruit drop.

Table 14. Risk and monitoring period for spined citrus bug activity.

	Flowering		Fruit drop		Golf ball			Colour break		Maturation	
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul

Monitoring: monitor fortnightly from September to May. Check fruit according to monitoring protocols (page 56) for damage. Collect and rear eggs to hatching to check for parasitism.

Threshold: 10% or more trees infested with one or more bugs in susceptible varieties.

Natural predators: SCB eggs are predated on by many parasitic wasps, with *Anastatus biproruli*, *Trisulcus oenone* and *T. agyges* being the primary parasitoid species. Nymphs and adults can be attacked by spiders, predatory bugs, praying mantis, assassin bug and numerous predatory wasps.

Management

Regular monitoring and prompt control are important because populations can increase rapidly and cause substantial damage. Spot-spraying trees with overwintering clusters of adult bugs is a good practice to reduce local SCB populations.

Work with your pest consultant to discuss IPM rates with selected insecticides to provide good control (see Table 18 on page 58).

Further reading on insect pests

Smith D, Beattie GAC and Broadley R (eds) (1997) '*Citrus pests and their natural predators: integrated pest management in Australia*', Department of Primary Industries, Queensland.

Citrus gall wasp: future population trends

Jianhua Mo, NSW DPIRD

Since its first detection in the early 2000s, the citrus gall wasp (CGW) has spread rapidly throughout the southern citrus production regions. In some places, the infestation level appears to be steadily rising, with no signs of easing. What is the future of CGW infestation in the southern regions – will it continue to rise, or will it decrease after some time? To answer the question, a preliminary model to predict future CGW population trends was developed. The model included the effect of CGW's primary parasitoid species, *Megastigmus brevivalvus*, on CGW populations. Where available, published and unpublished data were used to estimate the model parameters, including the fecundity and sex ratio of CGW and *M. brevivalvus*, and the natural mortality of CGW. Model parameters for which no data (published or unpublished) for estimation were tested as scenarios.

The model produces a variety of future CGW population trends in the absence of any human interventions. Without the parasitoid, the CGW population is predicted to steadily increase until it reaches a maximal level. With the parasitoid, the population is predicted to drop before stabilising or undergoing cyclic fluctuations. Figure 42 shows future trends of the CGW population and parasitism rate in 4 scenarios. The scenarios were separated mainly by the host-searching strategy of the parasitoid, with a more concentrated search leading to a more stabilised trend but higher overall populations after the initial rapid growth phase.

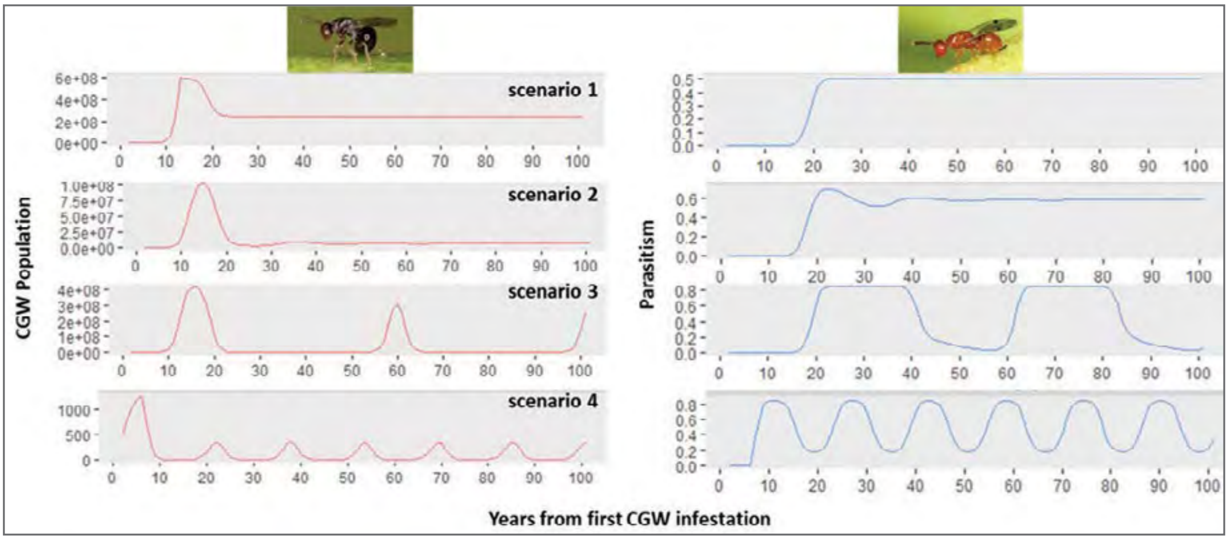

Figure 42. Four predicted citrus gall wasp population trends: 1, population peaks and then stabilises at a moderate level; 2, population peaks and then stabilises at a low level; 3, population peaks and then fluctuates with large infrequent peaks; and 4, population peaks and then fluctuates with frequent small peaks.

The duration of the first CGW population peak and the number of years it takes for the CGW population to stabilise after the initial peak increase with the time lag between the first arrivals of the CGW and the parasitoid (Figure 43). It appears that in most southern regions, CGW populations are still in the initial increasing phase.

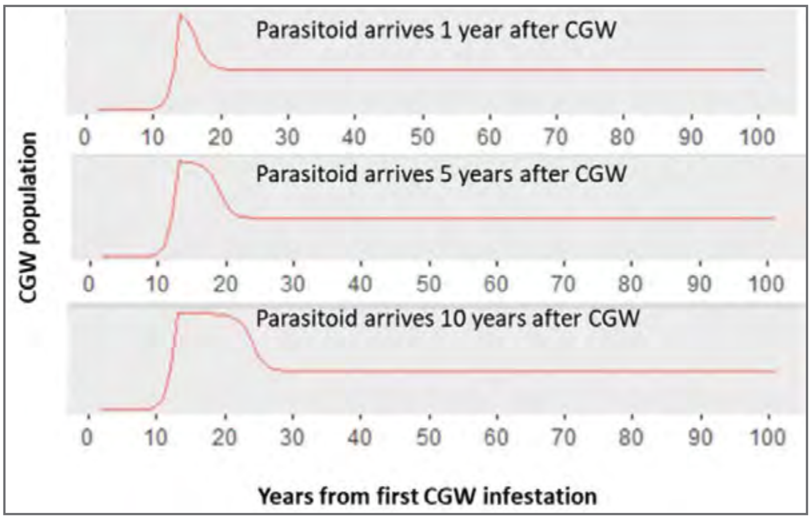

Figure 43. Three predicted citrus gall wasp population trends assuming the parasitoid arrives 1, 5, and 10 years after the first citrus gall wasp infestation.

The results confirm the importance of parasitoids. Unlike chemical interventions, the parasitoid population increases as the CGW population increases. As a result, it can change the CGW population trends and limit the infestation level. One interesting finding of the model is that once the parasitoid population has built up sufficient numbers, further parasitoid releases are unnecessary.

The preliminary model is based on our current knowledge of CGW and *M. brevivalvus*. A PhD study is underway to improve our understanding of their biology and ecology. The new knowledge will be used to update model parameters and improve model accuracy. The updated model will be used to compare the efficiency of different CGW control strategies, including releases of parasitic wasps, pruning, applications of systemic and foliar insecticides, and control thresholds.

A quick way to rate citrus gall wasp infestation in the orchard

Have you ever wondered how severe the gall wasp infestation is in your orchard? If so, here is a simple and easy way to rate the severity. Randomly select 50 or more galls and count how many are 50 mm or longer. If there is fewer than 3%, the infestation rate is low. If the percentage is over 25%, the infestation rate is high; between 3% and 25%, the infestation can be rated as low, moderate, or high, depending on its exact value. A 'rule of thumb' is that if the percentage is much closer to 3% than to 25%, rate the infestation as moderately low. If the percentage is much closer to 25% than 3%, rate the infestation as moderately high. If the percentage is neither close to 3% nor 25%, rate the infestation as moderate. These ratings are summarised in Table 15.

Table 15. Rating the infestation level of citrus gall wasp.

Percentage of galls 50 mm or longer					
Gall size category	≤3%	3–25%			≥25%
		Closer to 3%	Close to neither	Closer to 25%	
Infestation rating	Low	Moderately low	Moderate	Moderately high	High

To minimise human bias in selecting galls to measure and count, select galls by branch, e.g. randomly selecting terminal branches and measuring and counting all galls, big or small, in selected branches. More galls will give more reliable ratings.

The above rating method was based on gall size distribution data collected in the southern citrus regions from 2015 to 2018. Other gall size categories (other than 50 mm or longer galls used here) can also be used to rate the infestation level. For those interested in using other or multiple gall size categories to rate the infestation level, Figure 44 shows the relationship between gall size and the percentage of galls longer than in low, moderate and high infestations.

Acknowledgement

This project has been funded by Hort Innovation, using the citrus research and development levy, contributions from the Australian Government and co-investment from NSW DPIRD. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

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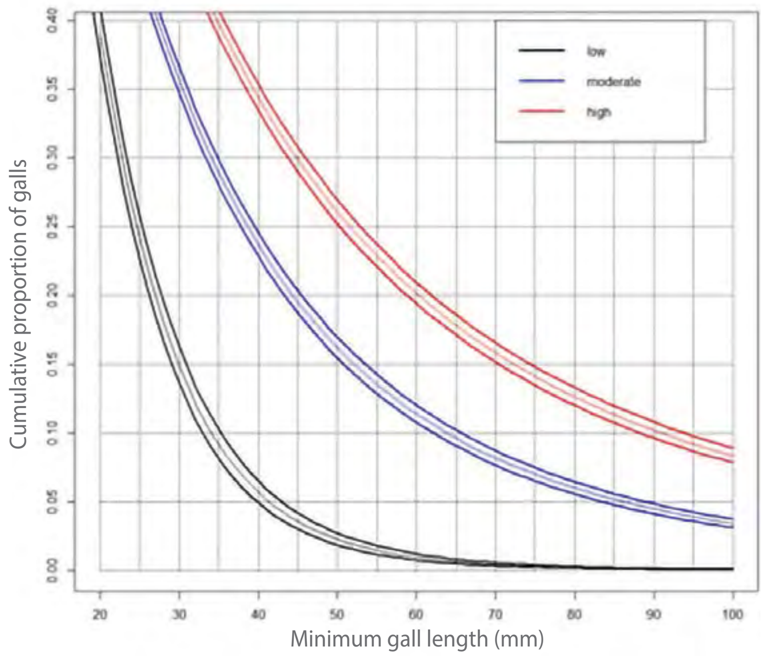

Figure 44. The relationship between gall length and the cumulative proportion of galls above that length for low (black), moderate (blue), and high infestations (red). Lines on either side of the central lines indicate a 95% confidence interval.

Managing Fuller's rose weevil

Jianhua Mo and Steven Falivene, NSW DPIRD

Description and life cycle

Fuller's rose weevils (FRW) are native to South America but are present in most citrus-growing areas of the world including Australia. Adults are flightless, grey–brown and about 8 mm long (Figure 45). They emerge from the soil, mostly from late January to mid April, although isolated emergence can occur in other months. They are long-lived; some live for more than 210 days, thus weevils found in citrus canopies at any time are a mixture of those that emerged from the previous and current years. Adult weevils are more easily found from February to August.

Emerged adults climb trees via trunks, weeds and low-hanging foliage touching the ground. The adults feed on citrus leaves, chewing along leaf margins, leaving a serrated edge (Figure 46). Foliage near the trunk or touching the ground is most likely to be damaged.

All weevils are females and they reproduce asexually. Eggs are laid in clusters of 20–30 glued together in yellowish, papery masses under fruit calyces (Figure 47) or in bark crevices or micro-sprinklers. After hatching, the larvae drop to the soil and feed on citrus roots. Mature larvae are legless, yellow and about 6 mm long. Adults emerge 7–9 months after the larval and pupal stages in the soil.

Figure 45. An adult Fuller's rose weevil.

Figure 46. Serrated leaves can indicate Fuller's rose weevil activity.

Figure 47. An egg mass (yellow circle) protruding from under the calyx of a Navel orange.

Damage

Feeding by either the adults or larvae does not cause economic damage. However, eggs under the fruit calyx are unacceptable in several export markets for Australian oranges.

Monitoring

Medium to high FRW infestations are easily identifiable by a large number of leaves with serrated margins. Detect all levels of infestations by shaking branches over a light-coloured mat (Figure 48). This will dislodge the adult weevils, which then fall and are easily seen against the mat (Figure 49).

Detect FRW eggs by removing fruit calyces and looking for papery masses underneath, although it is easier and more effective to detect FRW by looking for adults. A detailed monitoring procedure for quarantine export markets is outlined in the *Australian citrus to Korea, China and Thailand integrated pest management and packing house controls* (https://citrusaustralia.com.au/latest-news/2020/04/important-information-on-export-accreditation-for-china-korea-and-thailand-2020/) document from the Citrus Australia website.

Control

Controlling FRW requires a multi-strategy approach based on orchard hygiene, skirting and weed control as well as chemical control. FRW control is mandatory for quarantine-sensitive export markets. Some markets demand zero detection during monitoring.

Figure 48. A Fuller's rose weevil monitoring mat. A length of electrical conduit is placed into a sleeve on either end of the shade cloth mat to make it easier to place it under the tree.

Figure 49. Fuller's rose weevil adults are easily seen against the lighter background; the match head provides a scale.

Orchard hygiene

Both people and equipment can carry adult FRW into orchards. Orchards with none or negligible FRW need to minimise the risk of new incursions. One way to minimise this risk is to have pickers working in low-infestation blocks in the morning and high-infestation blocks in the afternoon. It is important that pickers shake out their picking bags before moving between orchards (Figure 50).

Skirting and weed control

FRW need something to climb to access citrus foliage in the canopies. Skirting trees and controlling weeds reduces the pathways to tree canopies, forcing the weevils to spend more time on the ground. This also makes them more vulnerable to predation by ants and birds.

Skirting and weed control are essential when using trunk band sprays because they make the FRW move over the insecticide-treated trunks. Mechanical skirting machines, either light gauge skirters (Figure 51) that can quickly and regularly trim new foliage (i.e. 3–4 times a year) or heavy duty blade skirters that make a single cut each year, can be used.

Figure 50. Shaking bags before entering a Fuller's rose weevil-free orchard can reduce the risk of infestation.

Figure 51. A light gauge skirting bar used to trim the canopy regularly throughout the season.

Chemical control

Trunk band spraying

Trunk band spraying (TBS) is spraying the trunk of the tree with a residual insecticide. When adult FRW crawl over the trunk to enter the canopy, they will come in contact with the insecticide and die. The registered insecticides for TBS are listed in Table 18 on page 58. Some chemical control options are not suitable for trunk spraying; always check the label. The cost per hectare varies considerably.

It is important to start the FRW control program in early December because FRW eggs laid in a fruit calyx in December will hatch before harvest. If the hatched eggs are detected at an export market inspection point, their presence could be interpreted as confirming their existence in the orchard. This could result in the fruit shipment being rejected.

Therefore, where there is pest pressure, re-application is required for continuous control.

In orchards with low FRW populations, TBS is only applied when detection occurs or as a preventative during peak emergence (e.g. 2 sprays, mid January and late February).

Continuously using TBS can induce secondary pest infestations (i.e. red scale, mites and mealybug), so limiting its use is advisable. However, the complete spray program from December to near harvest is essential in orchards with regularly detectable levels of FRW; secondary pests will need active management.

There are many types of TBS machines, most are made by growers (Figure 52). A series of videos on the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/insects-diseases-disorders-and-biosecurity/insect-pest-factsheets/frwtbs-videos) provides an overview of some of these machines.

The most novel machine presented in the videos is a double-sided TBS machine that can spray both sides of the tree with one pass (Figure 53).

The correct pressure and spray angle must be used so fruit are not contaminated with spray residue. Using kaolin clay is essential to enable the operator to check coverage and assess off-target issues (Figure 54).

Foliar sprays

Cyantraniliprole (e.g. Exirel®) was registered in August 2017 as a foliar insecticide for suppressing FRW. It is a Group 28 insecticide (different from other currently registered insecticides in citrus). The insecticide enters insects primarily by ingestion. Rapid feeding cessation usually sets in within a few hours of exposure. Field trials indicate it could be used to replace some or all trunk band spraying applications. Check with your packing shed manager to ensure chemical residues are within targeted export maximum residue limits (MRL).

Figure 52. A grower-built trunk band spraying rig.

Figure 53. A double-sided trunk band spraying rig that can spray both sides of the tree with one pass.

Figure 54. Kaolin clay is added to the insecticide mixture for coverage and overspray inspection.

Managing Queensland fruit fly

Steven Falivene, NSW DPIRD

Introduction

Fruit flies are a significant threat to horticulture, having the potential to affect how Australia trades competitively in international markets. Effectively managing Queensland fruit fly (QFF) ensures producers can develop, maintain and enhance domestic and international market access.

Queensland fruit fly (*Bactrocera tryroni,* Figure 55) is a serious pest of most fruit in Queensland and parts of NSW. It prefers humid conditions but can also survive in the drier urban and irrigated areas of south-western NSW. Having suitable hosts and habitat in urban and horticultural production areas has enabled QFF to expand its natural range.

Although citrus is not the most favourable host for QFF because of its thick skin and rind oil, most citrus varieties can be attacked. Some varieties are more attractive than others, especially Meyer lemon, grapefruit and early and late mandarins. Valencia oranges (Figure 56) and grapefruit that are held on the tree over summer have the highest risk, as that is when QFF is most active. Although Navel oranges are harvested in winter when QFF activity is low, daytime temperatures can be sufficient (>17 °C) to facilitate some QFF activity. Navel fruit have been infested with QFF during winter.

Citrus is most at risk when fruit starts to mature (i.e. from colour break). Immature green fruit are not a preferable host, however, they can be stung and become a breeding site for QFF. Fruit that has been stung might fall off the tree before harvest. If there are no other suitable hosts and fly populations are high, or fruit with thin skins or previous damage (e.g. splitting, hail damage) are available, fruit fly damage is more likely.

Figure 55. Queensland fruit fly on citrus.

Queensland fruit fly severity is highly variable; some orchards require continuous action (i.e. those close to infested towns or neighbours with unmanaged fruit trees) while others require action only when incursions occur (i.e. isolated blocks or districts).

Effective orchard quarantine practices that prohibit fruit from being moved into the orchard are important. Once established in an orchard, QFF slowly move out to surrounding areas. However, QFF is generally a localised orchard problem, with research showing that fruit flies only move several hundred metres in their lifetime. When orchards are actively managed for QFF, numbers can be reduced. Where QFF is not managed, it will continue to be a problem.

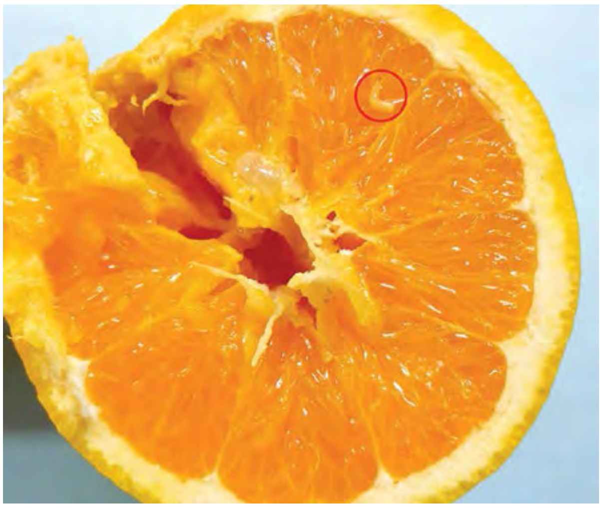

Figure 56. An orange with signs of Queensland fruit fly attack and a larva (in red circle).

Management must be appropriate for site conditions. The key to managing QFF is to monitor and, if threshold levels are exceeded, immediately start control measures.

In addition to the direct damage QFF can cause to fruit, an infestation can have serious implications for moving fruit within and between states, as well as for export. A QFF detected at a quarantine-sensitive market can quickly shut down trade and affect fruit prices.

Description and life cycle

Adult QFF are about 6–8 mm long and reddish-brown with yellow markings (Figure 57). It has slightly different markings from the Newman fly and Island fly (Figure 58 and Figure 59).

Queensland fruit fly is also different from the small dark brown *Drosophila* flies (also called vinegar or ferment flies) that loiter around ripe and decaying fruit. While *Drosophila* flies can be a nuisance where fruit and vegetables are stored, they are not considered to be an agricultural pest.

QFF overwinter mostly as adults, sheltering in protected locations, such as near houses and sheds. It is the overwintering population that starts the next generation. In early spring, they become active and the females lay eggs in suitably mature fruit . Larvae develop in the fruit and the fruit fly population continues to build up as more fruit becomes available for infestation. By late summer to autumn, fruit fly populations can be sufficient to readily infest any suitable unprotected fruit until cold weather comes in late autumn.

The female lays several hundred eggs during her lifetime. She lays about 6 eggs at a time, 3 mm deep in the fruit. In 2 or 3 days, tiny larvae (maggots) hatch from the eggs and burrow towards the centre of the fruit. The larvae develop through 3 stages and are about 6–8 mm long and yellowish when fully grown (Figure 61). When fully fed, the larva pupates (Figure 62), usually in the soil beneath the tree.

The larval and pupal stages each take from 9 days to several weeks, depending on temperature. At least 7 days elapse before the newly emerged adult female lays eggs.

The adults can live for many weeks and the females continue to lay eggs. There can be 5 or more overlapping generations during spring, summer and autumn. Fruit flies are most active in the early morning and late afternoon, resting in shaded spots during the hottest part of the day.

Figure 57. Queensland fruit fly (*Bactrocera tryoni*) has horizontal 'GT' stripes (blue circle), a yellow band on the abdomen and clear wings.

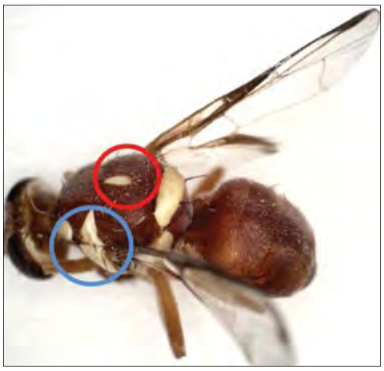

Figure 58. Newman fly (*Zeugodacus* spp. Perkins) has vertical 'tiger' stripes (blue circle) on its side and a yellow teardrop dot on the back (red circle).

Figure 59. Island fly (*Dirioxa pornia* Walker) has wings that are distinctly mottled black. It is mainly found in female traps.

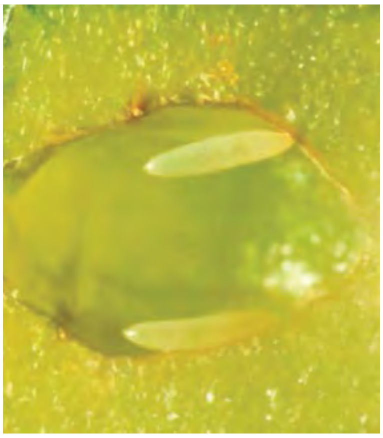

Figure 60. Queensland fruit fly eggs (about 1 mm).

Figure 61. Queensland fruit fly larvae (6–8 mm).

Figure 62. Queensland fruit fly pupae (6–8 mm).

Fruit fly stings

Fruit is most susceptible from the start of colour break (April to May). Active management throughout the season ensures low fruit fly numbers at high risk periods. Over-ripe fruit (i.e. missed during harvest) is highly susceptible.

The egg-site punctures in the fruit are commonly referred to as 'stings' (Figure 63). To identify them, make a shallow cut through the skin and look with a hand lens for the egg cavity containing eggs or the remains of hatched eggs. Eggs are small (about 1 mm), white and slightly banana-shaped. The sting mark might be a brown depressed spot, or have only a vague, bruised appearance; on green citrus fruit, the skin can colour prematurely around the sting site.

