Department of Primary Industries
and Regional Development

NSW GOVERNMENT

Citrus plant protection guide 2025–26

NSW PRIMARY INDUSTRIES MANAGEMENT GUIDE

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Department of Primary Industries
and Regional Development

Citrus plant protection guide 2025–26

Contributing authors

Andrew Creek, Citrus Development Officer
Dr Nerida Donovan, Citrus Pathologist
Steven Falivene, Citrus Development Officer
Dr John Golding, Research Horticulturist
Dr Mahmud Kare, Research Horticulturist
Dr Tahir Khurshid, Research Physiologist
Dr Dave Monks, Research Horticulturist
Dr Meena Thakur, Research Entomologist
Dr Jianhua Mo, former Entomologist

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Image acknowledgements

Cover: a recent planting at NSW DPIRD Dareton Research Station comparing different canopy training systems to improve the efficiency of orange and mandarin harvest. Photo: Mahmud Kare, NSW DPIRD.

Vectors: www.flaticon.com

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Contents

What's new

This 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 NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/manuals-guides).

Biosecurity is always important and an update on managing neglected orchards (page 5), as well as some points about preparing for huanglongbing, the biggest disease threat to citrus (page 18) are included.

This edition includes updates on NSW DPIRD citrus projects, including:

- two new NSW DPIRD salt-tolerant rootstocks that were evaluated as part of the 'Evaluation of new rootstocks for the Australian industry' have been trademarked (page 6)
- W. Murcott canopy management options to improve long-term yield and reduce alternate bearing (page 8)
- developing innovative orchard systems to improve yield and labour efficiency in the competitive citrus orchards projects (page 10)
- the citrus industry IPDM extension program has finished, producing over 46 outputs (page 14), including *Pests, beneficials, diseases and disorders in citrus*
- the NSW DPIRD climate team looked at the potential effects of climate change on citrus production (page 16)
- an update on the current Australian Centre for International Agricultural Research (ACIAR) project associated with managing the devastating citrus disease, huanglongbing (page 21).

Citrus varietal evaluation work in rootstocks and scions is an important focus for NSW DPIRD, and an update on the project is on page 24. Additionally, the variety seasonality charts and contacts for variety managers have been revised and are included on page 26.

The Cryptolaemus ladybird beetle is the featured natural enemy for this year (page 58). Cryptolaemus was released and worked effectively to assist mealybug management in demonstration sites at Mareeba in Queensland and also at Griffith in NSW as part of the IPDM extension program work.

This year's guide also has articles on managing resistance in post-harvest fungicides and how growers can prevent this from occurring (page 90).

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. We would also like to thank Dr Amanda Warren-Smith for her efforts in editing and publishing this guide.

Managing biosecurity in neglected orchards

Leonie Martin, Plant Biosecurity Officer, NSW DPIRD

With warmer weather just around the corner, it is a timely reminder that everyone has a general biosecurity duty under the *Biosecurity Act 2015* to take every precaution to prevent, minimise or eliminate a biosecurity risk as far as reasonably possible.

Neglected orchards (Figure 1) have the potential to become breeding grounds for unwanted pests and diseases that can spread to other orchards and affect a wide range of horticultural industries and activities. It is therefore crucial that good biosecurity practices are used.

Landowners and new owners of a neglected site are responsible for managing pests, diseases and weeds in their orchard.

To learn more about your general biosecurity duty responsibilities and what you need to do to ensure biosecurity risks are managed on your orchard, refer to the newly developed fact sheet on *Neglected horticultural enterprises* (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0019/1630351/abandoned-and-neglected-horticultural-enterprises.pdf).

How to report a biosecurity risk

If you believe there is a biosecurity risk:

- call the NSW Biosecurity hotline on **1800 680 244**
- report using the online form (https://forms.bfs.dpi.nsw.gov.au/forms/9247)
- email quarantine@dpird.nsw.gov.au

For more information about the Act, visit our website or contact us via email at biosecuritylegislation@dpird.nsw.gov.au or view the website at www.dpi.nsw.gov.au/biosecurityact

Figure 1. A neglected orchard. Photo: AdobeStock.

New salt-tolerant rootstocks trademarked for the Australian citrus industry

Dr Tahir Khurshid, Tree Physiologist, NSW DPIRD, Dareton

A salt tolerance rootstock trial was established in Bindoon, Western Australia, on 4 April 2013 as part of a Hort Innovation rootstock evaluation project. There were 11 rootstocks grafted to Washington navel. The rootstocks were from NSW DPIRD and USDA breeding programs, and from China. The rootstocks used in the trial are given in Table 1. Trees were planted 3 m apart within the rows and 7 m between rows in a north–south orientation. Rootstocks were planted in a single tree plot as a randomised complete block design replicated 3 times. Data on fruit yield were collected for 6 years and fruit quality for 4 years. Tree growth data were collected for 8 years from 2014 to 2021. During the study, leaf samples and water samples were also tested for sodium and chloride content to assess the salt tolerance levels of trees.

Table 1. The salt-tolerant rootstocks planted in Bindoon, Western Australia.

Rootstock used in the Bindoon trial	Breeding program
3812 (Scarlet mandarin* × *Citrus (Poncirus) trifoliata*)	Gosford breeding program, NSW DPIRD
3822 (Scarlet mandarin × *Citrus (Poncirus) trifoliata*)	Gosford breeding program, NSW DPIRD
3834 (Scarlet mandarin × *Citrus (Poncirus) trifoliata*)	Gosford breeding program, NSW DPIRD
3835 (Scarlet mandarin × *Citrus (Poncirus) trifoliata*)	Gosford breeding program, NSW DPIRD
Cox hybrid (Scarlet mandarin × *Citrus (Poncirus) trifoliata*)	Gosford breeding program, NSW DPIRD
F1 (63-199-31) Sunki mandarin × F. Dragon *Citrus (Poncirus) trifoliata*	USDA breeding program
F1 (62-109-49) Sunki mandarin × Mars *Citrus (Poncirus) trifoliata*	USDA breeding program
F1 (62-109-40) Sunki mandarin × Mars *Citrus (Poncirus) trifoliata*	USDA breeding program
X OP (59-24-8) Rangpur lime × Swingle *Citrus (Poncirus) trifoliata*	USDA breeding program
Zao Yang (*Citrus (Poncirus) trifoliata*)	Chinese rootstock selection, Dareton
Troyer citrange (Citrus sinensis × *Citrus (Poncirus) trifoliata*)	Standard rootstock (control)

* Scarlet mandarin is an old Australian variety, and is no longer grown commercially.

Fruit yield

The cumulative yield for 6 years (2018–2021) was 348 kg/tree and 324 kg/tree for rootstocks 3822 and 3834, respectively, compared to 317 kg/tree for the control (Tri22).

Fruit size distribution

Fruit size distribution was assessed for the exportable size class (77–90 mm). The mean fruit size percentages over 4 years were higher for 3834 (83%) than the control (Tri22; 78%). The Californian breeding rootstocks had a lower percentage of fruit in the larger size class (76–90 mm).