Damage to fruit

Fruit infested with QFF larvae usually fall from the tree. Damage by larvae tunnelling in the fruit varies with the type and maturity of the fruit, the number of larvae in it, and the weather. Often citrus fruits, although stung, do not develop larvae, but the stung fruit sometimes fall. Larvae can successfully develop in most citrus varieties including fruit on *Citrus trifoliata* (syn. *Poncirus trifoliata*) rootstock.

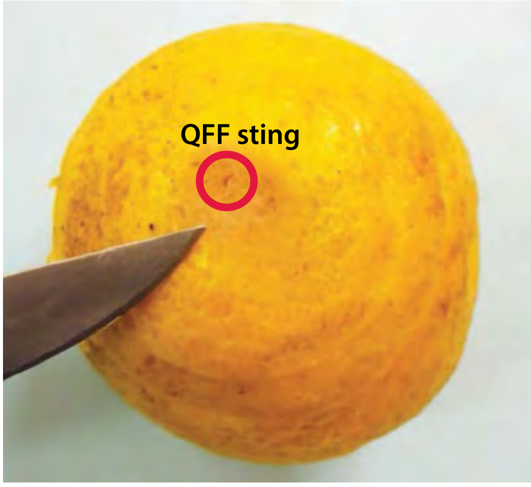

Figure 63. Fruit stung by Queensland fruit fly often get secondary fungal infections such as sour rot, brown rot or blue and green moulds.

Queensland fruit fly control

Queensland fruit fly is primarily spread to new areas by being carried in infested host fruit and vegetables. The first step in controlling QFF is monitoring, and if any are discovered, immediately implement the appropriate control procedures and ensure appropriate orchard hygiene.

In districts where QFF occurs, harvest fruit as early as possible. Fruit fly populations increase as the season advances and temperatures increase. As the fruit ripens it becomes more attractive to the egg-laying females. Do not send damaged or fallen fruit to the packing shed; dispose of reject fruit properly.

There are several chemicals registered for controlling QFF in citrus (see Table 18 on page 58). For more information on registered chemicals or chemical permits, visit the APVMA website (https://portal.apvma.gov.au/) or contact your local chemical services provider or agricultural advisor.

Monitoring

Monitor fruit fly populations with traps and check these regularly. Trap data will indicate fruit fly population trends in the orchard, can guide the protein bait spraying program and can indicate the baiting's effectiveness. Fruit should still be routinely checked for fruit fly damage.

The current recommendation is for one trap to be placed every 10–20 ha (about 300–450 m apart). A higher density will improve detection and identify problem areas but will also increase the time taken to monitor traps.

One male fly in a trap might just be a wind-blown traveller, but it is a good prompt to be ready to respond. If more than one male fly is found, this could indicate a local problem and a bait spraying program might be required. Try to identify the source by installing additional traps (i.e. at the corners of the orchard) and look for alternative hosts (e.g. tomatoes, peaches, figs and loquats).

Orchard management

The best long-term results are achieved when neighbours work together to implement an area-wide coordinated control program. Explain the situation and perhaps offer to remove trees and provide and plant alternative trees. Fruit fly exclusion netting works well for home orchards and gardens.

A combination of male lure traps and female-based protein traps could be appropriate. This might be an option for high-risk areas of the orchard (e.g. near a neighbouring unmanaged backyard tree).

If the block becomes heavily infested, refer to the APVMA website (https://portal.apvma.gov.au/) for treatment options, but discuss treatment plans with your packing shed manager before application; a cover spray on mandarins might disqualify a postharvest treatment. Always follow label directions and be aware that overseas maximum residue levels (MRLs) could differ from Australian MRLs.

Orchard hygiene

Orchard cleanliness is an essential component of managing QFF. As QFF has a wide host plant range, all fruit trees near the orchard, including those in back gardens and near sheds, must also be managed for fruit fly. Feral and neglected fruit trees should be removed and fallen or infested fruit should be destroyed. Ensure:

- unwanted fruit trees from around sheds, houses and along boundary fences are removed
- QFF in all other host plants is controlled
- all late hanging fruit missed during harvest is removed
- all fallen fruit is picked up and properly disposed of; do not send damaged or fallen fruit to the packing shed
- good orchard hygiene is maintained.

Bait spraying

Only apply 15–20 L of bait spray per hectare (follow label recommendations) and treat both sides of every second row. The bait and insecticide can be purchased separately and mixed, or pre-mixed solutions are available. A thickening agent will improve the bait's effectiveness. Follow label recommendations.

By setting up a special rig on a quad bike (see Figure 64), 1 ha of orchard could be treated in 10–15 minutes. Weekly sprays are required to control low-pressure infestations, while heavy infestations can require 2 sprays a week. Baits might need to be re-applied after rain.

Figure 64. A quad bike towing a Queensland fruit fly spraying rig used by 2PH farms (Emerald). This rig enables higher water volumes to be carried than if using the bike without the tank.

Females can lay eggs 7 days after emerging from the soil, so weekly spraying is important to eliminate new hatchings.

Resources

Monitoring and baiting

Bugs for bugs (www.bugsforbugs.com.au/whats-your-pest/fruit-flies/)

NSW DPIRD Queensland fruit fly website (www.dpi.nsw.gov.au/biosecurity/insect-pests/qff)

Fruit fly programs

Plant Health Australia (https://www.planthealthaustralia.com.au/national-programs/fruit-fly/)

Sunraysia Pest-free area website (www.pestfreearea.com.au/)

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An international effort to tackle Huanglongbing

Jianhua Mo, NSW DPIRD

Huanglongbing (HLB, also known as citrus greening) is an incurable disease of citrus. Infected trees gradually lose productivity and eventually die (Figure 65). HLB is caused by phloem-limiting bacteria, which are vectored by psyllids. In the Americas, Asia, and Oceania, the main vector is the Asian citrus psyllid (ACP; Figure 66). Both HLB and ACP are found in the Americas and Asia, including Indonesia, and in some parts of Oceania, including Papua New Guinea. It has recently decimated the Floridan citrus industry. Considering the devastating impact of the disease and the proximity of its current distribution, HLB and ACP are ranked as the number one biosecurity threat for the Australia citrus industry.

Figure 65. An HLB-infected citrus tree showing advanced dieback symptoms.

A tri-nation project funded by the Australian Centre for International Agricultural Research (ACIAR) is currently underway to improve how HLB is managed in Indonesia and enhance Australia's preparedness for the disease. The project is being led by the NSW Department of Primary Industries and Regional Development (NSW DPIRD), with collaborators from the Universitas Gadjah Mada (UGM) in Indonesia, the Chinese Citrus Research Institute (CRIC), and Citrus Australia Ltd (CAL). The key objectives of the project are to:

- improve our understanding of HLB and ACP and how they are managed in Indonesian and Australian citrus industries
- develop new management techniques based on using HLB-tolerant-rootstocks, high-density planting, ACP repellents, new ACP traps and lures, and inter-cropping.

Figure 66. An adult Asian citrus psyllid. Photo: Jeffrey W Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org.

The first workshop was held in Indonesia in February 2023. Project teams from Indonesia, Australia, and China and 2 international experts gathered to update Indonesia's citrus growers and pest and disease consultants on the latest HLB and ACP research findings and management practices (Figure 67). Presentations covered a range of topics including the global perspective of HLB and ACP; current HLB management practices; advances in Brazil, Indonesia, and China; graft transmission of the HLB pathogen; citrus germplasms in China; and HLB rootstocks and high-density plantings.

The Australian project team and the international experts visited citrus farms in 4 citrus-growing regions of Indonesia. Most growers appear to have learned to live with HLB and maintain productivity by periodically re-planting declining trees (usually less than 10 years after planting), and heavy use of insecticides (up to 30 sprays per year). As a result of such practices, the incidence of trees with HLB symptoms was low in most visited sites and ACP was difficult to find.

In addition to the workshop, smallholder citrus farmers in Indonesia were surveyed. Indonesia produces around 1.5 million tonnes of citrus from approximately 70,000 ha. Over three-quarters of citrus farms in Indonesia are small (<1 ha) and individually owned and managed. Mandarin is the most popular citrus variety. Most smallholder farmers rely on their citrus farms as their only income source. For additional income, they plant various companion crops (often vegetables and tropical fruits).

Investigation of HLB-tolerant rootstocks, high-density plantings, HLB transmission and detection, ACP repellents, and ACP traps and lures are in progress.

Figure 67. The project team and international experts at the first workshop in Indonesia.

Acknowledgement

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Asian citrus psyllid

Jianhua Mo, Mark Stevens and Nerida Donovan, NSW DPIRD

Introduction

While currently not found in Australia, the Asian citrus psyllid (ACP), *Diaphorina citri*, is a vector of the destructive citrus disease Huanglongbing (HLB, also known as citrus greening) in the Asia-Pacific region and the Americas. HLB-infected trees gradually lose productivity and eventually die (Figure 68 and Figure 69). In poorly managed orchards, trees can die within 5 years of planting.

Fruit from HLB-infected trees tend to be smaller than normal. When cut open, the fruit appears asymmetrical about the fruit axis (lopsided) and sometimes small, brownish–black aborted seeds are present. Leaves on HLB-infected trees usually have an asymmetric blotchy mottle pattern (Figure 70), which is a key field diagnostic feature.

All commercial citrus varieties are susceptible to HLB and currently there is no cure. The disease is present in many countries, including Australia's northern neighbours, Indonesia and Papua New Guinea, but is currently absent from Australia. Preventing the disease and its vector from coming into Australia and developing preparedness for any future incursions is a priority for the Australian citrus industry.

Early detection is the key to maintaining Australia's HLB-free status. Government and industry partners undertake awareness, surveillance and trapping activities across Australia to increase the chance of early detection; this will be enhanced by active participation from citrus growers and the wider community.

Identification

Adult ACP are 3–4 mm long. The forewings appear widest at the apex, with mottled brown patches (Figure 71). The eyes are red. The antennae are short and pale brown with black tips. When resting or feeding, the body of the adult and the plant surface form a roughly 45° angle (Figure 72). No other insects found in Australian citrus resemble ACP adults.

ACP nymphs are yellowish-orange and have prominent wing pads, especially in the later instars (Figure 73). They produce copious amounts of white and string-like honeydew (Figure 74) that might melt to form droplets when the temperature is above 36 °C. Honeydew might not be observed in unprotected environments due to the effects of wind and rain.

Figure 68. A huanglongbing-infected citrus tree with yellowing leaves. Photo: JM Bove, INRA Centre Des Recherches.

Figure 69. A huanglongbing-infected mandarin orchard in Bhutan showing sparse foliage and tree decline.

Figure 70. Asymmetric blotchy mottle on leaves from a huanglongbing-infected tree.

ACP eggs are approximately 0.3 mm long, elongated, almond-shaped, and tapered toward the distal end (Figure 75). They are laid in groups on young flush. Newly laid eggs are pale but then turn yellow and finally orange before hatching.

Aphids feed in groups (Figure 76 to Figure 78) on young foliage. Some aphid nymphs look superficially similar to ACP nymphs, but they do not have wing pads, nor do they produce string-like honeydew. Most aphids have a pair of upright, tube-like appendages (cornicles or siphunculi) on the back of their abdomen, while ACP nymphs do not.

Australia has many native psyllids, mostly living on native vegetation such as eucalyptus and wattle trees. These native species can be blown by the wind onto nearby citrus trees. Most native psyllids have transparent wings, in contrast to the almost opaque wings of ACP. Interestingly, one native psyllid, the spotted gum psyllid (*Eucalyptolyma maideni*) has a similar resting-feeding posture as the ACP (Figure 79). However, adults of this psyllid are bright green to yellow, in contrast to the mottled brown colour of ACP adults.

Figure 71. Asian citrus psyllid adult. Photo: David Hall, USDA Agricultural Research Service, Bugwood.org.

Figure 72. Asian citrus psyllid adult on a leaf.

Figure 73. Asian citrus psyllid nymphs have prominent wing pads. Photo: Jeffrey W Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 74. Asian citrus psyllid nymphs produce copious amounts of white string-like honeydew.

Figure 75. Asian citrus psyllid eggs. Photo: David Hall, USDA Agricultural Research Service, Bugwood.org.

Figure 76. Black citrus aphids (*Toxoptera aurant*). Photo: https://influentialpoints.com.

Figure 77. Melon aphids (*Aphis gossypii*). Photo: https://influentialpoints.com.

Figure 78. Spiraea aphids (*Aphis spiraecola*). Photo: https://influentialpoints.com.

Figure 79. Spotted gum psyllid (*Eucalyptolyma maideni*). Photo: www.bugguide.net.

Psyllids found in horticultural crops in Australia include the recently arrived tomato potato psyllid (*Bactericera cockerelli*), which is cicada-like with transparent wings (Figure 80). The adult of the Australian solanum psyllid (*Acizzia solanicola*) also has transparent wings and resembles a winged adult aphid with a prominent black head and thorax (Figure 81).

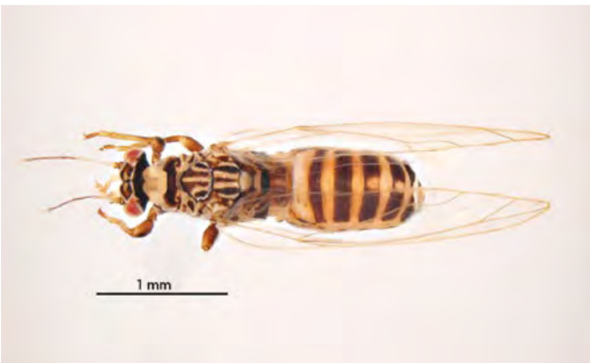

Figure 80. Tomato potato psyllid (*Bactericera cockerelli*) adult. Photo: Pest and Diseases Image Library, Bugwood.org.

Figure 81. Australian solanum psyllid (*Acizzia solanicola*). Photo: Nicholas A Martin, Plant and Food Research.

Hosts

ACP can exploit many host plants, especially species of the family Rutaceae. Among the main hosts in this family are orange jasmine *Murraya exotica* L. (a synonym for *Murraya paniculata*) and species and varieties of the genus *Citrus*. Although adults can feed on many species of Rutaceae, ACP cannot complete its development on all of them.

Distribution

According to the Invasive Species Compendium (https://www.cabi.org/isc/datasheet/18615), *Diaphorina citri* is more widely distributed than the citrus Huanglongbing (greening) bacterium *Candidatus* Liberibacter asiaticus, the major pathogen that it transmits (EPPO/CABI, 1996a). *Diaphorina citri* occurs in Afghanistan, Macau and Singapore where *Candidatus* Liberibacter asiaticus has not been recorded.

Life cycle

Asian citrus psyllid eggs hatch into nymphs, which pass through 5 instars before becoming adults (Figure 82). The total life cycle requires 15–47 days depending upon the region and season. Adults can live for several months. There is no diapause (dormancy period) and there are up to 10 generations a year, however 16 generations have been observed in field cages.

Biology and ecology

Adults start mating soon after emergence. Females lay eggs in the terminal tissue in leaf folds and on petioles, axillary buds, and the upper and lower surfaces of young leaves and tender stems. First and second instar nymphs mostly aggregate and feed inside the folded leaves, on the terminal stem and between the axillary bud and the stem of tender shoots. Young nymphs are docile and move only when disturbed or over-crowded. Adults are often found resting on the terminal portion of the plant, especially on the lower side of the leaves. When disturbed they readily take flight for a short distance. The females only lay eggs on the young and softer plant material. In the absence of suitable host tissue, egg laying ceases temporarily.

Asian citrus psyllid spreads locally by natural dispersal. Long-distance spread occurs by movement of host materials such as budwood, grafted trees and rootstock seedlings, and by the psyllid 'hitch-hiking' on harvested fruit along transport routes or on non-host materials.

Asian citrus psyllid acquires HLB during its nymphal stages and late instar nymphs and adults are capable of transmitting the disease.

Natural predators

In its native range in southern Asia, ACP is suppressed by a complex of parasitoids including *Tamarixia radiata* (Figure 83 to Figure 85) and *Diaphorencyrtus* species. *Tamarixia radiata* was introduced into Réunion Island in 1978 and later into Mauritius and provided satisfactory control of the pest and suppressed HLB transmission. Predatory lady beetles and pirate bugs are also recorded in Asia, but most of them have little effect, although *Chilocorus nigritus* is beneficial in supplementing the action of parasitoids. Several entomopathogenic fungi have been reported to infect ACP.

Figure 82. Asian citrus psyllid developmental stages. Photo: David Hall, USDA Agricultural Research Service, Bugwood.org.

Figure 83. A *Tamarixia radiata* wasp attacks an Asian citrus psyllid nymph. Photo: http://www.ucanr.org.

Figure 84. *Tamarixia radiata* male. Photo: Jeannette E Warnert, University of California.

Management

Integrated approaches combining cultural, biological and chemical options are needed to effectively and sustainably manage ACP.

In addition to using HLB-free seedlings and removing infected trees, controlling the psyllid vector is the key to effectively managing HLB.

Synthetic insecticides are the main tool for ACP control. However, frequent sprays have led to serious ACP resistance to many registered insecticides. Some alternative treatments such as mineral oils and kaolin have provided similar levels of ACP control to insecticides.

Biological control of ACP with *Tamarixia* wasps and entomopathogens has had limited success and the results have been highly variable.

Figure 85. *Tamarixia radiata* female. Photo: Jeannette E Warnert, University of California.

Integrated pest management

Andrew Creek and Jianhua Mo, NSW DPIRD

Food safety, environmental accountability and increasing insect resistance to pesticides are important issues facing modern horticultural industries. Adopting integrated pest management (IPM) addresses these issues and encourages sustainable production. IPM is based on managing the relationships between a variety of controls to manage orchard pests, beneficial insects and their environment. This involves:

- understanding pest life cycles so management options can target the most susceptible stages
- orchard hygiene practices
- removing alternative hosts for pests
- cultural controls such as slashing or seeding the inter-row to pasture, thus reducing the weed seed source and dust
- biological control using naturally beneficial predators (e.g. spiders, wasps, lacewings, assassin bugs, nabids and some beetles) to manage orchard pests and benefit the orchard ecosystem
- choosing to use selective chemical products that minimise disruption to beneficial arthropods.

Monitoring your crop

Regular crop monitoring to a protocol (page 56) and keeping good records are fundamental to knowing what is happening in the orchard. A monitoring protocol includes inspecting a pre-determined number of fruit (or leaves) at a set number of monitoring sites. The trees for inspection are chosen randomly as the person monitoring walks through the orchard. Monitoring frequency depends on the pest and disease pressures, which usually depend on seasonal conditions.

Monitoring saves money by detecting orchard pests early and implementing appropriate pest management before crop damage occurs. It can also save money when pest pressure is low, as calendar spraying can lead to unnecessary chemical use. Countries continually lower accepted maximum residue limits (MRL) to increase food safety. Insecticide resistance is an ongoing threat to the efficacy of chemical products. Regular crop monitoring and adopting IPM are important strategies for sustainable production techniques.

Biological control

Choosing to use selective chemical products that minimise disruption to beneficial arthropods will help enhance the natural beneficial insects and spiders in an orchard. Items in the pesticide tables (Table 18 on page 58 and Table 19 on page 63) in this guide with a green '1' (❶) indicate that, when used with care, these products have little effect on beneficials and are recommended for an IPM system. Some beneficial insects are available for purchase and release in Australia. The Goodbugs website (www.goodbugs.org.au) has a list of suppliers in Australia.

Copper and nutritional sprays will usually not harm beneficial insects. Carbamate, organophosphate and synthetic pyrethroid insecticides are toxic to most beneficial insects. If such an insecticide has been applied, at least 4 weeks should elapse before releasing beneficial insects.

Lacewings

Brown lacewings (*Micromus* spp.) and green lacewings (*Mallada* spp.; Figure 86) are general predators commonly seen in citrus orchards. They prey on aphids, moth eggs, small larvae, scales and whiteflies. A branch shaken in spring onto a white tray often reveals a lacewing larva on every shake. Green lacewing larvae are disguised by the debris of prey they carry on their backs (Figure 87). Brown lacewing larvae are not disguised and have clear pincers at the front for attacking prey. Green lacewing eggs are white and attached together on the end of fine white stalks, while brown lacewing eggs are football-shaped and laid flat on the back of leaves. Lacewings are available for purchase to release in citrus orchards. They are supplied as eggs and placed throughout infested trees. The larvae should hatch soon after arrival.

Figure 86. A green lacewing adult.

Lady beetles

Cryptolaemus and *Diomus* lady beetles (Figure 88) are mealybug predators. Both the adult and larvae feed on mealybugs and soft brown scales.

Rhyzobius lophanthae is a commercially available scale-eating lady beetle (Figure 89), and is an important natural predator of red scale and soft brown scale.

Vedalia lady beetles and *Hippodamia variegata* are also active predators in many orchards.

Rodolia cardinalis is a cottony cushion scale predator. Young larvae will suck out the contents of their prey while adult lady beetles will consume the entire contents of the cottony cushion scale.

Chilocorus circumdatus is a predatory lady beetle for controlling armoured scale insects such as red scale. *Chilocorus* are supplied in punnets containing a minimum of 50 adult beetles.

Predatory bugs

Predatory bugs such as damsel bugs (*Nabus* spp.) and assassin bugs (*Pristhesancus* spp.) are also common in orchards where IPM is practiced, including limited use of broad-spectrum insecticides. Different bugs feed on different pest insects. Many feed on small light brown apple moth larvae. Assassin bugs can also feed on spined citrus bugs.

Spiders

Spiders are the most common beneficial arthropods occurring naturally in citrus orchards. Spiders are generalist predators, eating small larvae and many other insect pests. Many citrus growers often overlook their contribution to pest management. Lynx spiders and jumping spiders are common if broad-spectrum insecticides are not used.

Wasps

Aphytis wasps are the most commonly purchased beneficial insects for citrus orchards. They are effective parasites of red scale, attacking large, second instar scales and unmated females. The tiny yellow wasps (Figure 90) lay their eggs under red scale covers, onto the red scale body. The wasp larvae feed externally on the scale body (ectoparasite).

Each wasp can lay up to 100 eggs. After hatching, the wasp larvae feed on the scale insect, which eventually dies. After 3 weeks, the adult *Aphytis* wasp will emerge from the parasitised scale, which then parasitises other scales, continuing the cycle of biological control.

Aphytis melinus is best suited to the inland citrus-producing regions of Sunraysia and the Riverina.

Figure 87. A green lacewing larva disguised by the prey debris it carries on its back.

Figure 88. An adult *Diomus notescens* on a citrus leaf.

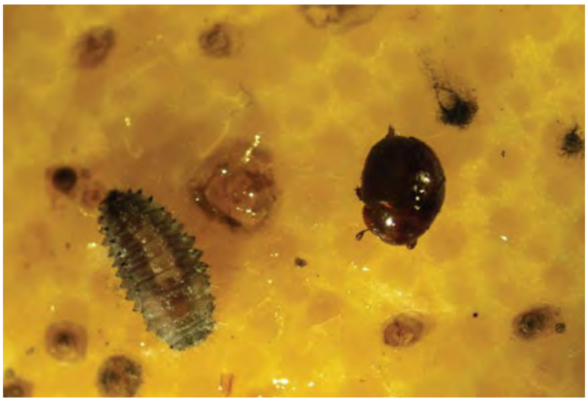

Figure 89. Both the larvae (left) and adult (right) of the lady beetle (*Rhyzobious lophanthae*) are important scale predators.

Figure 90. *Aphytis* wasp.

They are usually sold in cups of 10,000 wasps and the recommended release rate for citrus is 2.5 cups per hectare. Many growers choose 3 releases per year.

Comperiella bifasciata is a commonly found wasp that parasitises red scale. *C. bifasicata* is black and the females lay eggs inside the red scale body (endoparasite). A female wasp lays up to 50 eggs in different scales. One larva develops in each scale. *Comperiella* is an effective parasitoid of red scale and is widely established in the Riverina and Sunraysia citrus-growing regions.

Trichogramma wasps parasitise moth eggs, including light brown apple moth and *Helicoverpa*. The wasps are naturally present in orchards that do not use insecticides.

Two-spotted mite predators

Neoseiulus californicus is a two-spotted mite and broad mite predator (Figure 91). They can survive on alternative prey and pollen when pest pressure is low. *N. californicus* predatory mites are robust, being able to survive inland summer temperatures and establish in field crops. This works best when used preventatively or when mites are first noticed in the crop. *N. californicus* is available for purchase and orchard release.

The tiny, two-spot lady beetle is another naturally occurring predator of two-spotted mites.

Figure 91. A *Neoseiulus californicus* predatory mite feeding on a two-spotted mite. Photo: Biological Services.

Monitoring protocol

Monitoring to a protocol ensures pest problems are detected before they cause significant economic damage. Monitoring just a few trees in one section of the orchard can provide misleading results by either not detecting pests that later cause significant fruit damage or overestimating the presence of a pest and unnecessarily applying pesticides. Pesticide use adversely affects beneficial insects and can lead to secondary pest flare-ups that sometimes cause more problems than the original pest. Therefore, using a correct monitoring protocol ensures appropriate pesticide use. The following protocol is only a guide and should be modified for site conditions.

Select 5 fruit or shoots to be sampled from one tree; the number of trees to be sampled will depend on the size of the orchard (Table 16). Choose representative trees (i.e. healthy trees) throughout the whole block. A practical strategy is to walk down rows and select trees randomly along the row (Figure 92). If pest flare-ups are detected on one part of the block only, then further monitoring can better assess the extent of the damage and provide the opportunity to only spray the affected part of the block. This will save time, money and minimise the negative effects from spraying pesticides. Leaving parts of the block unsprayed preserves beneficial insect populations, which will help to repopulate them into the sprayed part of the block.

Pull fruit off the trees and remove the calyx to search for pests or pest damage. Check the shoot from where the fruit was taken for any signs of pests on the leaves or stems. Record any damage detected. At the end of the monitoring session, calculate the amount of pest or damage detection. For example, if 150 fruit were checked and 6 light brown apple moths were found, then the damage is 4% ($6 \div 150 = 0.04$, $0.04 \times 100 = 4\%$).

Table 16. Tree and fruit sampling guide.

Area (ha)	Trees sampled	Fruit sampled
<2	25	125
2–3	30	150
4	35	175
5–8	50	250
9–16	75	375

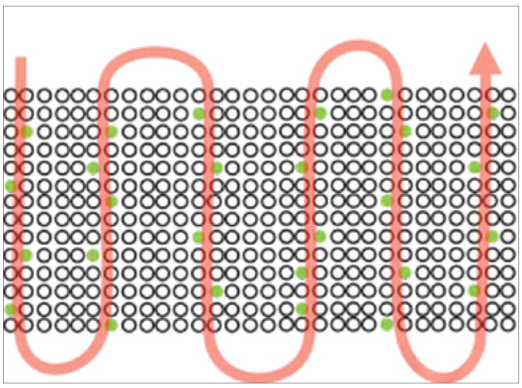

Figure 92. A suggested pattern to use while walking throughout the block for monitoring.

Insecticide chemical tables

Common citrus pests and their growing periods

Table 17. When to monitor common citrus pests.

	Cell division				Cell expansion							
	Bud break / Leaf expansion	Flowering		Fruit set/ drop	Golf ball		Colour break			Maturation	Harvest	
Insects	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
Aphids												
Black citrus aphid												
Brown citrus rust mite												
Budworms												
Citricola scale												
Citrophilous mealybug												
Citrus butterfly												
Citrus gall wasp												
Citrus leafminer												
Cottony cushion scale												
Fuller's rose weevil												
Jassids												
Katydids												
Kelly's citrus thrips												
Light brown apple moth												
Long-tailed mealybug												
Queensland fruit fly												
Red scale												
Snails												
Soft scales												
Spined citrus bug												
Two-spotted mite												

Denotes phenology   Denotes insect activity

Insect pests and chemical controls

Chemical registrations (Table 18) can change any time; always check and follow the label.

The product trade names in this publication are supplied on the understanding that no preference between equivalent products is intended and that the inclusion of a product name does not imply endorsement by the department over any equivalent product from another manufacturer. The earliest currently registered products are included herein.

Coloured dots denote that chemical's compatibility with integrated pest management (IPM):
❶ when used with care, a chemical will have little effect on beneficials and is recommended in an IPM program.
❷ this pesticide can be used with caution in an IPM program, but the chemical's effect on beneficials present should be assessed before application.
❸ this chemical is likely to have a negative off-target effect including on beneficial arthropods.
? = unknown.

Table 18. Insect pests and chemical controls registered for use in NSW (correct at August 2024) page 1 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Ants (black ant, coastal brown ant)	Pyriproxyfen	7C	❷	0	Distance® Plus
Aphids	Dimethoate	1B	❸	7	Dimethoate 400
	Malathion	1B	❸	3	Fyfanon® 440 EW, Hy-Mal®
	Pirimicarb	1A	❶	2	Pirimor® WG
Aphids (soil treatment)	Imidacloprid	4A	❷	140	Nuprid 350®
Armyworms (larval stage)	*Bacillus thuringiensis* (Bt)	11	❶	0	Dipel® DF
	Bacillus thuringiensis subsp. *Aizawai* (Btaz)	11C	❶	0	Bacchus® WG
	Bacillus thuringiensis subsp. *Kurstaki* (Btk)	11C	❶	0	Delfin® WG
Black (brown olive) scale	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Pyriproxyfen	7C	❷	7	Admiral® Advance, Distance® Plus
Bronze orange bug	Carbaryl (oranges and lemons only)	1A	❸	3	Bugmaster® Flowable
	Dimethoate	1B	❸	7	Dimethoate 400
	Malathion	1B	❸	3	Fyfanon® 440 EW, Hy-Mal®
	Methomyl	1A	❸	2	Electra® 225
Citricola scale	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Sulfoxaflor	4C	❷	1	Expedite Full, Transform Isoclast®
Citrophilous mealybug	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Buprofezin	16	❶	28	Applaud®
	Sulfoxaflor	4C	❷	1	Expedite Full, Transform Isoclast®
Citrus butterflies	Malathion	1B	❸	3	Fyfanon® 440 EW, Hy-Mal®
	Methomyl	1A	❸	2	Electra® 225
Citrus butterflies (larvae)	Carbaryl (oranges and lemons only)	1A	❸	3	Bugmaster® Flowable
Citrus gall wasp	Clothianidin	4A	❷	140	Samurai®
	Imidacloprid	4A	❷	140	Confidor® Guard (suppression only, soil insecticide)
Citrus leaf-eating weevil	Bifenthrin	3A	❸	0	Talstar® 100 EC
Citrus leafminer	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Botanical oil	Spray adjuvant	❶	0	Eco-oil®
	Clothianidin	4A	❷	140	Samurai®
	Diazinon	1B	❸	14	Diazinon 800
	Imidacloprid	4A	❷	140	Nuprid 350®
	Paraffinic oil	Spray adjuvant	❶	1	Biopest®

Table 18. Insect pests and chemical controls registered for use in NSW (correct at August 2024) page 2 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Citrus leafminer contd	Petroleum oil	Spray adjuvant	1	1	Banole® EC
	Spinetoram	5	2	1	Success® Neo
Citrus mealybug	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Buprofezin	16	1	28	Applaud®
	Spirotetramat (suppression only)	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
Citrus nematode	Cadusafos	1B	2	0	Rugby® 100G
Cotton bollworm (larval stage)	*Bacillus thuringiensis* (Bt)	11	1	0	Dipel® DF
	Bacillus thuringiensis subsp. *Aizawai* (Btaz)	11C	1	0	Bacchus® WG
	Bacillus thuringiensis subsp. *Kurstaki* (Btk)	11C	1	0	Delfin® WG
Cottony cushion scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Pyriproxyfen	7C	2	7	Admiral® Advance, Distance® Plus
Fruit spotting bug	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
Fruit-piercing moth	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
Fuller's rose weevil	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
	Clothianidin	4A	2	140	Samurai®
	Cyantraniliprole	28	2	0	Exirel®
	Gamma-cyhalothrin	3A	3	28	Trojan® (oranges and lemons only)
	Lambda-cyhalothrin (oranges and lemons only)	3A	3	28	Kaiso 240 EG®
Greenhouse thrips	Pyrethrins	3A	2	1	PyGanic®
Helicoverpa (budworms, ear worms)	Methomyl	1A	3	2	Electra® 225
	Spinetoram	5	2	1	Success® Neo
Helicoverpa (larval stage)	*Bacillus thuringiensis* (Bt)	11	1	0	Dipel® DF
	Bacillus thuringiensis subsp. *Aizawai* (Btaz)	11C	1	0	Bacchus® WG
	Bacillus thuringiensis subsp. *Kurstaki* (Btk)	11C	1	0	Delfin® WG
Jassids	Buprofezin	16	1	28	Applaud®
Kelly's citrus thrips	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Cyantraniliprole	28	2	0	Exirel®
	Spirotetramat	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
	Thiamethoxam	4A	2	49	Actara®
Lesser Queensland fruit fly (male)	Fipronil + acetoxy phenyl butanone	2B	1	0	Amulet Cue-Lure®
Light brown apple moth	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Bacillus thuringiensis (Bt)	11	1	0	Dipel® DF
	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
	Cyantraniliprole	28	2	0	Exirel®
	Methomyl	1A	3	2	Methomyl 225
	Methoxyfenozide	18	1	1	Prodigy®
	Spinetoram	5	2	1	Success® Neo
	Tebufenozide	16A	1	1	Mimic® 700 WP
	Tetra-decenyl acetate + tetra-decadienyl acetate	Pheromone	1	0	Splat LBAM HD-O™

Table 18. Insect pests and chemical controls registered for use in NSW (correct at August 2024) page 3 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Light brown apple moth (larval stage)	*Bacillus thuringiensis* subsp. *Aizawai* (Btaz)	11C	1	0	Bacchus® WG
	Bacillus thuringiensis subsp. *Kurstaki* (Btk)	11C	1	0	Delfin® WG
Locust (Australian plague, migratory and spur-throated)	Chlorpyrifos	1B	3	14	Chlorpyrifos
Long-tailed mealybug	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Buprofezin	16	1	28	Applaud®
	Methomyl	1A	3	2	Electra® 225
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
Looper caterpillars (larval stage)	*Bacillus thuringiensis* (Bt)	11	1	0	Dipel® DF
	Bacillus thuringiensis subsp. *Aizawai* (Btaz)	11C	1	0	Bacchus® WG
	Bacillus thuringiensis subsp. *Kurstaki* (Btk)	11C	1	0	Delfin® WG
Mediterranean fruit fly	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor® (suppression)
	Dichlorvos	1B	1	7	Biotrap DDVP cubes
	Spinosad	5	1	0	Naturalure® Fruit Fly Bait Concentrate
Mite, broad mite	Abamectin	6	3	7	Vertimec® Pro
	Paraffinic oil	Spray adjuvant	1	1	Bioclear®
Mite, brown citrus mite	Mancozeb	M3	2	0	Dithane® Rainshield® NeoTec®
	Mancozeb + zinc	M3	2	0	Manic® WG Fungicide Plus
Mite, brown citrus rust mite	Abamectin	6	3	7	Vertimec® Pro
	Fenbutatin oxide	12B	?	7	Vendex®
	Paraffinic oil	Spray adjuvant	1	1	Bioclear®
	Sulfur	M2	1	0	Brimflo 800, Grochem Dusting Sulphur, Thiovit® Jet Microgranule
	Zineb	5	1	7	Barmac Zineb
	Fenbutatin oxide	12B	?	7	Vendex®
Mite, citrus bud mite	Mancozeb	M3	2	0	Dithane® Rainshield® NeoTec®
	Mancozeb + zinc	M3	2	0	Manic® WG Fungicide Plus
	Sulfur	M2	2	0	Thiovit® Jet Microgranule
Mite, citrus red mite	Abamectin	6	3	7	Sorcerer® 36 (bare rooted and potted nursery stock)
	Paraffinic oil	Spray adjuvant	1	1	Bioclear®
Mite, citrus rust (Maori) mite	Abamectin	6	3	7	Vertimec® Pro
	Fenbutatin oxide	12B	?	7	Vendex®
	Mancozeb	M3	2	0	Dithane® Rainshield® NeoTec®
	Mancozeb + zinc	M3	2	0	Manic® WG Fungicide Plus
	Paraffinic oil	Spray adjuvant	1	1	Bioclear®
	Petroleum oil	Spray adjuvant	1	1	D-C-Tron® Plus
	Propineb	M3	2	7	Antracol® 700 WG
	Sulfur	M2	2	0	Brimflo 800, Grochem Dusting Sulphur, Thiovit® Jet Microgranule
	Zineb	5	1	7	Barmac Zineb
Mite, Oriental spider mite	Etoxazole	10B	1	7	ParaMite®
Orange fruit borer	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable

Table 18. Insect pests and chemical controls registered for use in NSW (correct at August 2024) page 4 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Pink wax scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
	Imidacloprid	4A	2	140	Nuprid 350®
	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Paraffinic oil	Spray adjuvant	1	1	Biopest®
	Petroleum oil	Spray adjuvant	1	1	D-C-Tron® Plus
	Spirotetramat	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
Purple (mussel) scale	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Spirotetramat	23	1	21	Movento® 240 SC
Queensland fruit fly	4-(p-acetoxyphenyl)-2-butanone + malathion	1B	1	0	Searles® Fruit Fly Wick (bait toxicant)
	Abamectin	6	3	7	Sorcerer® 36
	Dimethoate	1B	3	7	Dimethoate 400
	Hydroxyphenyl butanone acetate	1B	1	0	Dak Pot® Lure and Insecticide Trap C165
	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Pyrethrins	3A	2	1	PyGanic® (clean-up spray)
	Spinosad	5	1	0	Naturalure® Fruit Fly Bait Concentrate
Queensland fruit fly (male)	4-(p-acetoxyphenyl)-2-butanone	NA	1	0	Fly Bye™ Fruit Fly Lure
	Fipronil + acetoxy phenyl butanone	2B	1	0	Amulet Cue-Lure®
Red scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Buprofezin	16	1	28	Applaud®
	Chlorpyrifos	1B	3	14	Chlorpyrifos 500 EC
	Clothianidin	4A	2	140	Samurai®
	Imidacloprid	4A	2	140	Nuprid 350®
	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Paraffinic oil	Spray adjuvant	1	1	Biopest®
	Petroleum oil	Spray adjuvant	1	1	D-C-Tron® Plus
	Pyriproxyfen	7C	2	7	Admiral® Advance, Distance® Plus
	Spirotetramat	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
Rutherglen bug	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Pyrethrins	3A	2	1	PyGanic® (clean-up spray)
Slugs	Iron	NA	1	0	Protect-us™ Mineral Snail and Slug Killer
	Metaldehyde	5	1	7	Snail Trail Snail and Slug Pellets
	Methiocarb	1A	1	7	Mesurol® Snail and Slug Bait
Slug, brown field slug	Metaldehyde	5	1	7	Snail Trail Snail and Slug Pellets
Snails	Iron	NA	1	0	Protect-us™ Mineral Snail and Slug Killer
	Iron-EDTA complex	NA	1	0	Multiguard® Snail & Slug Killer
	Metaldehyde	5	1	7	Snail Trail Snail and Slug Pellets
	Methiocarb	1A	1	7	Mesurol® Snail and Slug Bait
	Silicate salts + copper complex	NA	1	0	Socusil® Snail Repellent
Soft brown scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Spirotetramat	23	1	21	Movento® 240 SC

Table 18. Insect pests and chemical controls registered for use in NSW (correct at August 2024) page 5 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Spined citrus bug	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
	Diazinon	1B	3	14	Diazinon 800
	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
	Methomyl	1A	3	2	Electra® 225
Stubby-root nematode	Cadusafos	1B	2	0	Rugby® 100G
Thrips (see Kelly's citrus thrips)	Dimethoate	1B	3	7	Dimethoate 400
	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
Treehoppers	Malathion	1B	3	3	Fyfanon® 440 EW, Hy-Mal®
White louse scale (citrus snow scale)	Buprofezin	16	1	28	Applaud®
	Pyriproxyfen	7C	2	7	Admiral® Advance
	Spirotetramat	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Expedite Full, Transform Isoclast®
	Sulfur	M2	2	0	Grochem Lime Sulphur
White wax scale	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
	Paraffinic oil	Spray adjuvant	1	1	Biopest®
	Petroleum oil	Spray adjuvant	1	1	D-C-Tron® Plus
Wingless grasshopper	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable
	Chlorpyrifos	1B	3	14	Nufarm Chlorpyrifos 500 EC
	Dimethoate	1B	3	7	Adama Dimethoate 400
Yellow peach moth	Carbaryl (oranges and lemons only)	1A	3	3	Bugmaster® Flowable

WHP = withholding period.
Source: APVMA Pubcris (https://portal.apvma.gov.au/pubcris).
Adapted from Tomlin CDS (2006) *The pesticide manual, a world compendium*, 14th Edition, British Crop Protection Council, Alton, Hampshire.

Note: users of agricultural chemical products must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

Insecticide active ingredients

Insect pests have been grouped. Some insecticides (Table 19) in the trade name column might only be registered for some of the insects listed in the insect pest column. Always read and follow the label directions.

Coloured dots in the IPM column denote that chemical's compatibility:
❶ when used with care, a chemical will have little effect on beneficials and is recommended in an IPM program.
❷ this chemical can be used with caution in an IPM program, but its effect on beneficials should be assessed before application.
❸ this chemical is likely to have a negative off-target effect including on beneficial arthropods.
? = unknown.

Table 19. Active ingredients of insecticides registered for managing insects in NSW (correct at August 2024) page 1 of 3.

Active (Group)	IPM	Insect pest	Example trade name
4-(p-acetoxyphenyl)-2-butanone (1B)	❶	Queensland fruit fly (male)	Fly Bye™ Fruit Fly Lure
4-(p-acetoxyphenyl)-2-butanone + malathion (1B)	❸	Queensland fruit fly	Searles® Fruit Fly Wick (bait toxicant)
Abamectin (6)	❸	Broad mite, brown citrus rust mite, citrus rust (Maori) mite	Vertimec® Pro
		Citrus red mite	Sorcerer® 36 (bare rooted and potted nursery stock)
		Queensland fruit fly	Sorcerer® 36
Acetamiprid + pyriproxyfen (4A + 7C)	❸	Black (brown olive) scale, citricola scale, citrophilous mealybug, citrus leafminer, citrus mealybug, cottony cushion scale, fruit spotting bug, Kelly's citrus thrips, light brown apple moth, long-tailed mealybug, pink wax scale, red scale, soft brown scale	Trivor®
		Mediterranean fruit fly	Trivor® (suppresion)
Bacillus thuringiensis (Bt) (11A)	❶	Armyworms (larval stage), cotton bollworm (larval stage), *Helicoverpa* (larval stage), light brown apple moth, looper caterpillars (larval stage)	Dipel® DF
Bacillus thuringiensis subsp. *Aizawai* (Btaz) (11A)	❶	Armyworms (larval stage), cotton bollworm (larval stage), *Helicoverpa* (larval stage), light brown apple moth, looper caterpillars (larval stage)	Bacchus WG®
Bacillus thuringiensis subsp. *Kurstaki* (Btk) (11A)	❶	Armyworms (larval stage), cotton bollworm (larval stage), *Helicoverpa* (larval stage), light brown apple moth, looper caterpillars (larval stage)	Delfin® WG
Bifenthrin (3A)	❸	Citrus leaf-eating weevil	Talstar® 100 EC
Botanical oil	❶	Citrus leafminer	Eco-Oil®
Buprofezin (16)	❶	Citrophilous mealybug, citrus mealybug, jassids, long-tailed mealybug, red scale, white louse scale (citrus snow scale)	Applaud®
Cadusafos (1B)	❷	Citrus nematode, stubby-root nematode	Rugby® 100G
Carbaryl (1A) (oranges and lemons only)	❸	Bronze orange bug, citrus butterflies (larvae), fruit-piercing moth, Fuller's rose weevil, light brown apple moth, orange fruit borer, pink wax scale, spined citrus bug, white wax scale, wingless grasshopper, yellow peach moth	Bugmaster® Flowable
Chlorpyrifos (1B)	❸	Locust (Australian plague, migratory and spur-throated), red scale, wingless grasshopper	Chlorpyrifos 500 EC
Clothianidin (4A)	❷	Citrus gall wasp, citrus leafminer, Fuller's rose weevil, red scale	Samurai®
Cyantraniliprole (28)	❷	Fuller's rose weevil, Kelly's citrus thrips, light brown apple moth	Exirel®

Table 19. Active ingredients of insecticides registered for managing insects in NSW (correct at August 2024) page 2 of 3.

Active (Group)	IPM	Insect pest	Example trade name
Diazinon (1B)	3	Citrus leafminer, spined citrus bug	Diazinon 800
Dichlorvos (1B)	1	Mediterranean fruit fly	Biotrap DDVP cubes
Dimethoate (1B)	3	Aphids, bronze orange bug, Queensland fruit fly, thrips (see Kelly's citrus thrips), wingless grasshopper	Dimethoate 400
Etoxazole (10B)	1	Oriental spider mite	ParaMite®
Fenbutatin oxide (12B)	?	Brown citrus rust mite, citrus bud mite, citrus rust mite	Vendex® miticide
Fipronil + acetoxy phenyl butanone (2B)	1	Queensland fruit fly (male), lesser Queensland fruit fly (male)	Amulet Cue-Lure®
Gamma-cyhalothrin (3A) (oranges and lemons only)	3	Fuller's rose weevil	Trojan® (oranges and lemons only)
Hydroxyphenyl butanone acetate + malathion (1B)	1	Queensland fruit fly	Dak Pot® Lure and Insecticide Trap C165
Imidacloprid (4A)	2	Aphids (black citrus), citrus leafminer, pink wax scale, red scale	Nuprid 350®
		Citrus gall wasp	Confidor® Guard (suppression only, soil insecticide)
Iron	1	Snails, slugs	Protect-us™ Mineral Snail and Slug Killer
Iron-EDTA complex	1	Snails	Multiguard® Snail & Slug Killer
Lambda-cyhalothrin (3A) (oranges and lemons only)	3	Fuller's rose weevil	Kaiso 240 EG®
Malathion (1B)	3	Aphids, bronze orange bug, citrus butterflies, pink wax scale, purple (mussel) scale, Queensland fruit fly, red scale, Rutherglen bug, soft brown scale, spined citrus bug, thrips (see Kelly's citrus thrips), treehoppers	Fyfanon® 440 EW, Hy-Mal®
Mancozeb (M3)	2	Brown citrus mite, citrus bud mite, citrus rust (Maori) mite	Dithane® Rainshield® NeoTec®
Mancozeb + zinc (M3)	2	Citrus bud mite, citrus rust (Maori) mite	Manic® WG Fungicide Plus
Metaldehyde (5)	1	Slugs, snails	Snail Trail Snail and Slug Pellets
Methiocarb (1A)	1	Slugs, snails	Mesurol® Snail and Slug Bait
Methomyl (1A)	3	Bronze orange bug, citrus butterflies, Helicoverpa (budworms, ear worms), light brown apple moth, spined citrus bug	Electra® 225
		Long-tailed mealybug	Methomyl 225
Methoxyfenozide (18)	1	Light brown apple moth	Prodigy®
Paraffinic oil (spray adjuvant)	1	Broad mite, brown citrus rust mite, citrus red mite, citrus rust (Maori) mite	Bioclear®
		Citrus leafminer, pink wax scale, red scale, white wax scale	Biopest®
Petroleum oil (spray adjuvant)	1	Citrus leafminer	Banole® EC
		Mite, citrus rust (Maori) mite, pink wax scale, red scale, white wax scale	D-C-Tron® Plus

Table 19. Active ingredients of insecticides registered for managing insects in NSW (correct at August 2024) page 3 of 3.