Total soluble solids

Fruit quality component data were collected for 5 consecutive years. The total soluble solids (°Brix values) varied slightly from year to year between rootstocks, but these results were not statistically different.

Trunk circumference

Both 3834 (8.7 cm) and 3822 (8.6 cm) had a greater trunk circumference than the control (Tri22; 6.2 cm).

Tree growth

The rate of tree growth was calculated by subtracting the tree height of the final year (2021) from the initial tree height (2014). The data indicated that trees on Troyer citrange and 3822 grew faster than other rootstocks.

Graft union

Graft union data were collected for all rootstocks to assess the degree of smoothness at the graft union. A smooth union indicates similar growth rates for the stock and scion, and this permits a thorough fusion of tissues at the graft union. The scion might overgrow the stock or vice versa. The ratio between stock to scion growth near the graft union provides a measure of the degree of 'benching'. It can give a means of predicting at a very early stage of a tree's life if a stock/scion incompatibility could be an issue with older trees. Benching is a term used to describe where either the stock or scion overgrows the other. The best score of 1.3 was recorded in rootstock 3834, suggesting the trees were close to having a smooth union.

Leaf sample data

The leaf sample data averaged over 5 years (2017–2021) indicated that 3822 (0.29) and 3834 (0.43) had lower chloride levels than the control rootstock (Tri22; 0.52).

New rootstocks

The following rootstocks from the NSW DPIRD breeding program were recommended and are now registered under their new names. The main characteristics of the rootstocks are:

Khurshid-Cox 3822 (Scarlet mandarin × *Citrus (Poncirus) trifoliata*)

Washington navel budded onto this rootstock had salt-excluding ability. The rootstock had 69% of fruit in size class (76–90 mm), desirable internal fruit quality with 12.0 °Brix, and an acceptable graft compatibility score of 1.5. Trees produced a 10% higher fruit yield than Troyer citrange and the biennial bearing index was 0.26.

Khurshid-Cox 3834 (Scarlet mandarin × *Citrus (Poncirus) trifoliata*)

Washington navel budded onto this rootstock had 83% of fruit in the large size class (76–90 mm), desirable internal fruit quality with 11.7 °Brix, and an acceptable graft compatibility score of 1.3. Trees produced a 2% higher fruit yield than Troyer citrange and the biennial bearing index was 0.24.

Acknowledgements

The projects 'Evaluation of new citrus rootstocks for the Australian industry' (CT17002) and 'Evaluation and commercialisation of new citrus rootstocks' (CT13042), are funded by Hort Innovation, using the citrus research and development levy and 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.

Hort Innovation CITRUS FUND

Hort Innovation Frontiers

Project information and final reports can be found on the Hort Innovation webpage (https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/).

W. Murcott mandarin canopy management

Steven Falivene, NSW DPIRD

NSW DPIRD led a four-season W. Murcott mandarin canopy management project from mid-2020 that was funded by Hort Innovation. The project was designed to investigate W. Murcott canopy management options to improve long-term yield and reduce alternate bearing.

Citrange was the main rootstock for the W. Murcott trees planted in early 2000. During the early years, the trees were vigorous, producing very good yields of high-quality fruit. However, when they grew into their allocated space at 10–12 years of age, the trees were mechanically hedged to allow for tractor row access (Figure 2). The hedging produced a vigorous response of water shoots that grew into the row and required trees to be hedged every year (Figure 3). The continual hedging to maintain row access resulted in declining yields.

Figure 2. Using a mechanical hedging machine is a quick and inexpensive way to remove large portions of the tree's canopy, but will remove it indiscriminately.

Figure 3. A vigorous water shoot with few leaves at the base and most fruiting wood at the top.

During the project, research trials, demonstration trials, and overseas study tours were conducted and grower practices were monitored.

Managing water shoots is essential for successful canopy management. The 2 main options to manage watershoots are mechanical hedging and intensive hand pruning.

Severely mechanically hedging one side of the tree (for example, within 1 m of the trunk) is a form of canopy 'reset' and provides a few years of good yield until it needs to be reset again. Alternate sides of the tree are severely hedged as needed.

Intensive hand pruning can provide higher long-term yield and profitability than mechanical hedging, but it requires a significant commitment to annual management and increased labour costs. A vital component of intensive hand pruning is managing the regrowth in spring when it is 200 mm to 400 mm long by thinning out and breaking the regrowth in half to promote side branching and a more compact and complex canopy. This style of pruning results in a more compact and productive tree (Figure 4).

Figure 4. An intensively pruned 2.4 m high W. Murcott tree has fruit that is easily accessible through the upper and lower parts of the canopy. The pruning style was implemented by South Australian W. Murcott grower, Ryan Arnold, after he participated in the South African and Spanish study tours. The cost of canopy management is about $3,000 per hectare; however, a 20-tonne increase in yield results in a net return of $7,000 per hectare. Pickers also favour his orchard because the fruit are easily accessible and requires very little ladder work.

Trials showed that waiting to manage regrowth at a later date on very vigorous trees resulted in a predominance of water shoot growth (Figure 5) that needed to be pruned out in the following season, which is time-consuming and removes productive canopy. This type of spring regrowth management pruning is popular in South Africa for high-density plantings when they train the tree in a triangular shape. However, in Spain, they had wider plant spacing and actively used a vase tree training style. Videos on the Spain and South Africa study tour (including triangular tree pruning), other canopy management videos are available from the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/canopy-management).

Figure 5. Water shoots emerging from the outer part of the canopy, bearing fruit and bending down with the weight of the fruit into the middle of the row.

W. Murcott canopy management options learned during the project are published in the *W. Murcott canopy management guide* from the NSW DPIRD website (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1619797/W-Murcott-canopy-management-guide.pdf).

Acknowledgements

The 'W. Murcott mandarin best practice canopy management' (CT19002) project was funded by Hort Innovation, using the citrus research and development levy and 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.

We thank W. Murcott 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.

High-efficiency citrus orchard systems for productivity and future robotic mechanisation

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

The New South Wales Department of Primary Industries and Regional Development (NSW DPIRD) is leading research to develop a more productive and efficient citrus industry. Rising production costs and increasingly complex labour arrangements are encouraging the need for innovative orchard systems to improve yield and labour efficiency.

A new five-year research project, 'Competitive citrus orchard systems' (CT23006), is underway at the Dareton Research Institute. Funded by Hort Innovation through the citrus R&D levy and the Australian Government, the project is led by Mahmud Kare, supported by a skilled team including Andrew Creek, Steven Falivene, Nerida Donovan and Dave Monks. Activities in the project will investigate how trellising, tree dwarfing, limb bending, hand pruning and applying plant growth regulators (PGR) affect productivity and labour efficiency in high-density plantings. These strategies will also prepare orchards for robotic mechanisation.