Active (Group)	IPM	Insect pest	Example trade name
Pirimicarb (1A)	1	Aphids	Pirimor® WG
Propineb (M3)	2	Citrus rust (Maori) mite	Antracol® 700 WG
Pyrethrins (3A)	2	Greenhouse thrips, Queensland fruit fly, Rutherglen bug	PyGanic®
Pyriproxyfen (7C)	2	Ants (black ant, coastal brown ant)	Distance® Plus Ant Bait
		Black (brown olive) scale, cottony cushion scale, red scale	Admiral® Advance, Distance® Plus Ant Bait
		White louse scale (citrus snow scale)	Admiral® Advance
Silicate salts + copper complex	1	Snails	Socusil® Snail Repellent
Spinetoram (5)	2	Citrus leafminer, *Helicoverpa* (budworms, ear worms), light brown apple moth	Success® Neo
Spinosad (5)	1	Mediterranean fruit fly, Queensland fruit fly	Naturalure® Fruit Fly Bait Concentrate
Spirotetramat (23)	1	Citrus mealybug (suppression only), Kelly's citrus thrips, pink wax scale, purple (mussel) scale, red scale, soft brown scale, white louse scale (citrus snow scale)	Movento® 240 SC
Sulfoxaflor (4C)	2	Citricola scale, citrophilous mealybug, citrus mealybug, fruit spotting bug, Kelly's citrus thrips, long-tailed mealybug, pink wax scale, red scale, white louse scale (citrus snow scale)	Expedite Full Insecticide, Transform Isoclast®
Sulfur (M2)	2	Brown citrus rust mite, citrus rust (Maori) mite	Brimflo 800, Grochem Dusting Sulphur, Thiovit® Jet Microgranule
		Mite, citrus bud mite	Thiovit® Jet Microgranule
Tebufenozide (16A)	1	Light brown apple moth	Mimic® 700 WP
Tetra-decenyl acetate + tetra-decadienyl acetate (pheromone)	1	Light brown apple moth	Splat LBAM HD-O™ Mating Disruption Agent
Thiamethoxam (4A)	2	Kelly's citrus thrips	Actara®
Zineb (5)	1	Brown citrus rust mite, citrus rust (Maori) mite	Barmac Zineb

Source: APVMA Pubcris (https://portal.apvma.gov.au/pubcris).

Adapted from Tomlin CDS (2006) *The pesticide manual, a world compendium*, 14th edition, British Crop Protection Council. Alton, Hampshire.

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Diseases and disorders

Nerida Donovan and Andrew Creek, NSW DPIRD

To avoid or reduce the effect of many diseases, always establish orchards with healthy nursery trees propagated using Auscitrus budwood and rootstock seed.

Anthracnose

Symptoms

Anthracnose is a rind blemish that can appear as firm, brown to black spots or a tear-staining pattern on fruit rind (Figure 93). 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.

Cause

The fungus *Colletotrichum gloeosporioides* is present throughout the orchard in deadwood and commonly invades citrus rind, but typically only causes decay when the rind has been damaged by other factors such as cold (Figure 94) or sunburn. Foggy and moist conditions throughout winter provide ideal conditions for the fungus to develop. Fungal spores are spread by rain splash. Postharvest anthracnose development can occur when fruit is 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 protectant copper spray before autumn rain will reduce anthracnose in the orchard.

Growers can consider applying a second copper spray if fruit will be harvested late in the season. For more information, see NSW DPIRD Primefact 757 *Using copper sprays to control diseases in citrus*.

Figure 93. Anthracnose can appear as a tear-staining pattern on the rind.

Figure 94. Anthracnose can appear on the rind after cold weather.

Black core rot

Symptoms

Also called alternaria core rot or centre rot, this disease is found in all growing areas. It can affect oranges and mandarins. In recent years it has been a significant problem in Imperial mandarin.

Black decay develops inside the fruit. The rind can also be discoloured brown at the stem or stylar end (Figure 95 and Figure 96). Affected fruit typically colour prematurely and drop.

Cause

Alternaria alternata fungus 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 harvesting susceptible varieties to allow infected fruit to drop first.

Figure 95. Black core rot in a mandarin.

Figure 96. Advanced black core rot in a mandarin.

Black spot

Symptoms

Black spot is a fungal disease that occurs in humid, summer rainfall areas mainly on lemons and Valencia and Navel oranges. Black spots start as 1–2 mm, red circular lesions on the rind (Figure 97). Continued disease development later in the season can lead to large, brown to black, irregularly shaped, sunken lesions. Infected fruit and leaves might drop.

Cause

The *Phyllosticta citricarpa* fungus causes black spot. Infection happens in moist conditions, but spores then stay dormant and fruit symptoms do not appear until ripening, mainly during warm weather.

Management

Harvest fruit at maturity to avoid in-field symptoms developing. 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 97. Citrus black spot early stages.

Brown spot

Symptoms

Brown spot occurs on mandarins, tangelos and tangors in humid, high-rainfall areas. Brown to black spots appear on young leaves, shoots and fruit rind (Figure 98). Spots are typically circular and surrounded by a yellow halo, 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 typically drop and infected shoots die back. Symptoms often appear soon after infection.

Cause

The *Alternaria alternata* fungus.

Management

Extended wet weather from early spring to autumn can lead to foliar and fruit damage. Heavy dews are sufficient to initiate infection. Trees with lush shoot growth are more prone to infection. 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, plus applying a systemic fungicide before warm, wet periods of highest disease pressure.

Figure 98. Brown spot symptoms on mandarin.

Chimeras

Symptoms

Abnormally shaped (Figure 99), textured or coloured leaves and/or fruit (Figure 100 and Figure 101).

Cause

A chimera is a genetic alteration or mutation of cells. Sometimes earlier ripening or later-maturing varieties develop from chimeras.

Management

Pruning can remove undesirable mutations, also called 'sports'. Many new varieties have originated from bud sports.

Figure 99. Chimera can cause abnormally shaped fruit.

Figure 100. Chimera can cause abnormally coloured fruit.

Figure 101. Chimera can cause striped fruit.

Citrus viruses and viroids

Symptoms

Affected trees can exhibit stunted growth (Figure 102), reduced production and fruit quality, tree decline or death. Other symptoms can include stem pitting (Figure 103), gumming (Figure 104) and bark peeling (Figure 105). Different diseases affect different citrus scions and rootstocks. Infected trees can be symptomless but still spread disease to susceptible varieties.

Figure 102. Stunted growth in an orange tree (left) caused by Citrus exocortis viroid.

Figure 103. Stem pitting in a grapefruit tree caused by Citrus exocortis viroid.

Figure 104. Fine pits and gumming caused by orange stem pitting strains of Citrus tristeza virus.

Figure 105. Severe bark peeling in an orange tree caused by Citrus exocortis viroid.

Cause

Viruses are small infectious agents that can only replicate inside living cells, whereas viroids are the smallest form of infectious agents and only infect plants. Numerous viruses and viroids affect citrus, including Citrus tristeza virus, Citrus psorosis virus, Citrus exocortis viroid and Citrus cachexia viroid. Infected propagation material, cutting tools and root grafting between field trees can spread viruses and viroids. Some diseases can also be spread by vectors, such as Citrus tristeza virus, which is spread by aphids (Figure 106).

Figure 106. Aphids, which are vectors of Citrus tristeza virus, on citrus shoots.

Management

There is no cure for graft-transmissible diseases; prevention is the best management option. Always source disease-free budwood and rootstock seed. Disinfect cutting tools in a 10% commercial bleach (1.25% available chlorine) solution.

Collar rot

Symptoms

Collar rot usually occurs at the bottom of the tree trunk. Gum first exudes from the affected area, and the bark becomes discoloured (brown to black), soft and wet. Over time the wood dries out, re-hardens and cracks. The disease can ringbark and kill affected trees.

Cause

Phytophthora species spores can be splashed onto the trunk in soil and water. Ants carry soil containing the spores up inside tree guards to their nests. The exuding gum from moist, softened bark is an early sign of collar rot (Figure 107).

Figure 107. An ant nest with collar rot.

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 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.

Copper spray injury

Symptoms

Typically the exposed (outward-facing) surface of the fruit shows signs such as stippling (Figure 108) or darkening of existing blemishes (Figure 109).

Cause

Spray injury can be caused by not following product label rates and recommendations. Injury can also happen if 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 is wet. Always follow label instructions.

Figure 108. Minor copper phytotoxicity spray injury, the outward-facing side of fruit shows signs of stippling.

Figure 109. Extensive copper phytotoxicity spray injury, the outward-facing side of fruit has darkened blemishes.

Creasing (albedo breakdown)

Symptoms

Creasing is also known as albedo breakdown. It is often a seasonal issue that can reduce packouts and increase the risk of fruit breakdown during transit. Fruit with albedo breakdown have a weak rind that is susceptible to cracking (Figure 110). Cracked rinds allow pathogens (disease-causing agents) to establish and decay the fruit. Fruit with creasing are more likely to split when packed.

Cause

Albedo breakdown is a physiological disorder where the underlying albedo layer collapses, giving the fruit rind a wrinkled appearance (Figure 111). 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

Choose varieties that are not susceptible; generally, early-maturing varieties are more susceptible than late-maturing varieties. Growers can often recognise blocks in their orchards that are more susceptible to albedo breakdown than others.

A high cropping level is thought to be associated with albedo breakdown. However, this could be a factor of the same climatic conditions that induced the high crop load. It is also associated with thin rinds; rinds normally become thinner with high crop loads.

Applying preharvest gibberellic acid (GA) and calcium foliar sprays reduces creasing. Susceptibility differs between scion varieties and rootstocks. Pruned trees have fewer fruit with creasing. Mature fruit rinds are more prone to creasing (Figure 112).

Calcium sprays can also help, however, research indicates that multiple sprays (i.e. 5–10) are required to provide the same level of control as a single GA application. The best time to apply foliar calcium sprays is in January and early February.

Although a lack of calcium is associated with the disorder, research shows that applying extra calcium fertiliser to soil already with sufficient calcium levels does not alleviate the problem.

Thorough spray coverage is essential, especially for the shaded part of the fruit that tends to exhibit worse symptoms than the unshaded side.

Figure 110. Rind separation from albedo breakdown.

Figure 111. Albedo breakdown in a Navel orange.

Figure 112. Severe creasing in an over-mature mandarin.

Frost injury

Symptoms

Frosted fruit can have rind scald (Figure 113 and Figure 114) and dry fruit sacs (Figure 115). Severely damaged fruit usually drop. Young, frost-damaged trees can suffer from bark splitting and foliage death. A succession of moderate frosts and cold winds can cause foliage curling and bleaching, exhibited by brown blotches (Figure 116).

Cause

Internal fruit damage can occur when weather conditions are 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 antifreeze.

Management

Do not plant trees in areas prone to severe frost. Frost fans increase airflow from the warmer inversion layer to delay frost formation. For more information on frost injury, see the *Frost damage in citrus Primefact* on the NSW DPIRD website (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/731630/frost-damage-in-citrus-D4-Edited-final-D3.pdf).

Figure 113. Frost injury to a Navel orange.

Figure 114. Chill injury to Star Ruby grapefruit.

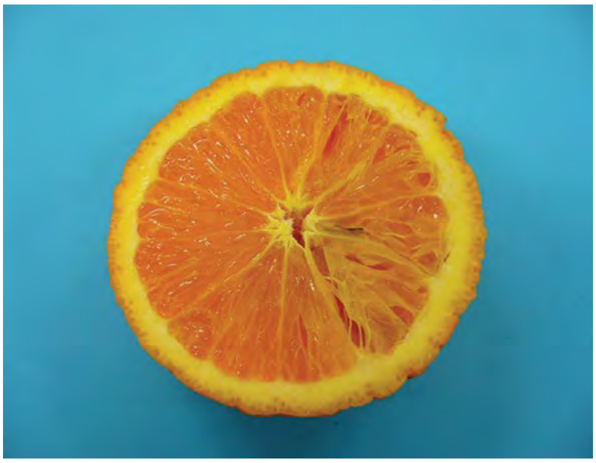

Figure 115. Dry fruit sacs in a Navel orange.

Figure 116. Frosted citrus leaf flush.

Greasy spot

Symptoms

Greasy spot is most common on grapefruit, lemon and early maturing orange varieties, but all citrus are susceptible to infection. Leaf symptoms appear 2–3 months after infection. Yellow spots appear on the upper leaf surface (Figure 117) and matching, slightly raised, pale brown blisters form on the undersides (Figure 118); lesions darken over time.

Cause

The *Mycosphaerella* fungus. Infection is favoured by rainfall or dew in autumn or spring.

Management

Copper-based fungicides in spring and autumn reduce disease incidence.

Figure 117. Greasy spot symptoms on a citrus leaf.

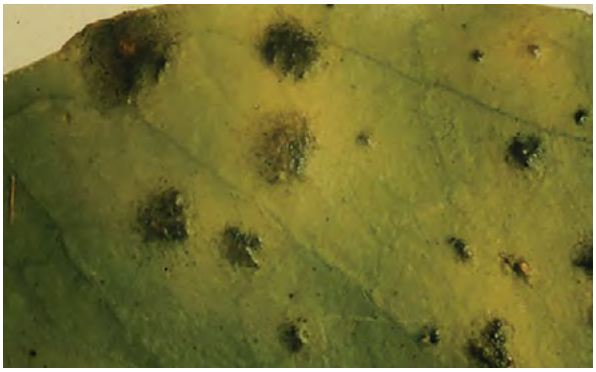

Figure 118. Greasy spot lesions on the underside of a citrus leaf.

Incompatibility

Symptoms

Incompatibility between the scion and rootstock is usually associated with declining tree health; the rootstock can outgrow the scion (Figure 119). Trees can also die prematurely.

Cause

Some scions are incompatible with certain rootstocks. Known incompatibilities include Imperial mandarin on *Citrus trifoliata* (syn. *Poncirus trifoliata*) (Figure 120), Eureka lemon on *C. trifoliata* and Navelina orange on C35 rootstock.

Management

Use compatible stock and scion combinations, or separate incompatible varieties using an inter-stock.

Figure 119. Incompatibility with Imperial mandarin on trifoliate orange stock.

Figure 120. Close-up of incompatibility with Imperial mandarin on trifoliate orange stock.

Lemon scab

Symptoms

Lemon scab affects lemons in coastal areas, causing young fruit to shed and rendering older, infected fruit unmarketable. Scab lesions are raised, irregular and wart-like on leaves (Figure 121), twigs and fruit (Figure 122). Initially they are grey to pink and darken over time. Affected growth is typically distorted.

Cause

Lemon scab is caused by the fungus *Elsinoe fawcettii*.

Management

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

Figure 121. Lemon scab symptoms on a leaf. Photo: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 122. The irregular raised lesions on fruit are symptoms of lemon scab.

Melanose

Symptoms

Melanose occurs on citrus in high-rainfall areas. Symptoms are small, raised spots about 1 mm in diameter, usually coloured dark brown to black (Figure 123). Spots darken with copper sprays and they can appear as streaks or tear stains. Early and severe infections result in masses of brown spots. As the fruit grows, cracks form in the brown masses; this symptom is referred to as mud-cake melanose. Twig dieback and wood rot can also occur.

Figure 123. Small raised melanose spots.

Cause

Phomopsis citri produces fungal spores on dead twigs during wet periods, which spread to young leaves (Figure 124) and fruit by rain splash. Fruit are susceptible for 3–5 months after fruit set.

Management

Pruning to remove deadwood reduces the spore load in affected trees. Applying a copper fungicide at petal fall and again 6–9 weeks later provides effective control.

Figure 124. Melanose lesions on citrus leaves.

Oleocellosis and water marks

Symptoms

Darkened spots on the fruit rind (Figure 125).

Cause

The phytotoxic action of peel oil released onto the rind causes oleocellosis in the field. Foggy, wet conditions can make rind turgid (swollen or distended) and more prone to rupturing oil glands during harvest. Turgid fruit suddenly exposed to low temperatures can cause peel oil release on unharvested fruit. Rough handling of the fruit during harvest or postharvest can cause the oil cells to rupture.

Management

Appropriately timed gibberellic acid treatment will reduce rind sensitivity to mechanical damage. Carefully handle fruit at harvest (Figure 126). Ensure pickers wear gloves. Do not harvest after rain or early on winter mornings when the fruit is cool and wet.

Figure 125. Oleocellosis watermarks on Navel fruit without gibberellic acid applied.

Figure 126. Handling oleocellosis can show a few days after harvest.

Phytophthora brown rot

Symptoms

Leaf infections appear as dark brown, spreading blotches (Figure 127). Infected fruit develop a rapidly spreading, brown rind discolouration (Figure 128). Brown rot-infected fruit usually falls from the tree.

Cause

Fungal spores of *Phytophthora* species are splashed onto leaves and fruit in soil and water.

Management

Skirting trees reduces the risk of soil splashing onto the tree canopy. Applying copper-based fungicides in autumn helps to limit the disease. Organisms such as snails and ants can carry soil containing spores up into the canopy and should therefore be controlled.

Figure 127. Left, the dark brown spreading blotches are leaf symptoms of brown rot. Right, a lemon from a tree infected with *Phytophthora* spp.

Figure 128. Phytophthora brown rot on oranges.

Citrus diseases and disorders

Phytophthora root rot

Symptoms

Feeder roots on affected trees die off quicker than they are replaced (Figure 129). Above the ground, citrus trees will show signs of stress, such as leaf yellowing and twig dieback, because the depleted root system cannot support the canopy (Figure 130).

Cause

Root decay is caused by *Phytophthora* species. Waterlogged, poorly-drained soil creates ideal conditions for phytophthora root rot.

Management

The disease is best managed using resistant or tolerant rootstocks, for example *Citrus trifoliata* (syn. *Poncirus trifoliata*), citrange hybrids or Swingle citrumelo. Sweet orange and rough lemon stocks are highly susceptible. Plant healthy nursery trees, ensuring the bud union is above ground level to avoid water splashing onto the susceptible scion. Prevent root rot by ensuring adequate soil drainage and well managed irrigation. Applying a registered systemic fungicide can help manage phytophthora.

Figure 129. Left: dead feeder roots on a seedling infected with *Phytophthora*. Right: active feeder roots from a healthy tree.

Figure 130. Leaves often turn yellow and drop from trees that are affected by phytophthora root rot.

Septoria spot

Symptoms

Septoria spot starts as small, light brown depressions on the rind (Figure 131). The spots can enlarge, merge and darken as the fruit ripens (Figure 132). Small black fruiting bodies can form in the sunken lesions (Figure 133). Navels and grapefruit are the most affected types of citrus, but all commercial varieties are susceptible.

Cause

Septoria citri produces fungal spores on twigs, leaves and leaf litter, which are spread to fresh tissue via water splash. Infection occurs during late summer or autumn when fruit is 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 tree pruning to improve air circulation in the canopy, can reduce disease incidence.

Figure 131. *Septoria* symptoms first show as small, light brown depressions on the rind.

Figure 132. *Septoria* symptoms after harvest.

Figure 133. Advanced septoria spot with small black fruiting bodies in the lesions.

Sooty mould

Symptoms

Sooty mould is a black, superficial fungal growth.

Cause

Sooty mould grows on the sugary, sticky honeydew secreted by sap-sucking insects (Figure 134). Ants are also attracted to the honeydew. Sooty mould does not rot the fruit, but it can affect fruit development by reducing photosynthesis.

Management

Control populations of honeydew-producing insects (e.g. aphids, soft scales and mealybugs) to reduce sooty mould. Oil or copper sprays can loosen mould so that it flakes off affected fruit and foliage.

Figure 134. Sooty mould grows on the sticky honeydew excreted by sap-sucking insects on the leaves and fruit.

For more information on harvesting citrus to prevent oleocellosis and other disorders, refer to the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus) for several resources including the *Australian fresh citrus harvest handbook* and videos (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/crop-management/harvest-factsheets/harvest-guides).

Fungicide chemical tables

Common citrus diseases and their growing periods

Table 20. Common citrus diseases and growing periods.

	Cell division	Cell expansion										
	Bud break, Leaf expansion	Flowering		Fruit set/ drop		Golf ball		Colour break		Maturation	Harvest	
Diseases	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
Anthracnose												
Brown rot												
Greasy spot												
Septoria spot												

Denotes phenology Denotes disease activity.

Diseases and chemical controls

Please note, chemical registrations can change at any time. Always read the label.

Note: users of agricultural chemical products must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

Table 21. Diseases of citrus and chemical controls registered for use in NSW (correct at August 2024) page 1 of 2.

Disease	Active ingredient(s)	Group(s)	WHP (days)	Example trade name(s)
Black spot	Azoxystrobin	11	0	Amistar® 250 SC
	Copper ammonium acetate	M1	1	Cop-IT®, Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750, Red Copper WG
	Copper hydroxide/cupric hydroxide	M1	1	Blue Shield®
	Copper hydroxide + mancozeb	M1 + M3	0	Mankocide® DF
	Copper oxychloride	M1	1	Coppox WG, Oxydul® DF
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Flowable Copper
	Fluopyram + tebuconazole	3 + 7	28	Luna® Experience
	Mancozeb	M3	0	Dithane® Rainshield® NeoTec®
	Mancozeb + zinc	M3	0	Manic® WG Fungicide Plus
	Propineb	M3	7	Antracol® 700 WG
	Zineb	M3	7	Barmac Zineb
Brown spot	Azoxystrobin	11	0	Amistar® 250 SC
	Copper oxychloride	M1	1	Coppox WG (mandarins)

Table 21. Diseases of citrus and chemical controls registered for use in NSW (correct at August 2024) page 2 of 2.

Disease	Active ingredient(s)	Group(s)	WHP (days)	Example trade name(s)
Lichens	Sulfur	M2	0	InnoSulph® 800 WG
Melanose	Copper ammonium acetate	M1	1	Cop-IT®, Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750, Red Copper WG
	Copper hydroxide/cupric hydroxide	M1	1	Blue Shield®
	Copper oxychloride	M1	1	Coppox WG, Oxydul® DF
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Flowable Copper
	Sulfur	M2	0	InnoSulph® 800 WG
Moss	Sulfur	M2	0	InnoSulph® 800 WG
Phytophthora brown rot	Copper oxychloride	M1	1	Coppox WG, Oxydul® DF
Phytophthora collar rot	Phosphorous acid	P07	0	Agri-fos® 600
Phytophthora root rot	Phosphorous acid	P07	0	Agri-fos® 600
Phytophthora stem rot/canker	Copper ammonium acetate	M1	1	Cop-IT®, Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750 WG
	Copper hydroxide/cupric hydroxide	M1	1	Blue Shield®
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Flowable Copper
Scab (lemon)	Copper ammonium acetate	M1	1	Cop-IT®, Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750, Red Copper WG
	Copper hydroxide/cupric hydroxide	M1	1	Blue Shield®
	Copper oxychloride	M1	1	Coppox WG, Oxydul® DF
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Flowable Copper
Septoria spot	Copper cuprous oxide	M1	1	AG Copp 750, Red Copper WG
	Copper oxychloride	M1	1	Coppox WG, Oxydul® DF
Sooty blotch (smoky blotch)	Copper ammonium acetate	M1	1	Cop-IT®, Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750, Red Copper WG
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG (Lemons)
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Flowable Copper
	Sulfur	M2	0	Amgrow Lime Sulphur

WHP = withholding period.
Source: APVMA Pubcris (https://portal.apvma.gov.au/pubcris).

Fungicide active ingredients

Trade names and diseases have been grouped. Some fungicides in the example trade name column might not be registered for all of the diseases listed in the disease column (Table 22). Always read the label.

Please note, chemical registrations can change at any time. Always read the label.

Note: users of agricultural chemical products must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

Table 22. Active ingredients of fungicides registered in NSW for managing citrus diseases (correct at August 2024).