One of the key measures of productivity is the amount of fruit-bearing canopy per hectare and the productive efficiency of that canopy (for example, kilograms of fruit per square metre of canopy). Equally important is improving labour safety and efficiency; making work easier and safer helps retain staff, reduces training time, and creates a more attractive workplace.

High-density orchard canopy management

Planting trees at a high density, without other interventions, aims to improve orchard productivity and profitability in the early years. However, once the trees fill their allocated space and the row spacing becomes too narrow for the tree's vigour, the inter-row branches block tractor access. To regain row access, trees need to be pruned, which removes productive branches from the fruiting zone, reducing yield.

In the research trial at Dareton, the vigour response from both hand pruning or mechanical hedging caused branches to grow out into the row, blocking tractor access, however, the mechanical hedging had a lower pruning cost. The results did not show any improvements in productivity, fruit size or quality, emphasising the need to plant trees at an appropriate density to match their varietal vigour and the environment. The greater the vigour, the wider the spacing.

Regrowth management techniques, learned on a recent W. Murcott trip to South Africa (Hort Innovation project CT19002), can be used to break the shoot tips at an early stage to improve branching and reduce vigour (refer to W. Murcott article on page 8 for more information). Excessive vigour in a high-density planting can also be managed by including other strategies, such as restructuring the canopy into a two-dimensional flat plane, with or without a trellised system, or reducing the size of trees with dwarfing rootstocks or viroids.

High-density trellising to improve citrus production efficiency

Trellising is a novel approach in citrus orchards where intensive canopy management aims to enhance light interception and penetration to maximise productivity. An existing Atwood navel and Hockney navel high-density orchard was converted into a trellised system through stumping and structural modification in March 2020. A new trellised orchard was established in October 2024 to evaluate different training systems using mandarin and orange varieties.

Five years on from the 2020 orchard conversion, some trees have grown into their allocated space on the trellis and formed a continuous fruiting wall (Figure 6). In 2025, the maximum yield from trellised trees was 66 t/ha, compared with 41 t/ha in the conventional high-density orchard without trellising. Canopy efficiency, measured as kilograms of fruit per cubic metre of canopy, was significantly higher in trellised trees, reaching 13.2 kg/m^3, while conventional trees averaged only 4.1 kg/m^3. Tree canopy volume, measured using digital 3D LiDAR technology, was around

5,000 m^3/ha in trellised blocks, whereas conventional blocks had nearly double the volume at 10,000 m^3/ha, yet produced fewer fruit. Fruit from the trellis trees was 2 mm larger than from the conventional trees. The next 4 years will be crucial to see if this productivity can be sustained. The new trellised orchard, established in October 2024, will provide valuable information on the management costs and early yield during the first 5 years.

Figure 6. A 15-year-old Hockney navel tree converted to a trellis structure that has nearly covered the trellis, yielding the equivalent of 66 t/ha of large fruit.

To further improve cost-effectiveness, demonstration trials are underway to evaluate smaller and more affordable trellising systems. The project team are working with other teams at the Australian Plant Phenomics Network (APPN) at the Australian National University (ANU) to develop a virtual model of trellised citrus orchards using machine learning. This will help design cost-effective orchard systems without needing to physically plant the trees, saving time and resources.

Training and pruning a trellised orchard is more intensive than conventional systems, particularly in the early years. However, once mature, trellised trees are easier to manage. Their structured canopy allows for precise, small pruning cuts (Figure 7), unlike conventional orchards, which often require the removal of large limbs (Figure 8). The pruning cuts on the trellis are more targeted than conventional cuts because the small, young, productive branches remain, while poor-quality branches and shoots are removed. Fruit above hand-reach in a trellised system is accessible using a three- or four-step platform, which is safer than a bow ladder used in conventional systems. It will also be easier to adopt robotic harvesting in trellised versus conventional orchards, with plans to test this technology. In the meantime, the adoption of motorised platform picking in 2D canopy managed orchards is increasing to make harvesting easier and more consistent. It enables people of different ages, fitness levels, and experience to pick fruit at a good pace with less effort than traditional ladder picking.

High-density with viroid-dwarfed trees

Dwarfed trees can improve the canopy management of a high-density orchard to boost productivity. Vigorous trees with tight plant spacings need heavy pruning (manual or mechanical hedging) to maintain row access, which cuts out productive wood and reduces yield. Smaller trees mean less ladder work for pickers (improved harvest efficiency) and less pruning (lower cost). Trees can be dwarfed using dwarfing rootstocks or by inoculating trees with viroids to induce mild to moderate stunting. Both long-term and newly established trials with viroid-dwarfed trees at the Dareton Research Institute are being evaluated, including a recently inoculated block of mandarins, to build on previous research and provide new information on this technology.

Figure 7. Straight after pruning the converted Hockney navel orchard to trellis.

Figure 8. Straight after mechanically hedging the high-density navel conventional orchard. Most of the productive canopy is cut from the tree.

Limb bending, limb selection and plant growth regulator application

A demonstration site was established to quantify the effect of limb bending and selection on young trees. This practice, which has seen some international uptake, modifies the canopy composition to promote the reproductive growth/fruiting zone. In this experiment, the cost of limb bending and training will be assessed with a focus on improving pack-out percentage and production efficiency. The current use of PGRs to control growth rate and canopy expansion in citrus will also be evaluated by reviewing the literature and commercial orchards.

Economic viability to inform grower decisions

The 20-year profitability of each system has been and will continue to be evaluated to inform project recommendations and assist grower decision-making. The budgets show that up to 20 t/ha extra yield is required to pay for the extra costs of trellising, and that overhead netting enhances profitability in high-density trellised orchards. As the project progresses, the analyses will be updated. A scenario for a high-density trellised robotic-harvested orchard has been included to help the industry understand the challenges and assess potential.

Information delivery

Project outputs, including trial results and case studies with growers, will inform Australian citrus growers about competitive production systems for potential early adoption of innovative orchard management strategies aiming to improve productivity and efficiency.

Acknowledgements

The 'Competitive citrus orchard systems' (CT23006) project is funded by Hort Innovation, using the citrus research and development levy and 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.

Citrus industry integrated pest and disease management extension program

Andrew Creek, NSW DPIRD

Do you achieve good California red scale control?

Do you fully understand citrus gall wasp and its management options?

Does Queensland fruit fly cause you production losses?

The published outputs from the 'Citrus industry IPDM extension program' (CT19011) can improve your knowledge and help you manage the insect pests and citrus diseases in the orchard. Among other resources, one report, 3 posters, 30 fact sheets, 4 webinars, 7 videos and a field guide can be downloaded from the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/ipdm-extension-program; Figure 9).