Active and (group)	Disease	Example trade name(s)
Azoxystrobin (11A)	Black spot, brown spot	Amistar® 250 SC
Copper ammonium acetate (M1)	Black spot, lemon scab, melanose, phytophthora stem rot/canker, sooty blotch (smoky blotch)	Cop-IT®, Liquicop
Copper ammonium complex (M1)	Black spot, lemon scab, melanose, phytophthora stem rot/canker, sooty blotch (smoky blotch)	Copperguard®
Copper cuprous oxide (M1)	Black spot, lemon scab, melanose, septoria spot, sooty blotch (smoky blotch)	AG Copp 750, Red Copper WG
	Phytophthora stem rot/canker	AG Copp 750 WG
Copper hydroxide/cupric hydroxide (M1)	Black spot, lemon scab, melanose, phytophthora stem rot/canker	Blue Shield®
Copper hydroxide + mancozeb (M1 + M3)	Black spot	Mankocide® DF
Copper oxychloride (M1)	Black spot, lemon scab, melanose, phytophthora brown rot, septoria spot	Coppox WG, Oxydul® DF
	Brown spot	Coppox WG (mandarins)
Copper oxychloride + copper hydroxide (M1)	Black spot, lemon scab, melanose	Airone® WG
	Sooty blotch (smoky blotch)	Airone® WG (lemons)
Copper sulfate (M1)	Black spot, lemon scab, melanose, phytophthora stem rot/canker, sooty blotch (smoky blotch)	Cuprofix® Bordeaux, Tribasic Flowable Copper
Fluopyram + tebuconazole (3 + 7)	Black spot	Luna® Experience
Mancozeb (M3)	Black spot	Dithane® Rainshield® NeoTec®
Mancozeb + zinc (M3)	Black spot	Manic® WG Fungicide Plus
Phosphorous acid (33)	Phytophthora collar rot, phytophthora root rot	Agri-fos® 600
Propineb (M3)	Black spot	Antracol® 700 WG
Sulfur	Lichens, melanose, moss	InnoSulph® 800 WG
	Sooty blotch (smoky blotch)	Amgrow Lime Sulphur
Zineb (M3)	Black spot	Barmac Zineb

Source: APVMA Pubcris (https://portal.apvma.gov.au/pubcris).

Using copper sprays to control diseases in citrus

Nerida Donovan and Andrew Creek, NSW DPIRD

Introduction

Copper-based fungicides can be used to manage several fungal diseases that affect citrus fruit and foliage. This includes citrus scab in high rainfall areas, Septoria spot in drier inland regions and phytophthora brown rot, which can strike whenever conditions are favourable. Copper can also be used to manage anthracnose, a very common fungal disease that can be a secondary invader of fruit damaged by other factors, particularly in wet seasons. Anthracnose symptoms can also be seen postharvest on fruit that are over-mature or held too long in storage.

Warm, humid conditions favour several citrus fungal diseases. In Australia, most disease-management programs rely on copper sprays to protect the foliage and fruit from infection. Successful disease management depends on both even distribution and good retention of copper over all of the plant surfaces.

How copper works

Copper sprays are protectant fungicides that must be applied evenly to the plant or fruit surface before the disease develops to prevent infection. Copper is not a systemic chemical and cannot be carried internally through the plant to kill the pathogen; it only protects where it lands. Once the copper is applied, it sticks and does not spread across the fruit or leaf surface.

As the fruit and foliage grow, the new tissue is not protected. Rain and wind also erode the copper coverage over time. When to re-spray depends on the diseases to be managed, the copper formulation used and weather conditions. More frequent applications are needed during wet seasons, in orchards with overhead irrigation or higher rainfall regions. For low rainfall regions such as the Riverina and Sunraysia, one copper spray in autumn is generally sufficient.

In recent years, an increase in fruit blemish has been seen in the Riverina where weakened rind tissue is invaded by *Colletotrichum gloeosporioides* (the fungus that causes anthracnose; Figure 135). Wet seasons and foggy mornings have exacerbated these issues. Varieties that hang on the tree for longer (i.e. late Navels and Valencia) have a greater chance of exposure to stresses such as frost. Follow-up sprays might be needed.

Copper is most effective on diseases that need free water to develop. When there is water on the plant's surface (from rain, dew or irrigation), plant exudates form weak acids, lowering the surface water pH. As the pH drops, the solubility of the copper product increases, slowly dissolving to release a small and constant supply of copper ions. When fungal spores or bacteria come into contact with surface water containing these copper ions, the ions travel through the pathogens' cell walls and disrupt cellular enzyme activity.

Copper sprays should be used with other management practices to reduce disease problems in the orchard. Fungal spores linger in in dead wood within the tree canopy so pruning to remove this reduces the number of fungal spores in the canopy, thereby reducing disease incidence when conditions are favourable for disease development.

Figure 135. Tear staining on fruit where injured cells are invaded by *Colletotrichum gloeosporioides* (the fungus causing anthracnose).

Copper formulations

Table 23 lists some Australian copper formulations and their particle sizes.

In the past, most copper products were wettable powders and contained about 50% copper as the active ingredient. However, today's formulations contain from 8% to 75% copper and application rates vary accordingly. Products are formulated as wettable powders, water-dispersible granules, liquid flowable suspensions or aqueous liquids.

Copper products can also contain small amounts of impurities. Some cheaper products can contain high levels of undesirable heavy metals such as arsenic, mercury, lead and cadmium.

Table 23. Some Australian copper formulations and their particle sizes.

Active ingredient	Median particle size (microns)
Copper hydroxide	0.15–2.50
Copper oxychloride	1.40
Cuprous oxide (red copper)	1.00–1.44
Tribasic copper sulfate (green and blue copper)	0.70–3.00

Source: Company technical brochures.

Particle size and retention

Copper fungicide efficacy is considerably improved by reducing the particle size. Smaller particles improve coverage as there is significantly more surface area per gram of product from which copper ions can be released in the presence of moisture (Figure 136).

Research has shown that:

- regardless of whether the product is a liquid, liquid flowable or dry formulation, there is little difference in the level of control per unit of metallic copper. The most important factor affecting product effectiveness is the formulation's particle size and how well it sticks to the plant surface (i.e. its rainfastness)
- products with a smaller particle size tend to have better coverage, rainfastness and longevity
- frequent applications of copper at lower rates are more effective than the same amount of copper applied in fewer applications.

The main factors influencing copper retention on plants are:

- particle size; smaller particles stick better
- rainfall; which can either directly dislodge particles or solubilise them
- wind; large particles over 3 or 4 microns in diameter can be blown off plant surfaces
- physical dislodgement or dilution of particles due to plant surface growth (e.g. fruit expansion)
- excessive spray application volumes resulting in run-off and/or stripping of copper from leaf and fruit surfaces.

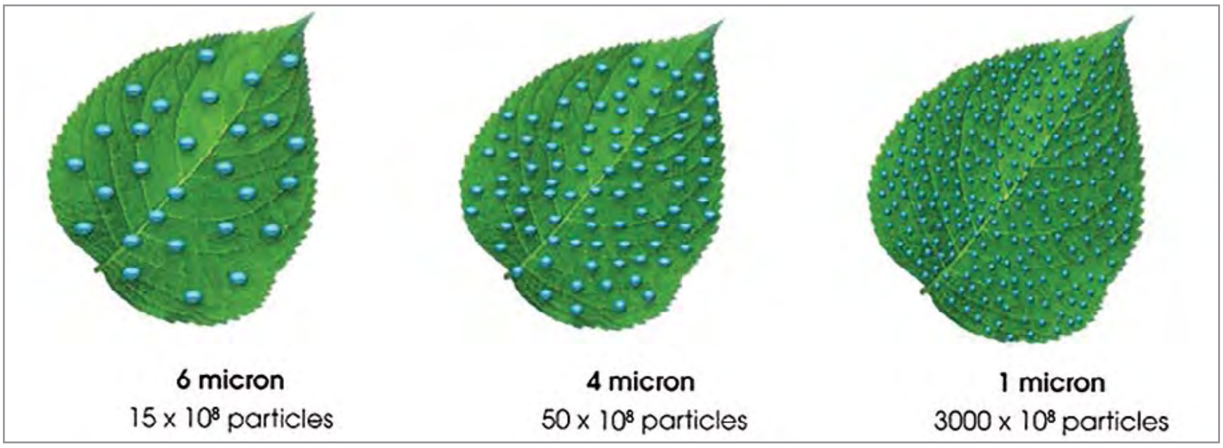

Figure 136. Leaf coverage improves with smaller particles of copper fungicide.

Effect of water pH

Most copper products are formulated to be almost insoluble in water at pH 7.0. As the pH of water decreases, the solubility of the copper fungicide increases and more copper ions are released. If the water or spray solution is too acidic (i.e. pH <6.5), excessive amounts of copper ions can be released, burning the plant tissue. Copper formulations with high amounts of soluble copper can also be prone to releasing too many copper ions.

Copper formulations vary in their solubility. The most soluble formulations are less persistent (Table 24). For example, copper hydroxide has fairly high solubility and activity, but is not very persistent under wet coastal conditions.

Table 24. Comparison of solubility and persistence of copper formulations.

Copper formulation	Solubility	Persistence	
Copper oxychloride	0.00001 mg/L	Least	Most
Cuprous oxide	0.64 mg/L		
Copper hydroxide	0.64 mg/L		
Tri-basic copper sulfate	3.42 mg/L		
Copper sulfate	142 g/L (0 °C)		
	220 g/L (0 °C)	Most	Least

Source: Melpat International Pty Ltd.

Damage from copper sprays

Copper sprays can damage the tissue between the oil glands, causing dead (necrotic) spots to appear. This gives the leaves or fruit rind a speckled or stippled appearance (Figure 137 and Figure 138).

The spots appear similar to those caused by melanose, but they are almost black and are often on the exposed surface of the fruit. Copper sprays can also darken existing blemishes, such as those caused by wind.

Copper-based fungicides can typically be safely applied with low rates (<0.5%) of horticultural mineral oil. However, some tank mixes that include copper can damage citrus fruit. This hazard was found to be greater when high rates of oil were included in the mixture and applied at low spray volumes.

Some copper-based fungicides can reduce plant vigour if too many copper ions pass into the leaf and/or by other impurities in the product. Copper salts such as copper chloride (an impurity) can be present in some brands of copper hydroxide and oxychloride if not completely oxidised during manufacturing. These levels can be as high as 2% in some low-quality copper formulations.

Low-quality copper formulations with high levels of impurities (for example lead and cadmium) might reduce plant growth and cause fruit blemish. Always use a good-quality copper formulation.

The timing, frequency and rate of application are also very important, particularly with spring and summer applications.

Figure 137. Copper damage to citrus leaves.

Figure 138. Copper stippling on a lemon.

It is important to apply copper with water volumes that provide good coverage but do not cause excessive run-off (Figure 139). Excess spray droplets will run to the lowest point and either run off, leaving unprotected strips on the fruit surface, or dry, leaving copper residues. These concentrated copper residues can burn plant tissue (Figure 140).

Figure 139. Excessive water rates result in spray run-off, wasting spray, and contaminating soil and the environment. Photo: Citrus Research International.

Figure 140. Fruit stippling caused by excessive copper residues or the release of excessive amounts of copper ions.

Copper can also accumulate in some soil types, causing damage to citrus roots and soil microorganisms, and interfering with plant nutrient uptake.

Citrus leaves and fruit are sometimes difficult to wet, as the leaves are waxy and the fruit is round, with a thick waxy cuticle. Adding a non-ionic wetter will help improve product retention. Always follow the product label recommendations.

Copper-based fungicides can be applied with a range of fungicides and insecticides. Check product labels for the manufacturers' guidelines before mixing and application.

Copper-induced phytotoxicity is common when copper is applied:

- with products that make the tank mix acidic
- at high temperatures (>30 °C)
- at high rates for 3 or 4 successive applications
- to wet, turgid fruit and the drying conditions are slow (e.g. with early morning dew or immediately after rain)
- when the drying conditions are cool and slow, or the humidity is high
- when certain aqueous liquid formulations (i.e. copper and ammonia complexes) are used
- when copper is mixed with high rates (>0.5%) of horticultural mineral oil.

Best-practice tips for applying copper

- Copper sprays are protectant fungicides and need to be applied before infection starts.
- Use correct water volumes to achieve good, even coverage of the plant and fruit surfaces.
- The protective layer diminishes over time and offers only short-term protection under certain conditions (e.g. in wet or humid climates or where overhead irrigation is used); if infection is likely over longer periods, re-application might be necessary.
- Smaller particle size results in better rainfastness and retention of the copper product.
- Apply copper sprays only as per the manufacturers' recommendations.
- The ph of the water used to apply copper should be >6.5.
- Frequent applications using low rates of copper are effective and less toxic to plants than infrequent applications at high rates.
- Do not over-apply copper.
- Do not apply when fruit or leaf temperatures are high, humidity is high or the fruit is wet.

Further reading

Albrigo LG, Timmer LW, Townsend K and Beck HW (1997) Copper fungicides – residues for disease control and potential for spray burn *Proceedings of the Florida State Horticultural Society*, 110: 67–70.

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Budwood and graft-transmissible disease

Nerida Donovan, Graeme Sanderson and Steven Falivene, NSW DPIRD

Blocks throughout Australia are not reaching full productivity because trees were propagated using a questionable source of budwood, such as from a neighbour's trees. Sourcing your own budwood might save a few cents a tree initially, but the reduced yield from poorly producing trees can end up costing more than $2,000/ha/year. Poor productivity could be due to a transmitted disease or a poor bud line.

Many viruses and viroids can cause stunting (Figure 141), yield loss and even death in some scion and rootstock combinations, yet other varieties can be symptomless carriers. For most graft-transmissible diseases, symptoms will not be seen in nursery trees but will appear a few years later in the orchard (Figure 142). By then the disease is likely to have spread to surrounding trees through root grafting or on cutting tools. Nothing can be done to save infected trees; they need to be removed and the site re-planted.

A Hockney Navel orange planting at Dareton research station shows the effect of using infected budwood (Figure 143). Trees were planted in 2002 using viroid-infected budwood. In 2005, additional trees were planted on Troyer citrange using high health status budwood from a tested source (i.e. Auscitrus). Twelve years after the first planting, the healthy trees are now larger than the infected trees planted 3 years earlier. A row of C35 rootstock was also established with the infected budwood and the viroid has had a strong dwarfing effect on these trees.

Using viroid dwarfing to moderately restrict tree size can be desirable, particularly to improve productivity per hectare in high density plantings. However, different viroids induce different levels of dwarfing (mild, moderate, severe) in different citrus varieties. Therefore it is important to know what is in your budwood. More information is available from the *Dwarfing citrus trees using viroids* Primefact (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/orchard-development).

The only way to be sure of the health status of budwood and rootstock is to obtain it from a tested source, as supplied by Auscitrus. Auscitrus also maintains 'mother trees' and distributes budwood of new varieties on behalf of Australian variety managers and owners.

Figure 141. Stunting in an orchard caused by a severe strain of Citrus exocortis viroid from untested budwood propagation.

Figure 142. Symptoms of bark scaling induced by a severe strain of Citrus exocortis viroid.

Figure 143. Left: Hockney Navels on Troyer citrange planted in 2005 using high health status budwood.
Middle: Hockney Navels on Troyer citrange planted in 2002 using low health status budwood.
Right: Hockney Navels on C35 planted in 2002 using low health status budwood that was viroid-infected.

Orchard biosecurity: managing the risk of an exotic incursion

Rebekah Pierce, Dr Louise Rossiter, Deirdre Gunning, NSW DPIRD

Why is biosecurity important?

Australia, due to its geographical isolation, is free from many plant pests and diseases that affect overseas plant industries. As well as avoiding the production challenges of controlling a new pest, Australia's freedom from exotic plant pests and diseases preserves existing trade opportunities and provides evidence to support new market opportunities. Biosecurity protects industries, livelihoods and the natural environment.

Reporting

If an emergency plant pest (EPP) was to become established in NSW, it could severely affect agricultural production, native flora and trade access. Early detection and reporting are essential for successfully eradicating or minimising the impact of an EPP.

A pest or disease is considered an EPP when it is:

- a known pest or disease overseas that has not been detected in Australia
- a pest or disease occurring in some Australian states and territories and not others
- an entirely new or unknown pest or disease of uncertain origin.

Monitoring trees, educating staff and knowing what is normal and what is suspicious in your orchard are the simplest ways to detect an EPP. Familiarising staff with high priority exotic pests and diseases relevant to your industry and inclusion in orchard monitoring activities is imperative for early detection.

Suspected EPPs can be reported by:

- phoning the Exotic Plant Pest Hotline on **1800 084 881**. In NSW, calling the Exotic Plant Pest Hotline will send you to the NSW Department of Primary Industries and Regional Development (NSW DPIRD). Report details will be taken and forwarded to Plant Biosecurity staff for action. All calls are taken seriously and treated confidentially.
- emailing report details directly to biosecurity@dpi.nsw.gov.au
- submitting report details on an online form (https://www.dpi.nsw.gov.au/biosecurity/report-a-pest-or-disease).

Important information to include when reporting includes:

- your name and contact details
- location of the pest or disease
- name of the plant affected and a description of the pest or disease, plant symptoms and damage to the plant
- clear photos if reporting by email or an online form.

A hotline officer will respond to your report and guide you on how to proceed. You may be asked to submit a sample for diagnostic analysis. A sample of an insect pest should be collected when it is first observed in case the pest is difficult to find when required later for identification.

Once an EPP is confirmed, notification is provided to state and national governments as well as affected industries. An official response according to a nationally approved response plan may be implemented. For an EPP in NSW, NSW DPIRD will be the lead organisation.

Growers are encouraged to report suspected EPPs as short-term effects of an EPP response are highly preferable to the long-term management costs that would be suffered if the pest became established. Grower involvement is central to an effective EPP response and NSW DPIRD will work with growers through all stages of the response. Strict rules for confidentiality are in place to protect individual growers. For more information, see the Emergency Plant Pest reporting webpage (https://www.dpi.nsw.gov.au/biosecurity/plant/reporting,-diagnostics-and-biosecurity-collections/emergency-plant-pest-reporting-and-what-happens-next).

How to protect your orchard

Orchard hygiene and pest-free propagation material

Orchard hygiene is integral to biosecurity best practice in orchards. To ensure people, vehicles and equipment do not transfer pests, diseases and weeds to your orchard, implement a '**come clean go clean**' strategy. This involves all vehicles, machinery, staff and visitors arriving on the orchard clean (e.g. clean boots) and ensures they are clean when they leave. This can involve a footbath for shoes and a wash down area for vehicles and machinery and disinfectant for cleaning orchard equipment, such as pruning tools.

Other actions can be taken to manage the risks associated with visitors and seasonal staff. Provide a visitor register (book and/or QR code) and make sure that it is signed by all visitors. Develop a questionnaire for visitors and include questions such as:

- have you visited other farms and orchards in the past 48 hours?
- have your boots and clothes been washed since the last orchard visit?
- has the vehicle been washed down since the last orchard visit?

Restricting the movement of visitors and non-farm vehicles on the orchard also helps other orchard hygiene measures.

As well as ensuring all machinery and visitors are clean on arrival, always use high health status, pest-free propagation material from known, trusted sources. Ensure all propagation material and orchard inputs are fully tested, free from pests and disease and preferably certified. Keep good records of orchard inputs.

Orchard biosecurity management plan

Developing and implementing an orchard biosecurity management plan provides clear direction to visitors and staff on what their biosecurity obligations are for your orchard. It also helps to identify the risks associated with introducing an unwanted pest or disease and to put in place measures to manage that risk. It does not have to be complicated and it can be improved over time.

Checklists have been developed by the industry in collaboration with Plant Health Australia (https://www.planthealthaustralia.com.au/national-programs/farm-biosecurity-program/) to support identifying risks and the actions that can manage those risks as part of a plan. These checklists are part of the *Biosecurity manual for citrus producers* (https://citrusaustralia.com.au/latest-news/2018/04/biosecurity-manual-for-citrus-producers/) that have been developed for several industries providing key biosecurity best practice information.

High priority emergency plant pests

Several pests and diseases not currently present in Australia have been identified as high priority pests for the Australian citrus industry. If they were to become established in NSW, they could severely affect orchard production as well as potential market access nationally and internationally. Knowing what they look like, identifying the symptoms that might be seen in your trees and reporting suspected pests helps with early detection and increases the chance of eradication.

See the following pages (Figure 144 to Figure 147) and follow the links for information on identifying citrus high priority pests:

- citrus canker (https://www.dpi.nsw.gov.au/biosecurity/plant/insect-pests-and-plant-diseases/citrus-canker)
- mandarin stem pitting (https://www.planthealthaustralia.com.au/pests/mandarin-stem-pitting/)
- African citrus psyllid (https://www.dpi.nsw.gov.au/biosecurity/plant/insect-pests-and-plant-diseases/african-citrus-psyllid)
- Asian citrus psyllid (https://www.dpi.nsw.gov.au/biosecurity/plant/insect-pests-and-plant-diseases/asian-citrus-psyllid).

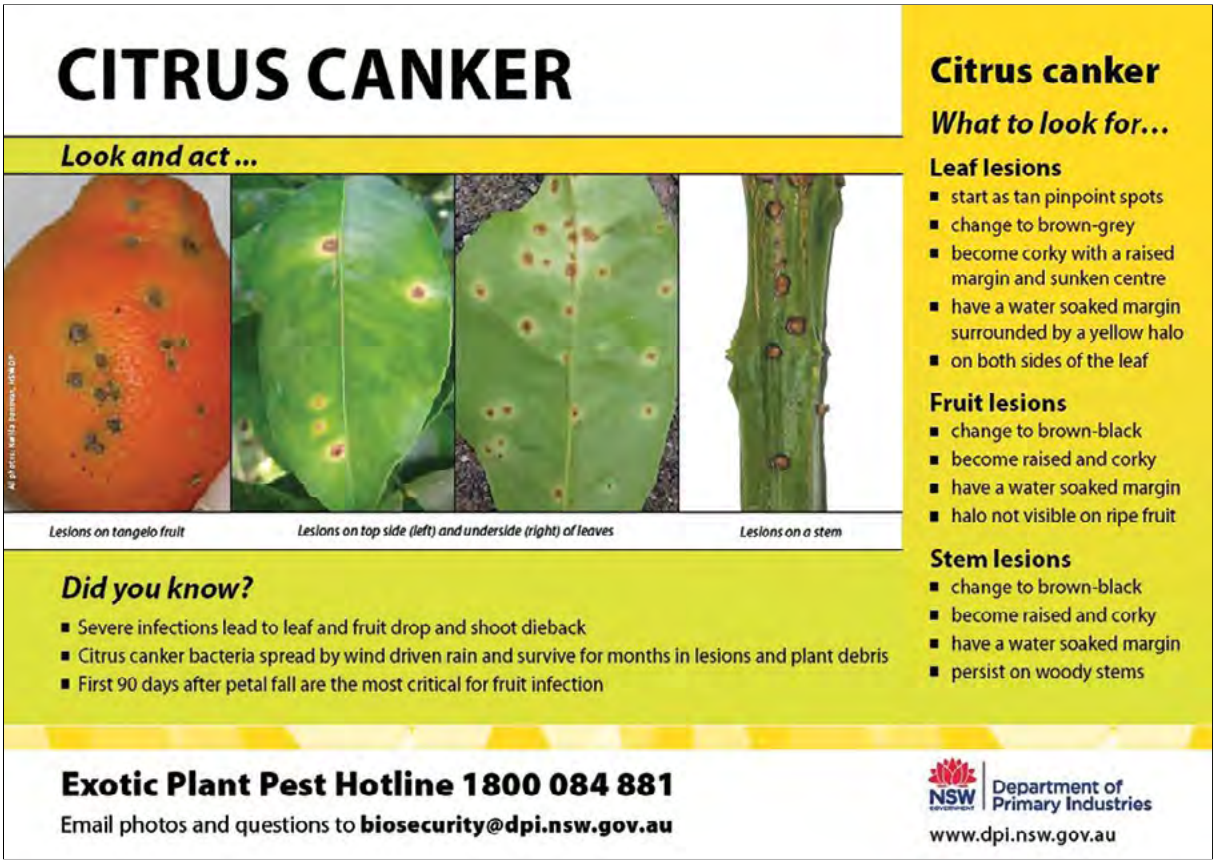

Figure 144. Citrus canker poster displaying signs and symptoms of the disease.