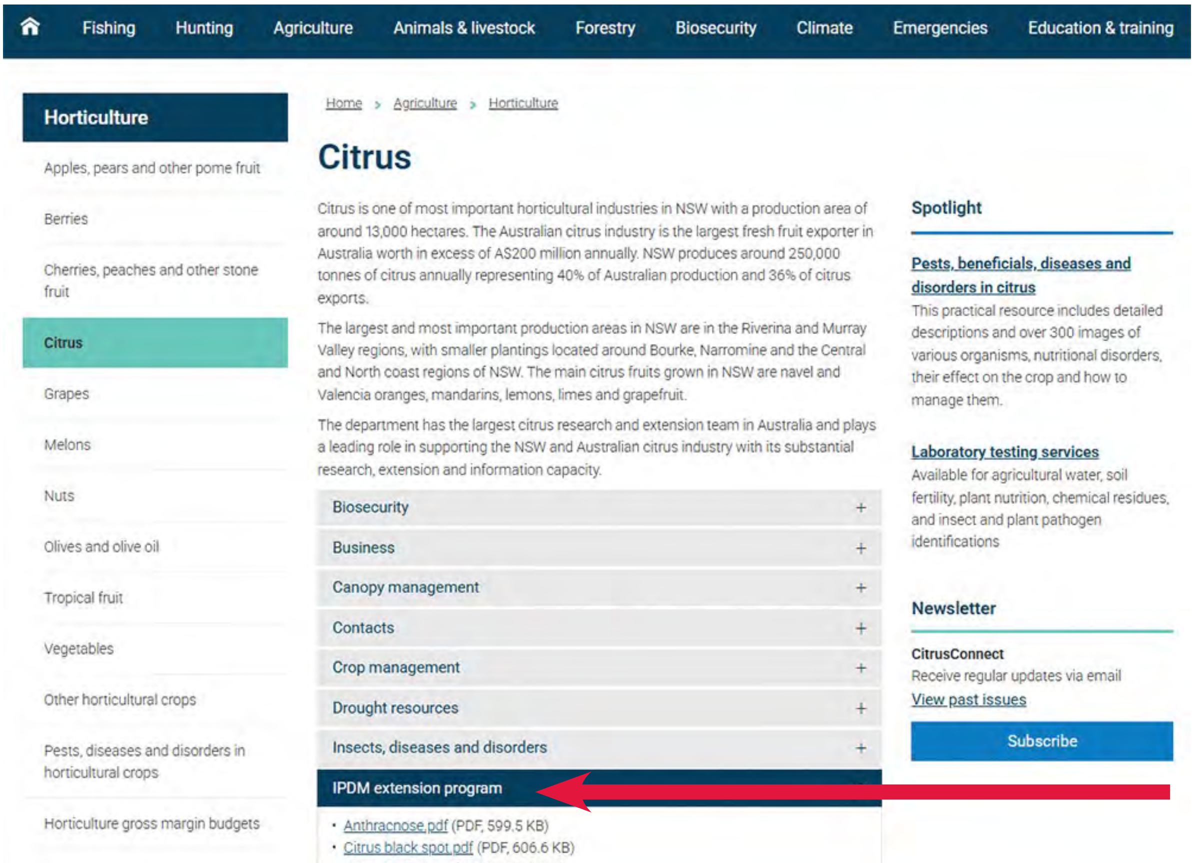

Figure 9. A screenshot of the NSW DPIRD website showing the IPDM extension program folder (red arrow).

Demonstration sites

Nationally, the IPDM extension program facilitated 8 demonstration sites in citrus production regions where alternative and sustainable pest and disease management practices were implemented. The demonstration sites were used for seasonal farm walks and are featured in some of the video resources.

Posters

The posters titled '*Pests of southern citrus*', '*Citrus diseases*', and '*Natural enemies of citrus pests*' were distributed to attendees at various events. The posters, which can be downloaded from the website, are designed to be hung up in packing sheds for practical and easy reference.

Fact sheets

The 30 IPDM-focused fact sheets feature most of the pests and diseases of grower concern as identified by a survey undertaken by the project team in 2022. The fact sheet '*Natural enemies in Australian citrus*' includes a table that shows the effect that many registered insecticides, miticides, and fungicides have on beneficial insects. Growers are encouraged to use the chemistry solutions that have the least effect on the beneficial insects that are naturally within the citrus orchard ecosystem. If we look after the good bugs, they can get into parts of the tree and attack citrus pests where it is difficult to obtain effective chemical control.

Webinars

Webinars with experts are published with chapter titles for ease of finding the specific topics: citrus gall wasp, California red scale, managing citrus diseases in southern Australia and citrus soil health. For example, if you wanted to understand the California red scale life cycle and development, watch the webinar video titled 'California red scale – managing it sustainably' and skip directly to the chapter where Dr Meena Thakur (NSW DPIRD Research Entomologist) explains the insect pest in detail. If you want specific red scale chemical control, take note of the section where Rob Weppler (Entomologist, Riverina IPM) explains how different registered chemistries work and how to sustainably use the chemistry tools available to assist red scale management.

Videos

The short videos are on:

- integrated pest management of citricola scale
- monitoring for citrus gall wasp
- citrus gall wasp demonstration site
- good bugs, great citrus: natural enemies in citrus
- the citrus industry IPDM demonstration site at Arcifa Bros.

The Arcifa Bros demonstration site features an export-focused family orchard and their sustainable methods used for pest management. A very clear guide for Aphytis parasitic wasp release, to assist red scale management, is contained within this video. Aphytis wasps and a single spring insecticide were once the mainstay of southern citrus insect pest control.

Two longer videos have been published with information to help growers avoid production losses from Queensland fruit fly. These videos also have chapter titles, so viewers can quickly seek the information they are after. These informative videos are titled 'Andrew Jessop discusses all things Queensland fruit fly' and 'Queensland fruit fly with Dan Papacek'.

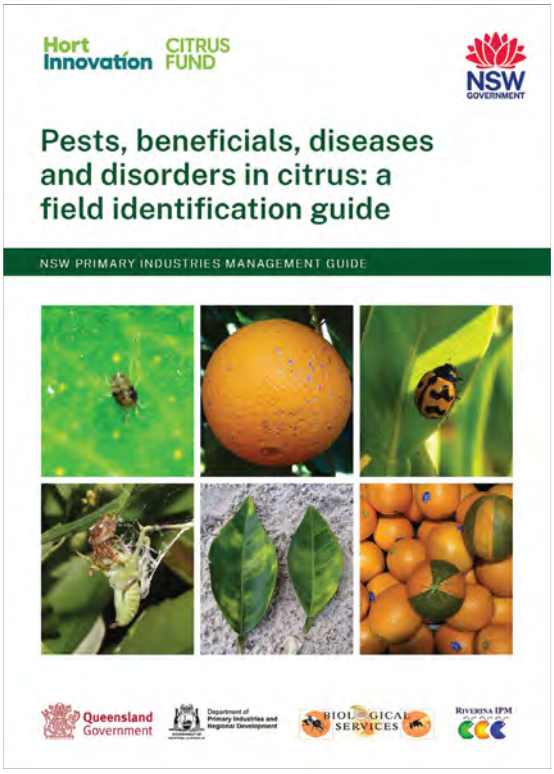

Figure 10. The cover of *Pests, beneficials, diseases and disorders in citrus: a field identification guide.*

Field guide

The project team recently published an A5-sized field guide, titled '*Pests, beneficials, diseases and disorders in citrus: a field identification guide*' (Figure 10). This practical guide is designed to assist growers and rural supply store horticulturists. Copies are available from the NSW DPIRD Griffith and Dareton offices. Rural supply store horticulturists are distributing the field guide in the Riverina region, while packers are distributing the guide in the Sunraysia and Riverland regions.