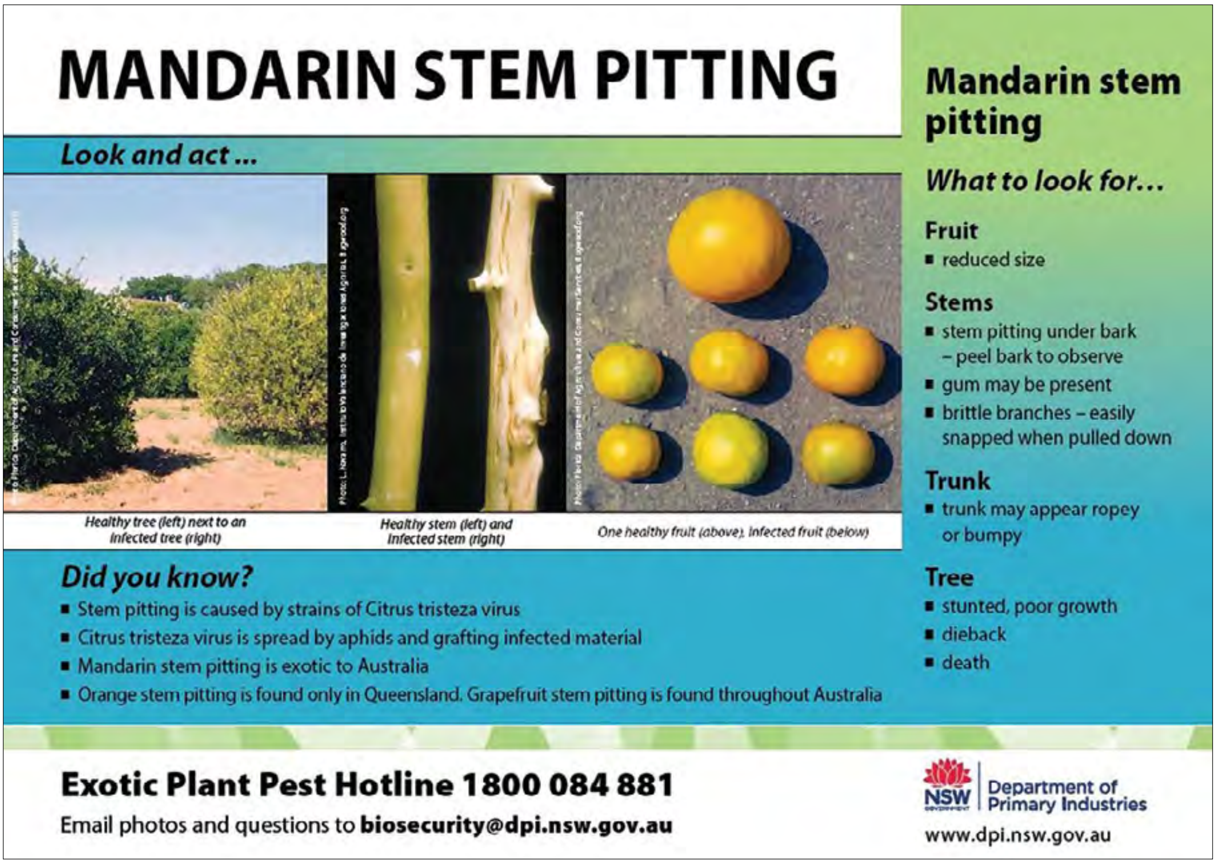

Figure 145. Mandarin stem pitting poster displaying signs and symptoms of the disease.

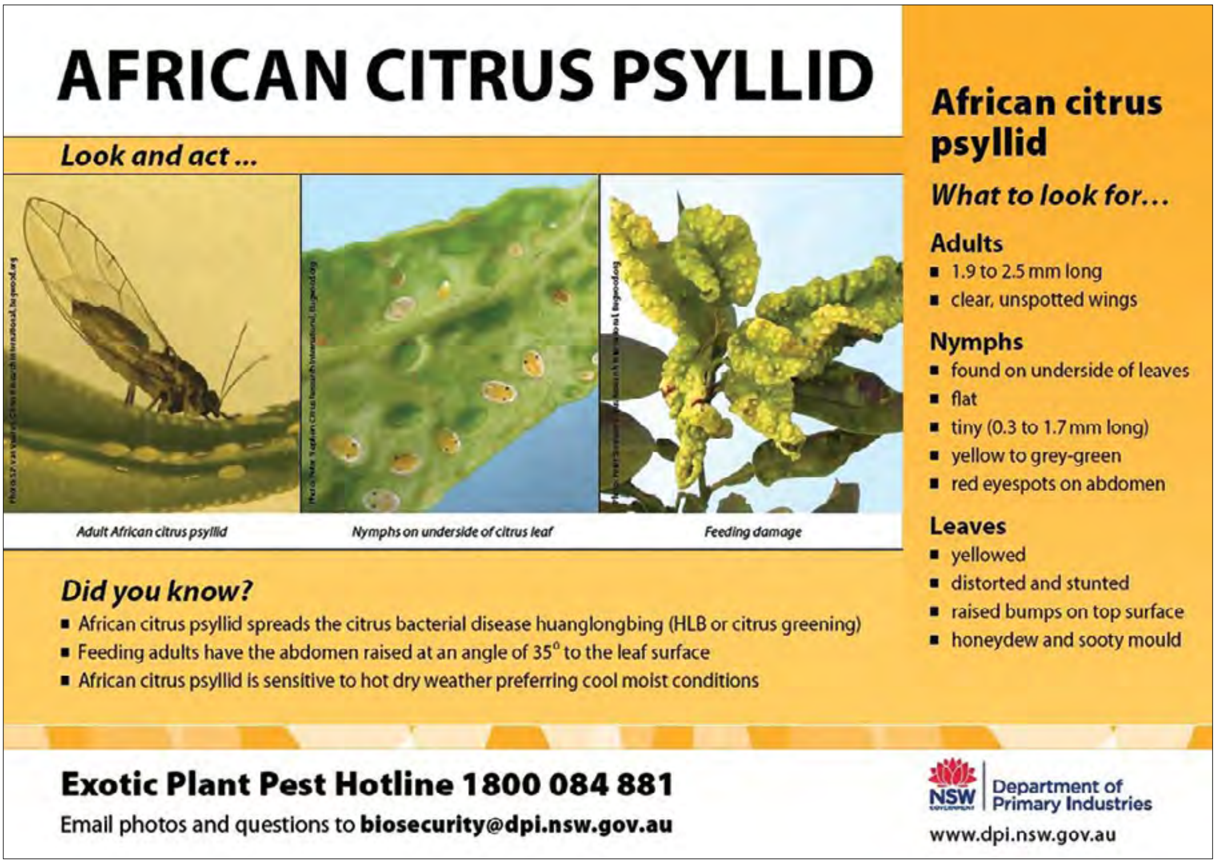

Figure 146. African citrus psyllid poster displaying signs and symptoms of the pest.

Figure 147. Asian citrus psyllid poster displaying signs and symptoms of the pest.

Managing potential resistance to postharvest fungicides

John Golding, NSW DPIRD

Postharvest fungicides such as imazalil (Magnate® or Fungaflor®) play an important role in controlling postharvest decay, such as green mould and blue mould, and are essential for storing and marketing citrus. However, continually using these postharvest fungicides without proper management allows fungicide-resistant decay spores to develop and build up within a packhouse, particularly if packhouse hygiene is poor. Over time, the fungus can grow on fungicide-treated fruit, resulting in fruit breakdown in the market. Resistance to postharvest fungicides occurs when the decay fungi continue to grow in the presence of the fungicide, therefore making the fungicide ineffective. This fungicide resistance is a serious postharvest problem that must be managed in the packhouse to minimise potential postharvest losses and claims. The Postharvest sanitation and fungicide resistance survey (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/citrus-connect/2020-citrusconnect-articles/postharvest-sanitation-and-fungicide-resistance-survey) is a not-for-profit service that looks for decay-causing fungi in the packhouse and identifies if these fungi have any technical resistance to common postharvest fungicides (Figure 148). Some of the packhouse results from last season are presented in Table 25.

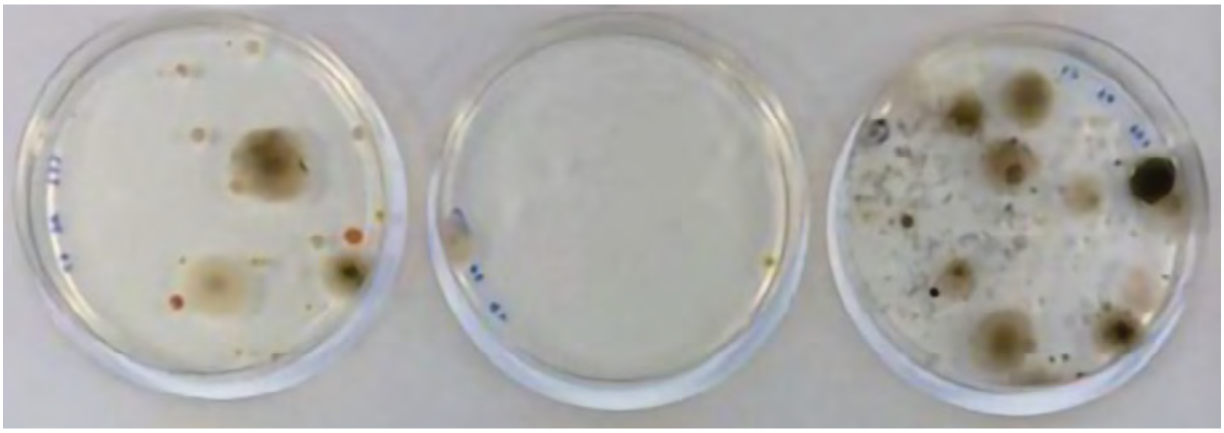

Figure 148. Test plates with postharvest fungicides added to the agar were placed in the packhouse in different locations. Technical resistance to the different fungicides was classified if the decay spores grew on the amended fungicide.

Table 25. Examples of sanitation and technical resistance to postharvest fungicides found in a sample of 7 citrus packhouses from the Postharvest sanitation and fungicide resistance survey.

	Untreated			TBZ			Imazalil			Fludioxonil			Pyrimethanil		
Shed	S*	E	C	S	E	C	S	E	C	S	E	C	S	E	C
A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B	2	3	4	1	1	1	1	1	1	1	1	1	1	1	1
C	4	2	2	1	2	2	1	1	1	1	1	1	1	1	1
D	1	3	4	2	4	4	1	1	1	1	1	1	1	1	1
E	4	4	4	4	4	4	1	1	1	1	1	1	1	1	1
F	4	3	2	3	3	2	2	2	1	1	1	1	1	1	1
G	4	4	4	4	4	4	4	4	4	1	1	1	1	1	1

* Position in packhouse: S – the start of the packing line, E – the end of the packing line, C – in the coolroom.
Level of sanitation/technical resistance: **1** = very low, **2** = low, **3** = moderate, **4** = high.

There were large differences in sanitation and technical resistance to postharvest fungicides between the packhouses. Packhouse A had very low levels of general moulds and decay with no detectable technical resistance to any postharvest fungicide. This shows that potential fungicide resistance can be eliminated with good packhouse hygiene and fungicide management.

The results from Packhouse B show that while higher levels of green and blue mould spores were detected, no technical resistance was found. This shows that the postharvest fungicides effectively controlled these decay fungi during storage. However, the results from Packhouse C showed that while the levels of green and blue mould were similar to Packhouse B, there was some technical resistance to thiabendazole (TBZ, e.g. Vorlon® or Tecto®) fungicide starting to develop in Packhouse C (as indicated with the growth of green and blue mould spores on the TBZ-amended agar plates). Since any increase in technical resistance will reduce fungicide efficacy, these results must be monitored and managed. This is illustrated in the results from packhouses D and E, where there are high levels of green and blue mould and high levels of technical resistance to TBZ. This is a problem as the continued use of TBZ will make it ineffective in controlling green and blue mould.

While TBZ can be an effective fungicide for controlling sensitive strains of green and blue mould, it also has the additional benefit of reducing chilling injury. This additional benefit of TBZ, especially the heated TBZ application, is that it is one of the few postharvest treatments available to suppress chilling injury during cold treatment for export. Therefore it is vital that TBZ use in the packhouse is properly managed to maintain its fungicide efficacy and to ensure resistance does not get out of control. Fortunately, no technical resistance to fludioxonil or pyrimethanil was detected in any of the tested packhouses.

Technical resistance to TBZ fungicide was common in many packhouses, while technical resistance to imazalil was less common. However, technical resistance to imazalil is problematic and requires active attention. Imazalil is a mainstay of many citrus postharvest fungicide programs, and its efficacy needs to be actively managed to control postharvest decay. The technical resistance levels to imazalil identified in Packhouse F were a concern, as these moderate levels can quickly develop into more severe levels (Packhouse G). These very high levels of technical resistance to both TBZ and imazalil in Packhouse G were concerning, and active management was required to reduce them. Reducing fungicide resistance in packhouses with such high levels of technical resistance is a long and slow process of cleaning and fungicide rotations.

The best way to manage resistance is to prevent it from occurring.

Managing resistance to postharvest fungicides requires a whole-of-system approach, starting from harvest to packing and storage. The first step in managing resistance is knowing what is happening in the packhouse, i.e. monitoring for technical resistance. Some of the key management factors in reducing the risk of fungicide resistance include:

- **Monitor fungicide resistance**. Detecting resistance early increases the chance of managing and stopping its development. It is therefore critical to measure and monitor both packhouse sanitation and hygiene and the levels of technical resistance to postharvest fungicides.
- **Optimise fruit health**. Good postharvest practice to minimise physical damage to the fruit during harvest and handling.
- **Use best hygiene practices**. Lowering the populations of decay-causing spores in the packhouse, coolroom and on the fruit is essential for a successful management program. This includes removing rotten fruit from the packhouse and coolrooms, and regularly sanitising equipment, coolrooms and the packing line by washing (or using fogging technology).
- **Optimise fungicide use**. Understand how each fungicide works and develop strategies to minimise resistance from developing by using rotations and mixtures whenever possible and before resistance selection occurs.
- **Optimise fungicide efficacy**. The correct fungicide concentration and coverage determine the efficacy of the treatment and minimise the chances of decay spores surviving following treatment.

The Postharvest sanitation and fungicide resistance survey (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/citrus-connect/2020-citrusconnect-articles/postharvest-sanitation-and-fungicide-resistance-survey) is available to provide timely information to packers on the levels of sanitation and technical resistance to postharvest fungicides in their packhouses. This service is provided by NSW DPIRD and Citrus Australia. Test kits can be ordered on the Citrus Australia website (https://citrusaustralia.com.au/growers-industry/2020/10/how-to-best-manage-postharvest-fungicide-resistance/). After the order is made, a set of test plates are sent to the packhouse with instructions on where and how to put out the plates. After the test plates have been exposed to the air in different parts of the packhouse and coolroom, they are returned to NSW DPIRD in an Australia Post Express Post bag for analysis. The results are then returned as a confidential report to the packhouse. Third parties can also purchase the kit and place it in your packhouse on your behalf. For more information, contact John Golding on 02 4348 1926 or john.golding@dpi.nsw.gov.au

Acknowledgement

We would like to thank Citrus Australia, chemical companies, packhouse managers and growers for allowing the use of their anonymised data for this article.

The main postharvest diseases of citrus

Green mould

Symptoms

The early symptoms of green mould include soft watery stains in the fruit peel that develop white hairs. When the soft infection reaches about 20 mm in diameter, it often produces the typical olive-green spores on the surface (Figure 149). The rot then gradually spreads until it covers the fruit.

Cause

Green mould is caused by a *Penicillium* fungus that only infects the fruit through wounds in the peel, which are often inevitable during harvest and handling.

Management

Good harvest and handling practices are essential to minimise any fruit damage. Lowering spore levels in the packhouse with good hygiene and sanitation is also important. Use a postharvest fungicide within 24 hours of harvest and rotate fungicides with different modes of action in the packhouse to minimise the development of fungicide resistance.

Figure 149. Green mould.

Blue mould

Symptoms

Similar to green mould, the early symptoms include soft watery stains on the fruit peel. The blue-green spores then develop in the middle of the infection (Figure 150), but unlike green mould, blue mould can also spread or 'nest' with the packed box of fruit.

Cause

Blue mould is caused by a *Penicillium* fungus that infects the fruit through wounds in the peel. If not controlled, it can spread within packed boxes.

Management

Good harvest and handling practices are essential to minimise any fruit damage. Lowering spore levels in the packhouse with good hygiene and sanitation is also important. Use a postharvest fungicide within 24 hours of harvest and rotate fungicides with different modes of action in the packhouse to minimise the development of fungicide resistance.

Figure 150. Blue mould.

Sour rot

Symptoms

Sour rot produces a very soft, watery appearance on the peel (Figure 151) with a distinct margin between the decayed and healthy tissue. It is more common during long-term storage and spreads by contact with healthy fruit after packing, creating nests of infected rotting fruit in the packed box. It is characterised by a unique vinegary smell that can be smelt throughout the box.

Cause

Sour rot is caused by a fungus and is prevalent in growing areas with high rainfall, such as coastal-areas, and can be expressed during de-greening.

Management

Sanitising the recirculating water in dips and drenches is important to kill the free sour rot spores.

There are few postharvest fungicides registered for controlling postharvest sour rot. Some fungicides are not suitable for some export markets, making it more difficult to control the disease.

Figure 151. Sour rot.

Managing postharvest decay

The development of rots and decay after harvest is the most important problem for marketing fresh citrus fruit, particularly for fruit that might be stored and transported for many weeks (e.g. export). The major postharvest rots that develop on citrus fruit are green and blue mould (caused by the *Penicillium* fungus) and sour rot.

Instead of completely relying on postharvest fungicides to control decay, it is critical to take an integrated approach to managing postharvest decay (refer to Figure 152).

1. Harvest and handle fruit carefully to minimise physical injuries such as punctures, abrasions and cuts, as many rots rely on damage (wounds) to the skin for entry and infection.
2. Maintain hygiene and sanitation within the packing shed and keep fungi out of the packing shed and coolrooms to reduce the risk of decay.
3. Use sanitisers in the wash water and packing line.
4. Use appropriate fungicides and follow the label directions.
5. Keep the fruit in the coolroom.
6. Monitor the levels of spores and fungicide resistance in the packing shed and develop a strategy to manage them effectively.

A good postharvest fungicide program is essential to control citrus decay. Rotate fungicides with different modes of action to ensure potential fungicide resistance does not develop (Table 26). Continually using the same fungicide, particularly with poor packhouse practices and sanitation, will lead to fungicide resistance developing.

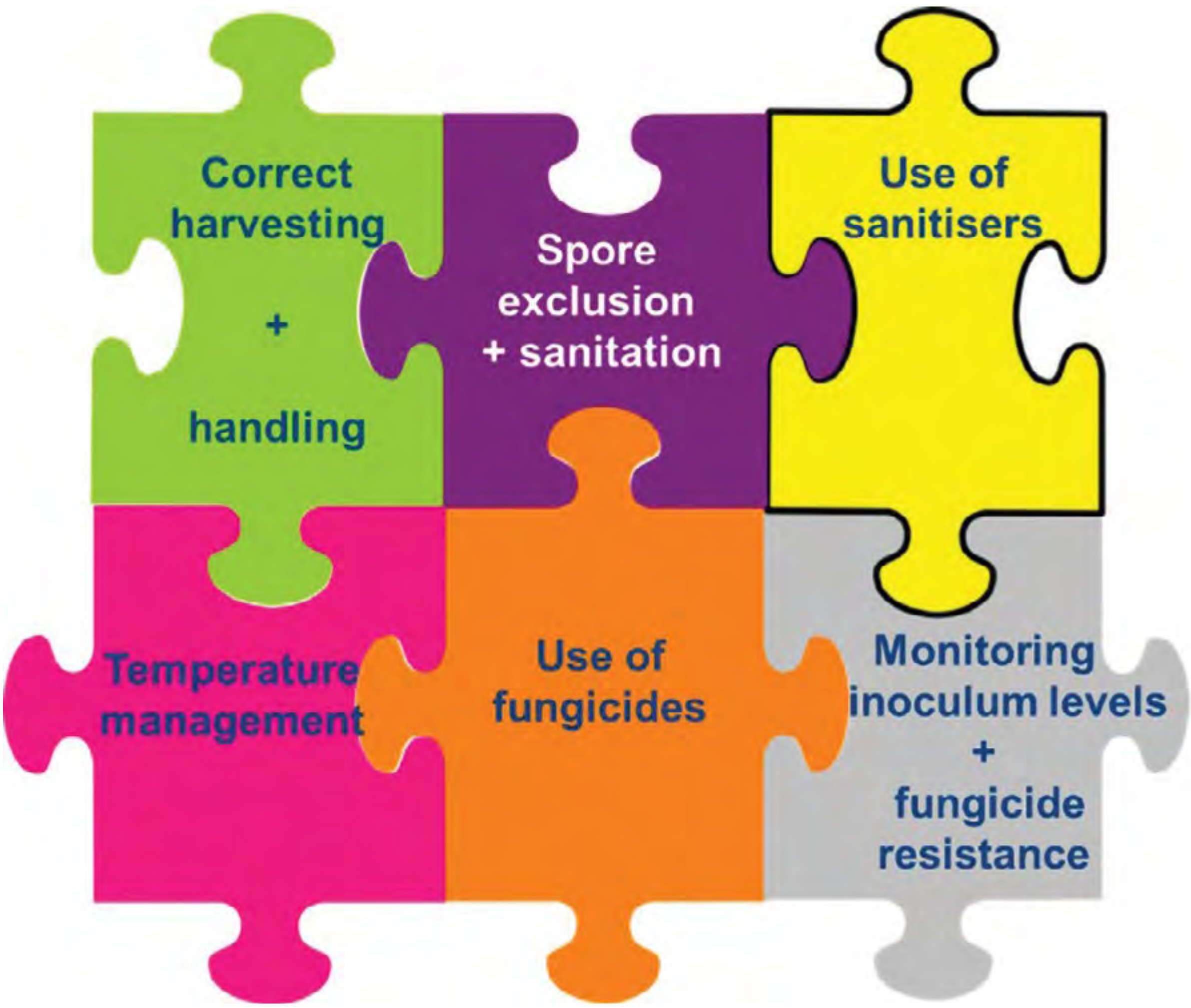

Figure 152. Postharvest fungicides are just one component of decay control.

Postharvest fungicides

Table 26. A summary of current postharvest fungicides (correct at August 2024).

Active ingredient(s)	Trade names[1]	What does it control	Fungicide group	FRAC group[3]
Fludioxonil	Scholar®, Fludy®	Blue mould, green mould, diplodia stem end rot	Phenylpyrrole	12
Guazatine[2]	Zanoctine®, Panoctine®	Sour rot with activity on blue and green mould	Multi-site activity (Guanidine)	M7
Imazalil	Magnate®, Fungaflor®	Blue mould, green mould	DMI (demethylation inhibitors) (Imidazole)	3
Imazalil and pyrimethanil	Philabuster®	Blue mould, green mould	DMI and anilinopyrimidine	3 and 9
Propiconazole and fludioxonil	Chairman®	Blue mould, green mould, sour rot	DMI and phenylpyrrole	3 and 12
Pyrimethanil	Penbotec®	Blue mould, green mould	Anilinopyrimidine	9
Thiabendazole (TBZ)	Vorlon®, Tecto®	Blue mould, green mould, and activity on stem end rot, *Phomopsis citri*	Benzimidazole	1

[1] Other trade names exist. Please see the APVMA website (https://portal.apvma.gov.au/pubcris) for all registered products.
[2] Check this is registered in your state/territory.
[3] FRAC = Fungicide Resistance Action Committee.

Common citrus weeds

Steven Falivene (NSW DPIRD), Anthony Cook (formerly NSW DPIRD) and Scott Mathew (Syngenta)

Only the most common citrus weeds are discussed here and include:

- annual ryegrass (*Lolium rigidum*)
- caltrop/yellow vine/cat's head (*Tribulus terrestris*)
- feathertop Rhodes grass (*Chloris virgata* Sw.)
- flaxleaf fleabane (*Conyza bonariensis*)
- khaki weed (*Alternanthera pungens*)
- wireweed (*Polygonum aviculare*).

Information on other weeds can be sourced from the NSW DPIRD WeedWise web page (https://weeds.dpi.nsw.gov.au/) or phone app (Figure 153).

Pre-emergent herbicides play an important role in an integrated weed control program: the aim is to substantially reduce weed numbers before applying any post-emergent herbicides. This markedly reduces the chances of selecting for post-emergent herbicide resistance. If weeds are present when the pre-emergent herbicide is applied, a registered knockdown herbicide should be added.

Figure 153. NSW Weedwise phone app screenshots.

Users of agricultural chemical products must always read the label or any permit before using the product and strictly comply with the label directions or permit conditions. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

Annual ryegrass

(*Lolium rigidum*)

Annual ryegrass leaves are hairless, narrow and bright green. The back of the leaf blade is shiny. The emerging leaf is rolled and the base of the plant is reddish purple, especially in seedlings (Figure 154). The mature plant can be up to 30 mm tall, with spikelets (flower stalks) containing 3–9 flowers (Figure 155). Seeds are 4–6 mm long, 1 mm wide and straw coloured. This weed is sometimes confused with perennial ryegrass (*Lolium perenne*).

Figure 154. An annual ryegrass seedling.

Seeds are dormant over summer, germinating from late autumn to early spring. Ideal germination conditions occur after significant autumn or winter rain. The optimum temperature for germination is 11 °C for buried seeds and 27 °C for surface seeds. Of the seeds in the annual bank, up to 99% will germinate within 3 years, although some can germinate up to 5 years after seed set.

Control

Annual ryegrass is resistant to many herbicide groups with different modes of action. Glyphosate resistance is common, and paraquat resistance is expected to increase because of over-reliance on this alternative knockdown herbicide. See Table 27 for a list of registered herbicides.

Comments

Testing annual ryegrass for resistance will help determine the most appropriate control strategies (see Avoiding herbicide resistance on page 109). Including future herbicide options in the test is recommended. Use a knockdown herbicide with a pre-emergent application. Knockdown sprays, such as glyphosate and paraquat, should only be used once the weeds reach the 3-leaf stage. Ryegrass is hard to kill before this due to its shiny leaf.

Some grass weeds are difficult to identify at the early post-emergent stage, which is when they are susceptible to knockdown herbicides. If there were mature annual ryegrass infestations in the previous winter or spring, controlling seedling grasses in the infested areas should be completed before they are taller than 50 mm.

Figure 155. Annual ryegrass producing seed (left); an annual ryegrass flower stalk (right).

Caltrop

(*Tribulus terrestris*)

Caltrop is also known as yellow vine or cat's head. It is a prostrate annual herb with stems spreading out for up to 2 m (Figure 156) from a woody taproot.

Leaves consist of 4–8 pairs of opposite oblong leaflets (Figure 157). It germinates in summer and becomes established quickly (within 2–4 weeks). Flowers are small (8–15 mm in diameter) and bright yellow (Figure 158).

Caltrop flowers from spring to autumn. The fruit consists of a woody burr with 4 long, hard, sharp, rigid spines (Figure 159), which are easily rapidly spread by boots, tyres and animals. Some seeds can survive for up to 7 years.

Figure 156. A thick stand of caltrop.

Figure 157. A caltrop seedling.

Figure 158. Caltrop has a small yellow flower.

Figure 159. The spines on a caltrop woody burr.

Control

Caltrop is quick to germinate and produce seeds. Control before flowering is essential. Glufosinate–ammonium is best used when the plant is no bigger than the 4-leaf stage.

Comments

Once the seed bank is reduced, isolated plants can be removed immediately by shovel. If these are carrying seeds, dispose of the whole plant.

This rapidly growing summer weed requires early control. To limit its spread and stop seed production, select an appropriate pre-emergent herbicide and follow this with an early post-emergent knockdown herbicide. Non-chemical strategies such as spot weeding, cultivation and mulching, as well as reducing traffic movement in infested areas, will reduce spread.

Feathertop Rhodes grass

(*Chloris virgata*)

Feathertop Rhodes grass (Figure 160 and Figure 161) is a tufted, annual or short-lived perennial that grows to about 1.2 m tall. Nodes (bumps) on the stems are red. The pale wheat-coloured seed head is digitate (multi-stemmed), with 7–19 erect branches pressed together. Good rain from spring to late autumn favours germination. The seed germinates on top of, or just below, the soil surface. Seeds remain viable for up to 12 months in the soil.

Control

Plants at the tillering (branching) stage are difficult to control with knockdown herbicides. Best results are achieved by targeting plants <50 mm tall or before tillering.

Group 1 herbicides such as haloxyfop provide reasonable control. Better control is achieved with a double knock strategy of applying paraquat 7–14 days after the initial knockdown spray.

Comments

If herbicide resistance is suspected, do a herb resistance test (see Avoiding herbicide resistance on page 109).

For effective long-term control, removing the seed bank as part of a continuous control strategy is critical.

Figure 160. A stand of feathertop Rhodes grass.

Figure 161. A flowering head of feathertop Rhodes grass.

Flaxleaf fleabane

(*Conyza bonariensis*)

Flaxleaf fleabane can grow up to 1 m tall and is multi-branched. The stems are covered with stiff hairs. Leaves are grey–green, coarsely toothed and covered in fine hairs.

A plant can produce over 100,000 windblown seeds (Figure 162) that germinate in the top 10 mm of moist soil in warm weather. Most seeds are viable for up to 18 months, but some can survive for several years.

Figure 162. A seed head of flaxleaf fleabane.

Control

For best results, fleabane should be sprayed when it is <50 mm in diameter (Figure 163). Many herbicides can control the weed up to this stage, but once it has reached the bolting stage, i.e. when the stem has elongated (Figure 164), many herbicides will not be effective.

Medium to high spray water volumes and adding an adjuvant might help cut through the waxy, hairy leaves. For more information, see the herbicide program options and application considerations in Managing weeds on page 104.

Fleabane is resistant to both glyphosate and paraquat. If you suspect your plants might be resistant to any herbicide group, consider getting a resistance test.

Comments

Pre-seeding fleabane can be slashed to prevent seed set and then treated with herbicides once the weed has sufficient foliage (about 100–200 mm tall).

Figure 163. Flaxleaf fleabane at the rosette stage.

Figure 164. Flaxleaf fleabane at the bolting stage, when the stem elongates.

Khaki weed

(*Alternanthera pungens*)

Khaki weed is a perennial that forms a dense mat of vegetation and produces a prickly burr (Figure 165). The seed is spread rapidly by animals and adheres to shoes and vehicle tyres. It has a deep and woody taproot, making it drought-tolerant and difficult to kill. Leaves are in pairs of unequal size (6–25 mm), oval and can have a rounded or pointed tip (Figure 166). The prickly burr is about 10 mm wide, with numerous spines. The plant is mostly active in summer, flowering from October to March and the top growth dies in winter. New shoots emerge from the rootstock in spring.

Figure 165. Khaki weed seeds spread around orchards in a similar way to caltrop.

Figure 166. A khaki weed seedling.

Control

Saflufenacil is a registered chemical control option. Paraquat will cause a brownout of khaki weed, but it will re-grow. Paraquat efficacy can be improved by using a double knock strategy, where paraquat is applied 7–14 days after the initial knockdown spray. Adding a registered Group 14 (previously G) herbicide such as oxyfluorfen to a knockdown herbicide might improve control. Bromacil applied as a pre-emergent herbicide can provide about 3–4 months of residual activity against khaki weed. It can also control seedlings.

Wireweed

(*Polygonum aviculare*)

Wireweed is a sprawling plant that can grow to 1 m in diameter (Figure 167) with wiry stems and small oval leaves 50 mm long. Clusters of pink-tinged flowers 2–3 mm long emerge from the leaf axils. The plant flowers from November to May in southern citrus-growing regions. It is characterised by a strong, fibrous taproot. Old plants can form large mats with strong stems that can get tangled in equipment when cultivating.

Seeds germinate from autumn through to early summer and the plant grows quickly in warm weather. Seeds are about 1 mm in diameter and can be long-lived (e.g. 5 years).

Figure 167. Wireweed is a sprawling plant.

Control

It is easier to control wireweed when it is young (Figure 168). It is difficult to control after lateral branching.

High water volumes are needed to cover and penetrate wireweed leaves. Use a recommended adjuvant. For more information on water volumes, managing leaf dust and adjuvants, see Applying herbicides on page 106.

Comments

Controlling wireweed early should be a priority and early identification is important. There are numerous pre- and early post-emergent herbicides that can be used to gain satisfactory control. Delaying control beyond the early branching stages will favour the weed's persistence.

Figure 168. A wireweed seedling. Photo: Trevor James, AgResearch NZ.

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Managing weeds

Steven Falivene (NSW DPIRD), Anthony Cook (formerly NSW DPIRD) and Scott Mathew (Syngenta)

Why manage weeds?

Rapid canopy establishment and early cropping are keys to profitability in any orchard, particularly in modern, capital-intensive systems. Weeds compete with trees for moisture and nutrients and can also create a microclimate that favours pests and diseases. Competition from weeds in young, developing orchards can result in slower canopy establishment and delayed productivity. Having an effective weed management strategy will help with orchard establishment, early yields and hygiene.

Hygiene comes first

Good orchard hygiene is the first step in any weed management strategy. It will help prevent any new weed species from establishing or moving across blocks. Good orchard weed hygiene includes:

- being aware of new weeds appearing; have them identified (if necessary) and make a plan to eradicate them and reduce their spread
- regularly cleaning orchard equipment to help stop new weeds from spreading.

Weed management strategies

The most appropriate weed management strategy will vary from site to site and will depend on factors such as orchard size, tree age, weed spectrum and density, soil type, available moisture and choice of under-tree management (e.g. bare earth, mulched or sod culture). Strategies will need to respond to changing weeds and growing conditions as they emerge. Weed management strategies can be grouped as either physical or chemical, and can incorporate elements of both.

Physical weed control

Cultivation

Cultivation was once a common practice in orchards and does reduce competition from weeds, but at some cost. Disturbing the topsoil is now known to negatively affect soil structure, levels of organic matter and can result in some root damage to trees, especially in blocks on dwarf rootstocks. Cultivation also increases erosion risk and evaporation.

Spot cultivation (e.g. using a hoe) is labour intensive, but might be an option for smaller orchards as an alternative to broad scale cultivation or spot spraying.

Thermal weeding

Research shows that flame or thermal weeding using propane burners, hot air or hot water can be effective on small seedlings, but is less effective on larger annuals or perennial weeds. There are also occupational health and safety issues and fire hazards associated with these methods. Do not use thermal weeding near trees less than 3 years old, as they can be severely damaged.

Mulching

If done correctly, mulching can suppress weeds. It might be more expensive than a chemical herbicide program, but in some situations (e.g. organic production) it can be a viable option. Mulching the under-tree row with large quantities of organic materials such as straw (Figure 169), clean hay or bark chips has multiple benefits including retaining moisture, regulating soil temperature, building up organic matter and soil microbes, as well as controlling weeds.

Figure 169. A thick layer of wheat straw mulch applied underneath the canopy of mature citrus trees.

To be effective as weed control, mulch must be applied at a sufficient thickness to act as a physical barrier to sunlight and weed growth. This thickness will depend on the type of mulch being applied.

Side-cast mowers that deposit slashings along the tree row can help build up organic matter, but this is not effective as a stand-alone mulch treatment if the aim is to achieve a weed-free strip.

Growers should also be aware of the possible nitrogen tie-up effect when using raw, non-composted mulches.

Plastic mulches can be used on young trees (Figure 170). The mulches last for 7–10 years, enough to help the trees establish. They also reduce water loss through soil evaporation.

Slashing

Slashing the inter-row is a good way to manage grasses and prevent upright growing weeds from setting seed. Grasses help to reduce orchard temperatures and provide a food source for some beneficial insects. Slashers that reach under trees in sprinkler-irrigated orchards are available (Figure 171). These have a retractable slashing head that can move out of the way of tree trunks and sprinkler heads. A sturdy stake needs to be placed beside the sprinkler for the slasher head to detect an obstruction.

Figure 170. Plastic mulch and sturdy tree guards protect trees from herbicide overspray.

Figure 171. An under-tree slasher.
Photo: www.fischeraustralis.com.au.

Chemical weed control

Chemical herbicides have been the mainstay of weed management in orchards since the mid 1940s. Using herbicides remains the most cost-effective and reliable approach to managing weeds in commercial orchards.

Types of herbicides and when to spray

The best time to spray for weeds is either just before (pre-emergent) or just after germination (post-emergent). Most weeds germinate in either spring or autumn. Small weeds are easier to control than older, more mature weeds.

Fruit being contaminated with herbicide overspray can cause market consignment rejections or complete market access closure. As a general rule, herbicide programs are organised to avoid spraying during fruit maturation and harvest, and herbicide boom shrouds are always used. See Herbicide overspray and maximum residue limits on page 107 for more information.

Orchard herbicides can be grouped into 3 broad categories (see Table 27 on page 111):

1. pre-emergent residual herbicides
2. post-emergent selective grass herbicides
3. post-emergent non-selective knockdown herbicides.

Pre-emergent residual herbicides perform best when applied to bare soil that is free from weeds, mulch and debris. Any material that prevents the pre-emergent herbicide from contacting and penetrating the soil surface will reduce the level of control. Most pre-emergent herbicides will provide effective control for a wide range of annual broadleaf weeds and grasses. Most require rain or irrigation within a set time for the herbicide to be effective.

Post-emergent selective herbicides are useful where grass is the predominant weed species. The active ingredients with registrations for use in NSW as selective grass herbicides are all members of the herbicide mode of action Group 1 (previously A). This group is highly prone to developing resistance and should be used in accordance with resistance-management principles.

Post-emergent non-selective knockdown herbicides perform best when applied to young, actively growing weeds. Due to their non-selective nature, many herbicides in this group can be harmful to fruit and nut trees. Young trees are particularly prone to injury if not protected from knockdown herbicides. Using tree guards on young trees is important to protect them from herbicides and other sources of damage. Consult herbicide product labels for specific recommendations.

Always read product labels thoroughly before applying any herbicide in an orchard. Failure to do so could result in poor product performance or damage to trees.

Applying herbicides

Controlling weeds in orchards should involve a scheduled herbicide program that aims to control as many weeds as possible rather than at an individual weed level. However, orchard weed monitoring is important because changing environmental conditions (e.g. temperature and rain) can significantly affect knockdown and pre-emergent programs. Every site needs a customised herbicide program. The following are some considerations to help with developing a herbicide program:

- Always spray during ideal Delta-T conditions (Figure 172).
- The most hazardous condition for herbicide spray drift is an atmospheric inversion, which usually occur during clear skies from sunset and sunrise. Do not spray under inversion conditions.

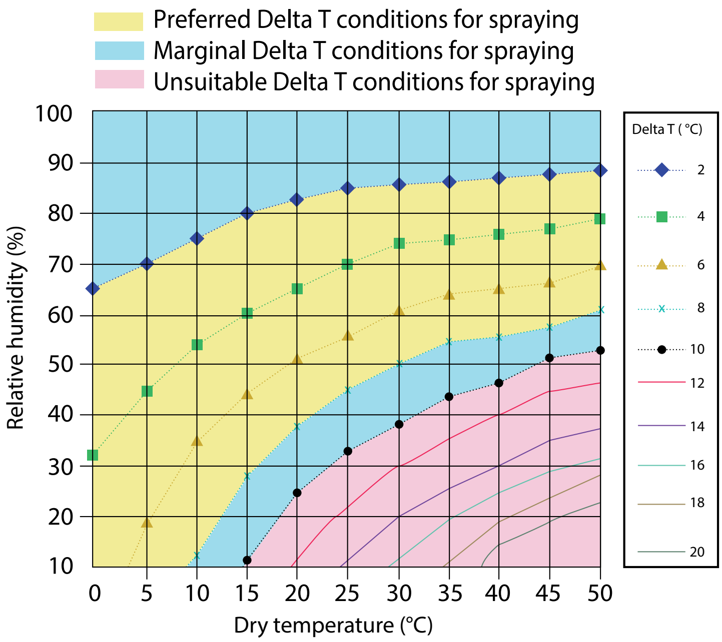

Figure 172. Delta T chart. Source: Bureau of Meteorology.

- As a suggestion, use 100 L/ha for systemic products (e.g. glyphosate) and 150–300 L/ha for contact and locally systemic products such as paraquat + diquat, or glufosinate–ammonium. Application rates above 400 L/ha might not be beneficial. As with most weeds, complete coverage is essential for good control.
- Dust is often present on the weeds and can deactivate some herbicides or cause a physical barrier, preventing the herbicide from contacting the plant surface. If the plants are dusty, spray them after rain or irrigation.
- Using an adjuvant can help improve spray coverage and spread of a herbicide solution, but might not be necessary. Before adding an adjuvant, always read the label and follow the label guidelines. If an adjuvant is required, the label will give directions about which one to use and how much to apply.
- Glufosinate–ammonium can be used to control a broad spectrum of weeds. It is also an option for occasional use in an intensive glyphosate program to reduce glyphosate herbicide resistance. It is best used when humidity is above 50% and temperatures are below 33 °C to ensure the drying time is sufficient for the spray to be effective. Adding a registered Group 14 (previously G) herbicide spike such as oxyfluorfen or carfentrazone to a registered knockdown herbicide might further improve control.

- Paraquat (Group 22, previously L) will control small grasses and broadleaf weeds. Adding diquat will broaden control to include some broadleaf weeds, such as capeweed. However, in most cases if these weeds are not prevalent, diquat is not needed. Paraquat is a Schedule 7 chemical (Dangerous Poison) and should be applied with great personal care. Paraquat should be applied after sunset or during overcast conditions so it can be absorbed and spread over the plant before sunlight activates the chemical.
- Annual ryegrass and feathertop Rhodes grass are resistant to glyphosate. If present, add haloxyfop or pendimethalin to the herbicide program and apply according to label recommendations. See Common citrus weeds on page 98 for more information.
- Fleabane is difficult to control because of its hairy leaf and resistance to Group 9 (previously M) herbicides. Higher volume coverage and double-knock techniques can be used (e.g. a follow-up spray with paraquat 10 days later). For more information on fleabane control, refer to NSW DPIRD WeedWise (https://weeds.dpi.nsw.gov.au/Weeds/Details/208).
- A suitable pre-emergent herbicide might control some knockdown-resistant weeds; bromacil and simazine are commonly used. While bromacil is more expensive, it can provide greater control. As a compromise, some growers use the lower rate of bromacil, but add simazine to provide a similar and more economical pre-emergent program. Some growers also use simazine and norflurazon pre-emergent mixtures. Flumioxazin is a pre-emergent herbicide that remains stable for up to 4 weeks on the soil surface until rainfall or irrigation occurs for its activation. When pre-emergent chemicals are applied correctly, they can provide up to 9 months of weed suppression, although occasional spot weeding might also be needed. Application on bare ground and rain or irrigation within a certain period after application are essential, although this timing can vary considerably between herbicides. Always check product labels.
- Bromacil can also act as a knockdown on some small plants and this needs to be considered when developing a herbicide program, especially for problem weeds (e.g. fleabane). However, it might take 4–6 weeks to provide a good brownout. A follow-up spray with a knockdown herbicide (e.g. paraquat) 2 weeks later will accelerate brownout. Most bromacil activity is by root uptake, therefore rain or irrigation is required for it to take effect. Applying it to weed foliage will enhance the efficacy of root uptake control.

Herbicide overspray and maximum residue limits

Contaminated fruit from herbicide overspray is a major risk to the citrus industry. A single detection at an export market could close down that market. To prevent herbicide overspray, skirt trees accordingly (Figure 173) and only use a shrouded herbicide unit (Figure 174). See the NSW DPIRD website for a video of a shrouded herbicide unit (https://www.youtube.com/watch?v=OPYZLK5hRyc).

Figure 173. Skirting trees using a circular saw cutter bar mounted on the forks of a tractor.

Figure 174. Rick Costa explaining his shrouded herbicide unit in a NSW DPIRD video.

Managing weeds

Herbicide sprayer setup

A properly configured and well-calibrated sprayer is essential to ensure herbicides are applied in accordance with label recommendations. It also helps achieve the intended weed control. Some important points to consider are:

- Always ensure effective agitation, especially when using dry flowable (DF), suspension concentrate (SC), water dispersible granule (WG) and wettable powder (WP) formulations.
- Ensure pressure gauges work accurately.
- Use the correct (specified) pressure range for the nozzles being used. Inadequate pressure will result in droplets that are too coarse and might not provide adequate coverage. Excessive pressure will produce finer droplets that are prone to spray drift.
- Flat fan nozzles have traditionally been the popular choice for herbicide spraying, but these are no longer appropriate when it comes to reducing spray drift. For more information refer to the section Herbicide application nozzle selection on page 109.
- Always use a low-drift type nozzle wherever possible, such as an air-induction (AI) nozzle.
- Select the correct nozzle size from the manufacturer's chart after a safe ground speed and the recommended application volume for the herbicide being used have been determined.
- Ensure a double overlap of the spray fans at the top of the target, not ground level. Too low will result in unevenly applied herbicide, while too high will increase the risk of off-target damage.
- If any nozzle's output (litres per minute) varies by more than 5% from the manufacturer's specifications, replace those nozzles.
- Ensure all equipment is properly calibrated before use. Herbicide labels can include mandatory advice on droplet spectrum, e.g. medium coarse. If so, be sure to choose the appropriate nozzle and operating pressure.

Simple and easy calibration

The most common procedure for calibrating herbicide spray equipment is:

1. Select the tractor engine rpm and gear to give a satisfactory ground speed in the orchard and the correct pump pressure.
2. Fill the spray tank with water and note the exact level reached.
3. Measure a 100 m strip and spray over it with water.
4. Measure the width of the sprayed strip.
5. Return the rig to the exact position where it was filled the first time and measure how much water it takes to refill the tank to exactly the same level as before.

The area covered by a full tank can then be calculated using the following formula.

If we assume

Length of sprayed area [L] = 100 m

Width of sprayed area [W] = 1.5 m

Tank capacity [T] = 500 L

Volume of water used in test spray [V] = 10 L

Product application rate [R] = 3.75 kg/ha

Then

The area covered by a full tank is

$$\frac{L \times W \times T}{V}$$

In this example, the area covered is

$$\frac{100\,\text{m} \times 1.5\,\text{m} \times 500\,\text{L}}{10\,\text{L}}$$

= 7,500 m^2 or 0.75 ha (there are 10,000 m^2 in a hectare)

The herbicide required in a full tank = area covered by full tank × application rate [R], so the amount of herbicide required is

= 0.75 ha × 3.75 kg/ha = 2.8 kg

Herbicide application nozzle selection

Peter Alexander , TeeJet

Selecting nozzles to apply herbicides should primarily focus on reducing the risk of spray drift without compromising efficacy. Drift (or loss) is a significant issue facing the industry and those applying herbicides have both a moral and legal obligation to adopt current best practice.

Research indicates that herbicides can be applied with coarse (350–450 microns) to very coarse (450–500 microns) droplet sizes without affecting efficacy. This also helps reduce the risk of spray drift. The exact droplet size will depend on the herbicide, the target and the conditions at the time of spraying. Growers need to be prepared to adjust either the application rate or select a different nozzle design for their planned outcome. For example, if using very coarse droplets, higher water volumes might be required to maintain high levels of efficacy, particularly when targeting fine leaf grasses with a grass selective (Group 1, previously A, e.g. Verdict® and Fusilade®) product.