NSW DPIRD gratefully acknowledges collaboration from Queensland Department of Primary Industries and Western Australian Department of Primary Industries and Regional Development extension staff for project delivery and the collaborative citrus growers and citrus packers who hosted events and demonstration sites for the Citrus industry IPDM extension program.

Acknowledgements

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Growing navel oranges in NSW: preparing for a changing climate

Climate change is altering the growing conditions for many agricultural commodities in NSW. Primary producers need evidence-based information about the changing climate and the risks and opportunities it might bring. Through its Vulnerability Assessment Project, the NSW Department of Primary Industries and Regional Development is enhancing the resilience of our primary industries by providing information and data to help the sector better plan for and respond to climate change. The project assessed the potential effects of climate change on various agricultural industries, including horticulture and viticulture, and identified some biosecurity risks associated with these industries to inform sound planning, risk management, and adaptation decisions.

Methodology and data

Climate projections were sourced from Climate Change in Australia's 'application-ready data'. This dataset comprises projections from 8 global climate models, each presenting a plausible future climate scenario. The models differ in their projections, generating uncertainty in our modelling, which is reflected in the confidence statements given in brackets in the text. Care should be taken when interpreting these results.

The Vulnerability Assessment Project aimed to identify potential changes. Intermediate and high emissions scenarios were used in the assessments (RCP4.5 and RCP8.5), but these are not the only future scenarios possible. The inclusion of climate variables relevant to the commodities was based on published research, expert knowledge and data quality and availability.

Citrus in NSW

Citrus is one of the most important horticultural industries in NSW, with a production value of $218.8 million for oranges in 2021–22, representing 52% of Australian production (NSW DPIRD). The main production areas in NSW are the Murray Valley and Riverina regions (Figure 11). Irrigation is critical to citrus production and is supplied from the Murray, Murrumbidgee and Lachlan Rivers.

Most citrus production is in the semi-arid to arid zones of NSW. The dry climate means fewer disease and insect issues than in coastal regions. Navel oranges were selected for this assessment due to their importance to the industry.

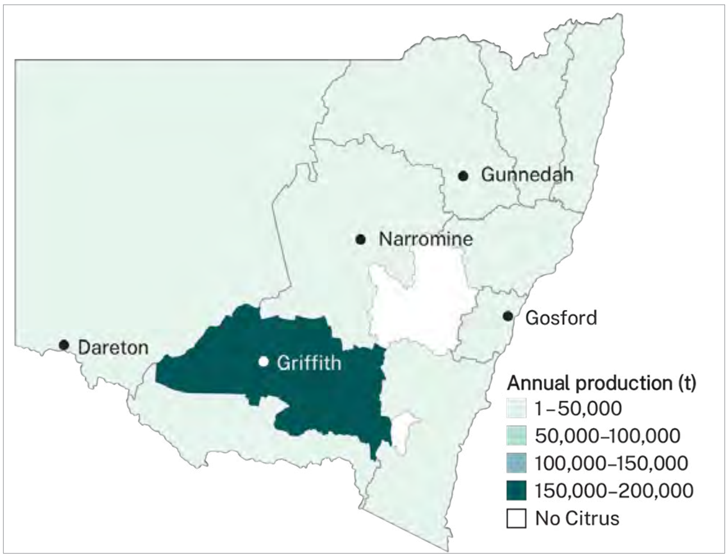

Figure 11. The main citrus-growing regions in NSW. Darker colours represent greater citrus production.

Climate and the citrus industry

All major navel orange growing regions in NSW are expected to remain highly suitable by 2050 under a changing climate. There are likely to be minimal to moderate improvements around the Gunnedah growing region.

Climate risks will affect the citrus life cycle in different ways (Table 2) and include:

- **Extreme heat**: a higher frequency of days above 38 °C and 40 °C could increase the risk of sunburn, which can affect yield and quality.
- **Frost**: there are likely to be fewer days with below-threshold temperatures affecting frost-sensitive phenophases such as bud burst and flowering.
- **Irrigation water requirements**: all citrus growing regions are likely to experience an increase in water demand (low to moderate confidence).

Table 2. The projected effects of climate change on citrus growth stages.

Growth stage	Climate suitability
Flower induction	Remain very high in all regions (high confidence).
Bud burst and initial shoot growth	Remain very high in all regions (high confidence) and increase in Griffith due to fewer days with temperatures below -3 °C.
Late shoot growth and flowering	Remain very high in all regions (high confidence).
Fruit set/cell division	Remain very high in all regions (high confidence).
Cell enlargement	Remain very high in all regions (moderate to high confidence).
Maturity and harvest	Remain very high in all regions (high confidence).

How to adapt

Adapting to extreme heat

As temperatures rise, citrus production could expand in the more southern mid-Murray regions of Deniliquin and Barham. Installing overhead netting might reduce the risks of sunburn.

Adapting to increased irrigation water requirements

Improving on-farm irrigation efficiency (such as through soil moisture monitoring and evapotranspiration scheduling software) might help to build resilience against water availability challenges.

For more information, please email vulnerability.assessment@dpird.nsw.gov.au or contact Steven Falivene on 0427 208 611.

This work has been produced by the NSW Primary Industries Climate Change Research Strategy funded by the NSW Climate Change Fund.

Huanglongbing: the biggest disease threat to citrus

Leonie Martin, Plant Biosecurity Officer, NSW DPIRD

Huanglongbing (HLB), also known as 'citrus greening', is one of the world's worst citrus diseases. HLB and its reported vectors are not present in Australia, but if introduced, would significantly affect the Australian citrus industry.

Three strains of bacteria are associated with the disease:

1. *Candidatus* Liberibacter asiaticus
2. *Ca*. L. africanus
3. *Ca*. L. americanus

HLB is transmitted by the Asiatic citrus psyllid (*Diaphorina citri*) and African citrus psyllid (*Trioza erytreae*).

The disease is found in Asia, Africa, and the Americas, including countries directly to our north. The Asiatic citrus psyllid is also found on some Pacific Islands. It could be introduced into Australia through the importation of infected plant material including budwood, leaves and fruit stems or infected vector insects (citrus psyllids).

The bacteria can infect all commercial citrus species and some citrus relatives; oranges, mandarins and mandarin hybrids are severely affected. The common garden plant, orange jasmine (*Murraya paniculata*), is also the preferred host of the Asiatic citrus psyllid.

There is no cure for infected trees. The only way to rid citrus orchards and home gardens of the disease is to replace infected trees (DAFF 2025).

What to look for

All growth stages of a citrus tree and all plant parts are affected by HLB. Symptoms can often be confused with citrus tristeza virus infection, Phytophthora root infection, citrus blight and nutrient deficiencies.

Trees

Symptoms of HLB include:

- leaf yellowing
- asymmetric blotchy mottling that crosses leaf veins but not the midrib (Figure 12), or symmetric foliar patterns consistent with nutrient deficiency symptoms
- lopsided, small, bitter-tasting fruit (Figure 13)
- dieback leading to the eventual death of the tree.

Figure 12. Huanglongbing symptoms on grapefruit leaves. Photo: JM Bové, INRA Centre de Recherches de Bordeaux, Bugwood.org.

Figure 13. Huanglongbing causes small, lopsided fruit with dark seeds and rind that does not colour properly. Photo: ME Rogers, UFL, idtools.org.

Psyllid vectors

The exotic Asiatic citrus psyllid (*Diaphorina citri*) and African citrus psyllid (*Trioza erytreae*) both carry the disease. Psyllids are small flying insects about 3–4 mm long. They look very similar to aphids but will jump when disturbed. They feed on new growth in a head-down, tail-up position (Figure 14 and Figure 15) and as nymphs (Figure 16 to Figure 18) and galls, they sit on leaves.

Spread of HLB and its vectors

The Asian and African citrus psyllids can fly short distances, but wind currents can carry them long distances. Psyllids can also be moved on host plants or by hitchhiking on non-host plants. Other means of spread include the movement of HLB-infected citrus plants or plant material (budwood, leaves or fruit stems) and plants and plant material infested with psyllid eggs or nymphs that are infected with HLB.

Figure 14. Asiatic citrus psyllid (*Diaphorina citri*). Source: David Hall, USDA Agricultural Research Service, Bugwood.org.

Figure 15. African citrus psylla (*Trioza erytreae*). Photo: SP van Vuuren, Citrus Research International, Bugwood.org.

Figure 16. Asiatic citrus psyllid nymph (*Diaphorina citri*). Image: Jeffrey W Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org.

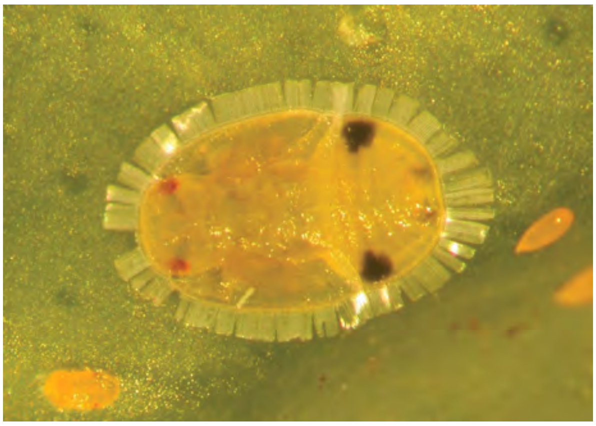

Figure 17. African citrus psylla nymph (*Trioza erytreae*). Source: Peter Stephen, Citrus Research International, Bugwood.org.

Figure 18. An African citrus psyllid infestation, note the nymphs on the leaf. Photo: Peter Stephen, Citrus Research International, Bugwood.org.

Actions to minimise risks

Put in place biosecurity best practice actions to prevent the entry, establishment and spread of pests and diseases.

- Practice 'come clean, go clean'.
- Ensure all staff and visitors are instructed in and adhere to your business management hygiene requirements.
- Have a biosecurity property plan in place and use it.
- Source propagation material of a 'known health status' from Auscitrus[1].
- Check your orchard frequently for the presence of new pests and any plants with unusual symptoms.
- Keep good records (document anything unusual).

To help keep HLB out of Australia, always abide by Australia's strict biosecurity rules. Imported shipments of plants or plant material may need to be treated and certified, so before you import anything, always check the Biosecurity import conditions system (BICON, https://www.agriculture.gov.au/import/online-services/bicon) for appropriate rules and regulations.

[1]Auscitrus is currently the only supplier of 'known health status' material.

How to report

Huanglongbing is a notifiable plant disease in NSW and must be reported within 1 working day. You can report notifiable plant pests and diseases by one of the following methods:

- call the Exotic Plant Pest Hotline on 1800 084 881
- email: biosecurity@dpird.nsw.gov.au with a clear photo and your contact details
- complete an online form (https://forms.bfs.dpi.nsw.gov.au/forms/9247)
- do not disturb the pest, but try to keep it contained, that is, close the door on a shipping container or contain the infected plant or psyllid in a plastic bag or container.

Acknowledgement

Thanks to Dr Nerida Donovan for providing subject matter expertise and for reviewing this article.

References and useful resources

Barkley P and Beattie GAC (2018) Huanglongbing and its vectors: information to develop a response plan for the citrus and allied industries. Citrus Australia, https://citrusaustralia.com.au/wp-content/uploads/Information-to-develop-a-response-plan-for-ACP-and-HLB-October-2018.pdf

Bové JM (2009) Huanglongbing. International Organization of Citrus Virologists, https://iocv.ucr.edu/citrus-diseases/huanglongbing

Department of Agriculture, Fisheries and Forestry (DAFF, 2025) Huanglongbing and vectors, https://www.agriculture.gov.au/biosecurity-trade/pests-diseases-weeds/plant/identify/huanglongbing

Fattore A and Donovan N (2024) Huanglongbing. NSW Department of Primary Industries and Regional Development, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/1564179/huanglongbing.pdf

NSW DPIRD (2017) Huanglongbing, https://www.dpi.nsw.gov.au/dpi/biosecurity/plant-biosecurity/insect-pests-and-plant-diseases/huanglongbing

Plant Health Australia (2024) Huanglongbing, https://www.planthealthaustralia.com.au/wp-content/uploads/2024/01/huanglongbing-FS.pdf

South Texas Citrus Alert (n.d.) Citrus greening, https://www.citrusalert.com/about-citrus-greening/

Thakur M, Donovan N, Lye J, Mo J (2024) Citrus huanglongbing. *Primefact 24/1029*, NSW Department of Primary Industries and Regional Development, https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1594768/Citrus-huanglongbing.pdf

Thakuria D, Chaliha C, Dutta P, Sinha S, Uzir P, Singh SB, Hazarika S, Sahoo L, Kharbikar LL and Singh D (2023) Citrus huanglongbing (HLB): diagnostic and management options. *Physiological and Molecular Plant Pathology*, 125: 102016, https://www.sciencedirect.com/science/article/abs/pii/S0885576523000711

Safeguarding Australia's citrus industry: progress on the ACIAR HLB project

Dr Meena Thakur, NSW DPIRD

Huanglongbing (HLB), also known as citrus greening, remains one of the most serious threats to global citrus production. The disease is caused by a phloem-limited bacterium spread by the Asian citrus psyllid (ACP, Figure 19, left), a small sap-sucking insect. Once trees are infected, they gradually decline, produce smaller fruit, and eventually die (Figure 19, right). HLB has devastated citrus industries in Asia and the Americas, including Florida, where it has caused major economic losses.