Most nozzles are colour coded to a specific droplet size range if used at the recommended pressure. Refer to the APVMA's Spray drift data guideline (https://apvma.gov.au/sites/default/files/publication/28766-spray_drift_data_guideline.pdf).

Consult your spray equipment supplier for appropriate nozzle types and configurations.

More information on managing spray drift can be found on the APVMA website (https://apvma.gov.au/node/10796).

Delta T

Delta T is an indicator of suitable spraying conditions; it depends on temperature and humidity. Delta T is calculated by subtracting the wet bulb temperature from the dry bulb temperature. High temperatures and low humidity are not suitable for most spray activities (including tree spraying) because the droplets will evaporate quickly.

The Delta T chart (Figure 172 on page 106) can provide a guide to suitable spraying conditions. Humidity and temperature measurements can be made with simple, inexpensive weather monitoring devices or by using a reliable weather reporting website.

Avoiding herbicide resistance

Herbicides work by interfering with specific processes in plants. This is known as the mode of action (MOA). Herbicide MoA classifications have been updated internationally to capture new active constituents and ensure the MoA classification system is globally relevant.

The global MoA classification system is based on numerical codes that provide infinite capacity to accommodate new herbicide MoA becoming available, unlike the alphabetical codes previously used. Refer to Table 27 on page 111 and the product label to determine the MOA group.

Glyphosate (Group 9, previously M) is extensively used in the industry with some orchards using up to 5 applications each year, only occasionally mixing with other herbicides. To reduce herbicide resistance, replace 2 of these glyphosate applications with a herbicide from a different group. More information is presented in Applying herbicides on page 106 and Common citrus weeds on page 98.

Glyphosate-resistant ryegrass is present in orchards and vineyards across Australia due to an over-reliance on Group 9 herbicides. Fleabane and feathertop Rhodes grass are also difficult to control with Group 9 herbicides.

Herbicide resistance management options such as the following should be used:

- using a lower risk herbicide in preference to a higher risk one, for example, never use a Group 1 herbicide when a Group 22 herbicide will suffice
- looking for surviving weeds after spraying and preventing them from setting seed
- using as many weed control techniques as practical (i.e. cultivation and hand hoe) and do not rely solely on herbicides
- using a double-knock technique when appropriate (e.g. applying a different herbicide 1–2 weeks later)
- spraying during the appropriate weather conditions such as low wind and suitable Delta T conditions (see Figure 172 on page 106)

- using a recommended adjuvant (sometimes recommended on the label); these can improve effectiveness by:
  - increasing herbicide penetration into the leaf
  - increasing the spread and subsequent leaf coverage
  - reducing incompatibility issues with other herbicides
  - counteracting poor water quality (see Spray sense, https://www.dpi.nsw.gov.au/agriculture/chemicals/spray-sense-leaflet-series)
  - modifying the droplet size for good coverage and reduced spray drift.

Some useful tips on avoiding resistance in are on the CropLife Australia website (https://www.croplife.org.au/resources/programs/resistance-management/herbicide-resistance-management-strategies-2-draft/).

To minimise the risk of herbicide resistance developing in your orchard, know the herbicide groups and recognise resistant weeds. Do not rely on chemicals from the same group for every spray.

Herbicide resistance testing

Any weed outbreak that is suspected of having herbicide resistance can be tested. This will provide valuable information about the herbicides that do not work, but more importantly, the herbicides that are effective. An approximate cost of a broad-spectrum test is $600–700. This would include at least 6 to 7 herbicides.

There are 2 types of tests available: a quick test and a seed test. The quick test involves live seedlings being sent away for re-potting and spraying. Once the plants have fully recovered they are sprayed with the herbicides of your choice. Results are usually reported between 4 and 8 weeks later. This is usually too late to enable re-treatment of the 'suspect' patches in your orchard, but does provide early knowledge about the nature of the problem and what is likely to work. One disadvantage of the quick test is it cannot test for pre-emergent herbicides, as the plants have already emerged.

A seed test requires seed to be sent and often involves breaking seed dormancy upon arrival. It is useful to test resistance to pre-emergent herbicides. The turnaround time is approximately 4 months and results are usually sent to clients in April (if seed was sent in December). This will allow ample time to decide what herbicides to use for the next treatment.

Contacts for herbicide resistance testing services providers

Plant Science Consulting
22 Linley Avenue, Prospect SA 5082
Phone: 0427 296 641
Email: info@plantscienceconsulting.com.au
Website: www.plantscienceconsulting.com
Seed test? Yes
Quick test? Yes

Charles Sturt University Herbicide Resistance Testing Service
Herbicide Resistance Testing
School of Agricultural and Wine Sciences
Charles Sturt University
Locked Bag 588, Wagga Wagga NSW 2678
Phone: (02) 6933 4001
Email: jbroster@csu.edu.au
Website: https://www.csu.edu.au/plantinteractionsgroup/herbicide-resistance
Seed test? Yes
Quick test? No.

Herbicide chemical table

Herbicide Mode of Action (MoA) classifications have been updated internationally to capture new active constituents and ensure the MoA classification system is globally relevant. The global MoA classification system is based on numerical codes, providing infinite capacity to accommodate new herbicide MoA coming to market, unlike the alphabetical codes currently used in Australia.

The numerical classification system should be fully implemented by the end of 2024.

A mobile app compatible with Android and Apple systems is available via the HRAC website (hracglobal.com) at no cost to users. It will cross-reference the herbicide active ingredient with its former MoA letter and new MoA number. Printed materials will also be made available.

Before using any herbicide (Table 27), always check and follow all label instructions.

Table 27. Herbicides and their uses.

Group*	Active ingredient	Example trade name(s)	Resistance risk	WHP (days)	Weeds controlled	Type/when applied
1 (A)	Fluazifop	Fusilade Forte® 128 EC	High	0	Annual and perennial grasses	Post-emergent selective
1 (A)	Haloxyfop	Verdict® 520	High	0	Annual and perennial grasses	Post-emergent selective
5,6 (C)	Bromacil	Bromacil 800 WP	Moderate	0	Broadleaf weeds and grasses	Post-emergent non-selective
5,6 (C)	Simazine	Gesatop® 600 SC (flowable)	Moderate	0	Broadleaf weeds and grasses	Pre-emergent residual
3 (D)	Oryzalin	Farmoz Cameo® 500	Moderate	0	Annual grasses and broadleaf weeds	Pre-emergent residual
3 (D)	Pendimethalin	Charger® 330 EC	Moderate	0	Annual grasses and broadleaf weeds	Pre-emergent residual
3 (D)	Trifluralin	Trilogy® 600	Moderate	0	Annual grasses and broadleaf weeds	Pre-emergent residual
12 (F)	Norflurazon	Zoliar® DF	Moderate	0	Broadleaf weeds and grasses	Pre-emergent residual
14 (G)	Carfentrazone	Hammer®	Moderate	0	Broadleaf weeds	Post-emergent non-selective
14 (G)	Flumioxazin	Chateau®	Moderate	98	Broadleaf weeds and grasses	Pre-emergent residual
14 (G)	Saflufenacil	Sharpen® WG	Moderate	0	Broadleaf weeds	Post-emergent non-selective
15 (J)	2,2–DPA	Dalapon®	Moderate	7	Perennial grasses	Post-emergent selective
22 (L)	Diquat	Relyon Diquat 200®	Moderate	0	Broadleaf weeds	Post-emergent non-selective
22 (L)	Paraquat	Gramoxone® 250	Moderate	0	Annual grasses and broadleaf weeds	Post-emergent non-selective
9 (M)	Glyphosate	Roundup Complete Herbicide®	Moderate	0	Annual and perennial grasses and weeds	Post-emergent non-selective
10 (N)	Glufosinate	Basta®	Moderate	0	Broadleaf weeds and grasses	Post-emergent non-selective
29 (O)	Dichlobenil	Casoron® 4G	Moderate	0	Annual grasses and broadleaf weeds	Post-emergent non-selective
29 (O)	Indaziflam	Alion® 500 SC	Moderate	14	Broadleaf weeds and grasses	Pre-emergent residual
29 (O)	Isoxaben	Gallery® 750	Moderate	0	Broadleaf weeds	Pre-emergent residual
13,34 (Q)	Amitrole	Amitrole® 250, AC Amon®	Moderate	56	Broadleaf weeds and grasses	Post-emergent non-selective

WHP = withholding period. *The number in the Group column represents the new MoA and the previous letter is shown in brackets.

Note: users of agricultural chemical products must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label or the conditions of the permit by reason of any statement made or omitted to be made in this publication.

Your responsibilities when applying pesticides

Farm Chemicals unit, Biosecurity and Food Safety, NSW DPIRD

The Australian Pesticides and Veterinary Medicines Authority (APVMA), NSW Environment Protection Authority (EPA), SafeWork Australia and SafeWork NSW are the government agencies that regulate pesticides in NSW.

Agricultural and Veterinary Chemicals Code Act 1994 (Commonwealth)

The APVMA administers the *Agricultural and Veterinary Chemicals Code Act 1994*. Under the Act, the APVMA is responsible for importing, registering, and labelling pesticides. States and territories regulate pesticide use.

Permits for off-label use

Where there is a need to use pesticides outside the registered use pattern, the APVMA can approve off-label use by issuing a **minor use**, **emergency** or **research permit**. In NSW, the *Pesticides Act 1999* does not allow off-label use unless a permit is approved by the APVMA. To search for current permits and registered products, go to the APVMA Pubcris website (https://portal.apvma.gov.au/pubcris).

Any individual or organisation can apply for a permit. The APVMA can be contacted on 02 6770 2300 or enquiries@apvma.gov.au.

The label

Chemical labels are legal documents. The *NSW Pesticides Act 1999* requires all chemical users to read and comply with label instructions.

Signal heading

Pesticides fall into 3 of the 10 schedules in the Poisons Standard. All pesticides carry a signal heading. Signal headings for pesticides include:

- Caution (Schedule 5)
- Poison (Schedule 6)
- Dangerous Poison (Schedule 7).

Re-entry intervals

The re-entry interval is the time that must elapse between applying a pesticide and entering the sprayed crop, unless the person is wearing full personal protective equipment (PPE).

Pesticides and the environment

Many pesticides are toxic to aquatic organisms, bees and birds. Following label instructions will minimise the risk to off-target organisms.

Many labels carry the warning: **Dangerous to bees. Do not spray any plants in flower while bees are foraging**. It is often safe to spray early in the morning or late in the afternoon but only when bees are not foraging.

Organophosphate and carbamate insecticides are toxic to some birds, especially in granular formulations. See the label for details on how to minimise the danger to birds.

Withholding periods

The withholding period (WHP) is the minimum time that must elapse between the last application of a pesticide and harvest, grazing or cutting the crop or pasture for fodder. The WHP serves to minimise the risk of residues in agricultural commodities and in foods for human and animal consumption.

Some export markets have a lower residue tolerance than Australian maximum residue limits (MRL). Contact your processor or packing shed to determine their market requirements.

Managing spray drift

Spray drift is the physical movement of chemical droplets onto a non-target area. Some chemicals can also travel long distances as a vapour after spraying. There could be a risk of injury or damage to humans, plants, animals, the environment or property.

Buffer zones reduce the risk of chemical drift reaching sensitive and non-target areas. Applicators must adhere to buffer zones and other drift reduction instructions on labels.

Safety instructions

Safety instructions on labels provide information about personal protective equipment (PPE) and other safety precautions that are essential when using the product.

Note: before opening and using any farm chemical, consult the label and the Safety Data Sheet (SDS) for safety directions.

Applying pesticides by aircraft

Product labels indicate which products are suitable for application by aircraft. They also provide a recommendation for the minimum water volume for aerial application. Drones are also aircraft.

More information on the legal requirements for aerial application is available on the EPA website (https://www.epa.nsw.gov.au/your-environment/pesticides/licences-and-advice-for-occupational-pesticide-users/aerially-applying-pesticides).

Pesticides Act 1999 (NSW)

The Environment Protection Authority administers the *Pesticides Act 1999* and Pesticides Regulation 2017, which control pesticide use in NSW. The aim is to minimise risks to human health, the environment, property, industry and trade.

The primary principle of the *Pesticides Act 1999* is that pesticides must only be used for the purpose described on the product label and label instructions must be followed.

The Act and Regulation require pesticide users to:

- only use pesticides registered or permitted by the APVMA
- obtain an APVMA permit if they wish to use a pesticide contrary to label instructions
- read the approved label and/or APVMA permit for the pesticide product (or have the label/ permit read to them) and strictly follow the directions on the label
- keep all registered pesticides in containers bearing an approved label
- prevent damage to people, property, non-target plants and animals, the environment and trade when applying pesticides.

Training

The minimum prescribed training qualification is the AQF2 competency unit, 'Apply chemicals under supervision'. However, chemical users are encouraged to complete the AQF3 competency units: 'Prepare and apply chemicals' and 'Transport, handle and store chemicals'.

Record keeping

Anyone who uses a pesticide for commercial or occupational purposes must make a record of their pesticide use. Records (e.g. Table 28 on page 114) must be made within 24 hours of applying a pesticide, be in English and kept for 3 years and include the:

- date, start and finish time
- operator details – name, address and contact information
- crop treated e.g. Navel oranges
- property address and a clear delineation of the area where the pesticide was applied
- type of equipment used to apply the pesticide e.g. knapsack, air-blast sprayer, boom spray
- full name of the product or products (e.g. Bayfidan 250 EC Fungicide® – not just 'Bayfidan')
- total amount of concentrate product used
- total amount of water, oil or other products mixed in the tank with the concentrate
- size of the block sprayed and the order of blocks treated
- wind speed and direction at the start of spraying
- weather conditions at the time of spraying and weather conditions specified on the label
- changes to wind and weather conditions during application.

Table 28. An example of a pesticide application record form.

Chemical application record		
Property address:		Date:
Owner:	Address:	Phone:
Person applying chemical:	Address:	Phone:

Spray application area	**Situation of use**			
Spray map including sensitive areas, wind direction, order of treatment	Area sprayed and order of spraying			
	Block name/ number	Area (ha)	Variety	Growth stage
	Pest(s)		Pest growth stage	Pest density
GPS reference: S E	**Application equipment**			
Comments (including risk control measures for sensitive areas):	Equipment type	Nozzle*	Pressure	Speed
No-spray zone (metres):	Water quality (e.g. pH, hardness)	Droplet size	Boom height (above target)	Other

Chemical details							
Full product name: (including additives)	Chemical rate	Water rate	Total amount of concentrate	Total amount of chemical mix used	Mixing order	Re-entry period	WHP

Weather details						
Rainfall (amount and time from spraying)	Before: mm		During: mm		After: mm	
Time of spraying:	Temperature ºC	Relative humidity %	Delta T	Wind direction from	Wind speed	Variability e.g. gusting speed and direction
Start:						
Finish:						
Start:						
Finish:						

Clean-up	
Disposal of rinsate:	Decontamination of sprayer:

*Include brand and capacity, e.g. TeeJet AI 11002.
Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Globally Harmonised System of classifying and labelling chemicals

The Globally Harmonised System (GHS) is an international system for classifying hazards and communication about dangerous goods and hazardous substances. The GHS replaces the old hazardous substances and dangerous goods classification.

The SafeWork Australia website (https://www.safework.nsw.gov.au/resource-library/list-of-all-codes-of-practice) lists all the codes of practice you will need, including *Labelling of workplace hazardous chemicals* and another for *Preparation of safety data sheets for hazardous chemicals* to provide industry with guidance on how to comply with the GHS.

Work Health and Safety Act 2011 (Commonwealth)

SafeWork Australia administers the *Commonwealth Work Health and Safety Act 2011* and the Work Health and Safety Regulation 2011.

The Act defines the responsibilities of employers or the person conducting a business or undertaking (PCBU) and the responsibilities of workers. The Regulation covers hazardous substances and dangerous goods, including applying the GHS in Australia.

SafeWork Australia has published several Codes of Practice (https://www.safework.nsw.gov.au/resource-library/list-of-all-codes-of-practice) for different industries and situations.

Work Health and Safety Act 2011 (NSW)

SafeWork NSW administers the *Work Health and Safety Act* 2011 and the Work Health and Safety Regulation 2017.

The Act implements the *Commonwealth WHS Act* in NSW. It outlines the primary responsibility of the employer or the PCBU to maintain a safe workplace. There is an emphasis on consultation with workers, risk assessment and management, and attention to worker training and supervision.

The WHS Regulation 2017 explains how to manage hazardous substances (i.e. most pesticides). It includes identifying hazardous substances in the workplace, and assessing and managing risks associated with their use.

The WHS Regulation 2017 includes responsibilities for managing risks to health and safety at a workplace including:

- correctly labelling containers
- maintaining a register of hazardous chemicals
- identifying risk and ensuring the stability of hazardous chemicals
- ensuring that exposure standards are not exceeded
- information, training and supervision for workers
- keeping spill containment kits on site
- keeping SDS for chemicals on site
- controlling ignition sources and accumulation of flammable and combustible materials
- providing fire protection, firefighting equipment, emergency and safety equipment
- developing and displaying an emergency plan for the workplace
- providing stability, support and appropriate plumbing for bulk containers.

Dangerous Goods (Road and Rail Transport) Act 2008

The Environment Protection Authority (EPA) and SafeWork NSW administer the *Dangerous Goods (Road and Rail Transport*) *Act* 2008 and Regulation. The EPA deals with transport while SafeWork NSW is responsible for classification, packaging and labelling.

This act regulates the transport of all dangerous goods except explosives and radioactive substances.

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Brian McKinnon, Lecturer Farm Mechanisation
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Natalie O'Leary, Profarm Trainer.

Analytical laboratories

Below is a list of commercial laboratories that undertake analysis of food commodities and other materials for chemical residues:

Eurofins Agroscience Testing
Phone 02 9900 8442
https://www.eurofins.com.au/locations/eurofins-agroscience-testing-lane-cove/

National Measurement Institute
Phone 1800 020 076
Email: info@measurement.gov.au

National Association of Testing Authorities
Phone 02 9736 8222
https://www.nata.com.au

Information sources

APVMA (https://portal.apvma.gov.au/)

Australian Code for the Transport of Dangerous Goods by Road and Rail (www.ntc.gov.au/heavy-vehicles/safety/australian-dangerous-goods-code/)

Bureau of Meteorology (www.bom.gov.au)

Environment Protection Authority (www.epa.nsw.gov.au/)

Hazardous Substances Information System (http://hcis.safeworkaustralia.gov.au/)

Managing risks of hazardous chemicals in the workplace (https://www.safeworkaustralia.gov.au/doc/model-code-practice-managing-risks-hazardous-chemicals-workplace)

National Association of Testing Authorities (https://www.nata.com.au)

NSW DPIRD resources on QFF (www.dpi.nsw.gov.au/biosecurity/insect-pests/qff)

Safe use and storage of chemicals in agriculture (https://www.safework.nsw.gov.au/hazards-a-z/hazardous-chemical)

SafeWork Australia (https://www.safework.nsw.gov.au/resource-library/list-of-all-codes-of-practice)

Work Health and Safety Act 2011 (www.legislation.gov.au/Details/C2017C00305)

Work Health and Safety Regulation 2011 (www.legislation.gov.au/Details/F2011L02664)

Resources

Citrus and agricultural industry

Citrus Australia (www.citrusaustralia.com.au)
Griffith and District Citrus Growers Inc (www.gdcga.com.au)
Hort Innovation (www.horticulture.com.au)
National Farmers' Federation (www.nff.org.au)
NSW Farmers' Federation (www.nswfarmers.org.au)
Sunraysia Citrus Growers (http://mvcitrus.org.au/mvcb/)
WA Citrus (www.wacitrus.com.au)

Federal government

ABC Rural News (www.abc.net.au/rural)
Australian Trade and Investment Commission (www.austrade.gov.au)
Department of Agriculture and Water Resources (www.agriculture.gov.au)
Department of Human Services (www.humanservices.gov.au)
Plant Health Australia (www.planthealthaustralia.com.au)

State government

NSW Department of Primary Industries and Regional Development (www.dpi.nsw.gov.au)
NSW Local Land Services (www.lls.nsw.gov.au)
NSW Office of Environment and Heritage (www.environment.nsw.gov.au)
NSW Rural Assistance Authority (www.raa.nsw.gov.au)
QLD Department of Agriculture and Fisheries (www.daff.qld.gov.au)
SA Primary Industries and Regions (www.pir.sa.gov.au)
SafeWork NSW (www.safework.nsw.gov.au)
VIC Department of Environment, Land, Water and Planning (www.depi.vic.gov.au)
WA Department of Primary Industries and Regional Development (https://www.agric.wa.gov.au/)

Rural assistance

Health NSW (www.health.nsw.gov.au)
NSW Rural Assistance Authority (www.raa.nsw.gov.au)

Agencies and universities

CSIRO (www.csiro.com.au)
New Zealand Ministry for Primary Industries (www.mpi.govt.nz)
NSW DPIRD Citrus (https//www.dpi.nsw.gov.au/agriculture/horticulture/citrus)
QLD Department of Agriculture and Fisheries (www.daf.qld.gov.au/business-priorities/agriculture/plants/fruit-vegetable/fruit-vegetable-crops/citrus)
South Australia Research and Development Institute (www.pir.sa.gov.au/research)
Tasmanian Institute of Agriculture (www.utas.edu.au/tia)
United States Department of Agriculture (www.usda.gov)
University of Florida Citrus Extension (www.crec.ifas.ufl.edu/extension/)
WA Department of Primary Industries and Regional Development – citrus (https://www.agric.wa.gov.au/crops/horticulture/fruit/citrus)

Alternative systems (organics)

Australian Organic (www.austorganic.com)
NASAA Certified Organic (https://nasaaorganic.org.au/)
Organic Federation of Australia (https://organicindustries.org.au/OFA)

Integrated pest management

Australasian Biological Control Association Inc (www.goodbugs.org.au)

Biological Services (www.biologicalservices.com.au)

Bugs for Bugs (www.bugsforbugs.com.au)

Pesticides – use and disposal

APVMA (www.apvma.gov.au)

ChemClear (www.chemclear.com.au)

drumMuster (https://www.drummuster.org.au/)

InfoPest (www.infopest.com.au)

Climate and environment

Bureau of Meteorology (www.bom.gov.au)

Department of the Environment (www.environment.gov.au)

NSW Environment Protection Authority (www.epa.nsw.gov.au)

Office of Environment and Heritage (NSW) (www.environment.nsw.gov.au)

The Long Paddock (www.longpaddock.qld.gov.au)

Business

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, www.agriculture.gov.au/abares)

Freshcare Australia (www.freshcare.com.au)

Market Information Services (www.marketinfo.com.au)

NSW DPIRD citrus farm budget handbook (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/crop-management/harvest-factsheets/harvest-guides)

NSW DPIRD citrus publications

There are many publications on the NSW DPIRD citrus webpage (www.dpi.nsw.gov.au/agriculture/horticulture/citrus). These are regularly updated and new publications added.

NSW DPIRD citrus contacts

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Seasonal Conditions Monitoring Program

State Seasonal Update: Conditions and Outlook

The **State Seasonal Update** is produced monthly and is the official point of reference of seasonal conditions across NSW for producers, government, stakeholders and the public.

Combined Drought Indicator: Latest NSW Drought Maps

Is an interactive tool that provides a snapshot of current seasonal conditions for NSW, factoring in rainfall, soil moisture and pasture/crop growth indices.

Seasonal Conditions Information Portal

Uses technology that allows fast, stable transfer of data and information direct from the EDIS system to your computer. The portal contains several downloadable features from the **NSW Combined Drought Indicator.**

Farm Tracker Mobile Application

Farm Tracker is a tool you can use to record seasonal conditions. You can:

1. Complete a simple crop, pasture or animal survey
2. Keep and manage a photo diary of your farm
3. Monitor the same paddock over many years

Have your say

Complete this survey and tell us what is important to you as DPI continues to improve our Seasonal Conditions monitoring program. Eg. improved local accuracy of data and climate networks, better ways of communicating, or strengthening linkages to drought management and relief measures.

Department of Primary Industries

www.dpi.nsw.gov.au

NSW GOVERNMENT