HLB and ACP are not present in Australia, but they are found in nearby regions including Indonesia and Papua New Guinea. This proximity, combined with the severe effects observed overseas, places HLB and ACP at the top of Australia's biosecurity priority list.

To strengthen Australia's preparedness and share management knowledge, a tri-nation research project funded by the Australian Centre for International Agricultural Research (ACIAR) with co-investment from Hort Innovation is underway between Australia, Indonesia, and China. The project is led by NSW DPIRD, in partnership with Universitas Gadjah Mada (UGM) in Indonesia, Badan Riset dan Inovasi Nasional (BRIN, Indonesia), the Chinese Citrus Research Institute (CRIC, China), and Citrus Australia Ltd (CAL, Australia).

The project has 2 main goals:

1. To understand and improve how HLB and ACP are managed in Indonesia and use those lessons to enhance Australia's preparedness.
2. To develop and test practical management options, such as HLB-tolerant rootstocks, high-density planting, ACP repellents and lures, and intercropping systems to help sustainable production and reduce reliance on insecticides.

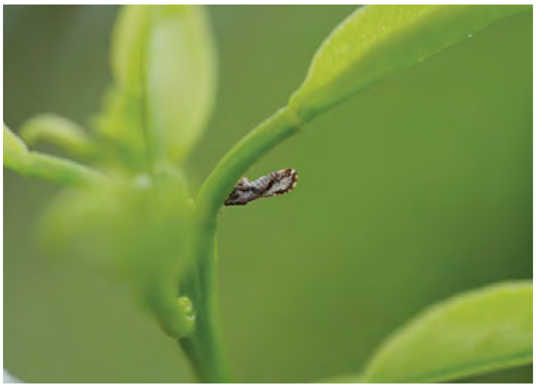

Figure 19. An adult Asian citrus psyllid (top) and an HLB-infected citrus tree with advanced dieback symptoms (bottom).

The project will also build Australian capacity by having numerous officers trained in field identification and appropriate and realistic management strategies.

Capacity building

Workshops (Figure 20 to Figure 22) were held in Indonesia where researchers from Australia, Indonesia, and China, along with international citrus experts, have updated each other, growers, and local plant protection officers on global advances in HLB management, including tolerant rootstocks, graft transmission, and high-density orchard systems.

Structured surveys (Figure 23) with smallholder farmers complemented these workshops. The surveys captured detailed information on farm size, orchard management, intercropping, ACP distribution, and grower attitudes. This information is helping researchers understand the spread of the disease and to design targeted extension, communication, and training strategies for both Indonesian and Australian audiences, ensuring that practical insights are shared between countries.

Project engagement at regional citrus forums has helped improve understanding of HLB management, ACP identification, and overall biosecurity awareness in Australia. Cross-country knowledge exchange has been enhanced through participation in major industry events such as Australia's Citrus Congress (2023, Figure 24), the CRIC-hosted HLB workshop in China (2024), and the International Organization of Citrus Virologists conference in Mildura (2025).

Figure 20. Capacity building workshop (2024) in Yogyakarta, Indonesia.

Figure 21. Steven Falivene discussing optimum nutrition and canopy management practices with Indonesian growers.

Figure 22. Dr Nerida Donovan presenting at a capacity building workshop (2025) in Bengkulu, Indonesia.

Figure 23. The Indonesian team interviewing growers during surveys.

Economic analysis

Economic analyses (Figure 25) of intercropping and high-density systems are underway. More than 3/4 of Indonesian citrus farms are <1 hectare and are often intercropped with vegetables or tropical fruit. The economic studies are helping us to understand how different orchard designs influence profitability, labour efficiency, and sustainability and the potential effect of HLB on smallholder profitability. This information is vital for guiding research priorities and practical extension advice for growers and to help build Australian models of HLB economic effect.

Figure 24. Indonesian project leader Siti Subnadiyah presenting at the Citrus Congress 2023.

Figure 25. Steven Falivene training students on economic analysis and modelling.

Field trials

- **HLB-tolerant rootstocks** were imported from the United States into Australia and Indonesia for evaluation in field trials under local conditions, and under HLB and ACP pressure in Indonesia. Field trials have been established in Australia, with 10 scion varieties to evaluate growth and graft compatibility. Germplasm imported to Indonesia in 2024 will be grafted with local scions in 2026 and established in field trials in 2027. Monitoring of these trees will continue in subsequent projects.
- **High-density planting trials** have been established in 3 Indonesian regions, Malang, Bengkulu, and Yogyakarta, using Australian and local rootstock varieties. Growth performance and tree health will be monitored in different planting densities and rootstock–scion combinations. These trials aim to identify which systems are most productive and economically viable in smallholder conditions.
- **Botanical repellents**, particularly citronella and clove oils, have shown strong potential in deterring ACP and are being further trialled in Indonesia to assess their effects on beneficial insects and longevity. Researchers in Indonesia are also collaborating with chemical pesticide manufacturers to commercialise a citronella-based formulation, as no botanical oil-based products are currently registered there. This could provide a valuable rotation option for ACP management.
- **Acetic acid-based lures** have proven attractive to ACP in Indonesia and are now being tested in Australia in 2 different regions with known high native psyllid activity. Although ACP is not present in Australia, lures that attract fewer non-targets will be better suited for future ACP monitoring, providing a valuable early-warning tool for surveillance and biosecurity preparedness.

Looking ahead

The current project finishes in June 2026. A final workshop in Indonesia in early 2026 will share outcomes with growers, researchers, and industry partners. By combining rigorous scientific research with practical field engagement and cross-country collaboration, the project has laid a strong foundation for regional HLB preparedness, ensuring that both Indonesian smallholders and the Australian citrus industry are better equipped to face the threat of HLB and ACP. Looking ahead, the project partners are seeking to develop a second project phase to extend this research linking diagnostic innovation, surveillance tools, and grower education to ensure the Australian citrus industry remains well-prepared for any future HLB or ACP incursions.

Acknowledgements

This project, 'Safeguarding Australia's citrus industry' (CT20003), is funded by ACIAR, with co-investment from Hort Innovation Citrus Fund, and in-kind contributions from NSW DPIRD, Citrus Australia Ltd, University Gadjah Mada, and The Citrus Research Institute of China.

Citrus variety evaluation program – sharing knowledge and shaping choices

Dave Monks, Research Horticulturist, Dareton

The Citrus Variety Evaluation Program remains one of the most authoritative tools growers have for understanding how new citrus varieties perform under Australian conditions. The work at Dareton and in Western Australia gives growers clear, independent information they can use when planning future plantings or comparing the performance of already planted trees.

Three new rows of drip irrigation have been installed at Dareton, where 12 varieties will be planted in spring. A new automated hot-house irrigation system will be installed shortly to house the growing list of new varieties entering the program. New rootstocks are also being grown in the greenhouse (Figure 26) to monitor their performance; they include 'Barkley' and 85-24, with 'US Gallasch' to be collected this coming season.

In October, 7 new varieties were top-worked at sites in West Gingin and Harvey in Western Australia, with 2 more sites added at Dandaragan. The varieties included Rosy Red Valencia, Cambria navel, low-seeded Taylor-Lee mandarin, and UF900 to evaluate their fit with Western Australian conditions.

Over 30 varieties were regularly sampled and evaluated from early April through mid-October. As usual, the season started with mandarins and lemons, with the first oranges entering evaluation about 6 weeks later.

Throughout the year, the program's findings were shared widely at grower events and field days in Dareton and Western Australia, with strong attendance from growers and industry representatives. Additional fruit displays (Figure 27) were set up at field days in the Riverina and at regional forums.

During 2025, more than 220 visitors came to the Dareton site to see the new material first-hand and discuss their blocks, markets, and management goals. The program's strength lies in these practical conversations – walking through the rows, looking at fruit, and talking about what works. This, combined with phone calls, fact sheets and conference presentations, gives growers access to the latest, independent information about new citrus varieties in Australian conditions.

Figure 26. New varieties growing in the hot-house for planting out this season.

Figure 27. A fruit display at a grower field day.

The Dareton site also hosted several major delegations in 2025. In February, the Global Victoria Inbound Horticulture Trade Mission tour group visited, bringing international buyers and Victorian exporters together to discuss opportunities for collaboration and export growth. In March, 72 delegates were welcomed for the International Organization of Citrus Virologists field day, an event focused on advancing citrus disease management worldwide. Later in the year, the Murray Valley Regional Forum brought over 50 growers and industry leaders to Dareton. In Western Australia, Citrus WA coordinated a suite of field and pack-house meetings showcasing new mandarins and oranges with updates from the national trial program.

More and more new varieties come into Australia through the Hort Innovation co-funded 'Evaluation of new citrus varieties 2022–2027 (CT22000)' from breeding programs in Queensland, Korea, Spain, South Africa, Florida, and California.

Take advantage of the access you have to this material, get in contact with Dave Monks (dave.monks@dpird.nsw.gov.au) or Kevin Lacey (kevin.lacey@dpird.wa.gov.au) to discuss your planting considerations or organise a visit.

To access fact sheets on varieties that have finished their evaluation, visit the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus).

Acknowledgements

The 'Evaluation of new citrus varieties 2022–2027' (CT22000) project is 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. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

Citrus rootstocks and varieties

Tahir Khurshid, Dave Monks and Andrew Creek, NSW DPIRD

Rootstocks

Rootstock selection is one of the most important factors to consider when planning a new block. For any orchard, the rootstock should suit the soil type. For example, a rootstock that is susceptible to phytophthora should not be planted in heavy clay soil or an area with poor drainage. Rootstock traits strongly influence fruit qualities such as fruit size, juice content, Brix and acid levels. Different rootstocks can be used to extend the marketing period of a scion variety in an orchard. Common rootstocks used in Australia and their horticultural traits are shown in Table 3.

The scion or variety selection must be compatible with the rootstock. Symptoms of incompatibility include excessive rootstock suckering, bud union creasing and rootstock overgrowth. Incompatibility is often overcome by using a sweet orange interstock.

More information on the compatibility of rootstocks and common citrus scions, as well as characteristics of the recently released Chinese rootstocks, such as Zao Yang, are included in Primefact 21/121, *Selecting citrus rootstocks* (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus).

Table 3. The general effects of rootstocks on citrus fruit quality.

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

Varieties

The NSW Department of Primary Industries and Regional Development (NSW DPIRD) strongly recommends that nursery trees be purchased from a reputable nursery, where the nursery uses budwood and rootstock seed purchased from Auscitrus. Auscitrus provides true-to-type and high-health-status propagation material to the Australian citrus industry. Since the inception of the Auscitrus scheme, orchard productivity has improved due to more consistent, predictable, and uniform tree growth (each tree in each patch starts the same as every other), and superior growth because trees are healthier. The Auscitrus budwood and rootstock seed source trees are tested to make sure they are free of harmful graft-transmissible diseases that negatively affect orchard health. The Auscitrus source trees are propagated using wood from the foundation trees in the National Citrus Repository, which are maintained in insect-proof structures and regularly tested for disease as an insurance policy to protect the Australian citrus industry.

Australian growers have a range of varieties to select from to meet market demand. Some are public varieties, while most of the new citrus varieties in Australia are subject to plant breeder's rights (PBR). PBR are exclusive commercial rights for a registered variety of plant. Variety owners usually have a variety manager to manage their intellectual property rights in Australia. Variety Access, Australian Nurseryman's Fruit Improvement Company (ANFIC), Nuleaf IP, Advanced Production Methods and Chislett Farms are examples of PBR citrus variety managers. Each manages a different variety portfolio (Table 4).

Chislett
Farms

Citrus | Avocados | Olives
Pistachios | Almonds | Walnuts

Wholesale Nursery

Chislett Farms supplies premium nursery-grown trees and rootstocks, produced under strict NIASA-accredited protocols to ensure clean, disease-free plant material.

Our accreditation mandates quarantine and hygiene standards that prevent virus and pathogen entry, delivering trees that establish fast, grow uniformly, and support long-term orchard performance.

Grown in 100% coir and propagated in controlled nursery environments, our trees develop strong healthy root systems for reliable field success.

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jonathan@chislettfarms.com.au | 0400 923 411 | www.chislettfarms.com.au

Table 4. Contacts for variety managers in Australia.

Symbol (used in tables)	Contact
P	**Public variety** Contact: Auscitrus Email: contact@auscitrus.com.au Phone: 03 5027 4411 Web: www.auscitrus.com.au
1	**Mildura Fruit Company** Email: info@mfc.com.au Phone: 03 5021 1644
2	**Australian Nurseryman's Fruit Improvement Company** (ANFIC) Contact: Dr Gavin Porter Email: info@anfic.com.au Phone: 0419 639 509 Web: anfic.com.au
3	**Chislett Farms** Contact: Jonathon Chislett Email: jonathan@chislettfarms.com.au Phone: 03 5038 8238 Web: www.chislettfarms.com.au
4	**Favco**, and **Carter and Spencer** Contact: Deon Doss Email: info@favcoqld.com.au Phone: 07 3717 1500
5	**Nu Leaf IP Pty Ltd** Contact: Matthew Cottrell Email: matthew@nuleafip.com Phone: 0438 594 010
6	**Variety Access Australia** Contact: Wayne Parr Email: ggrove@bigpond.com.au Phone: 0418 862 016 Web: www.varietyaccess.com.au
7	**D & J M Clark** Email: clark.dj@bigpond.com Phone: 0427 248 511

Auscitrus distributes both public and private variety propagation material. Only public varieties are listed on the Auscitrus order form. In the case of PBR varieties, the variety manager arranges a special order form for the supply of high-health-status propagation material to an approved nursery. You can approach the nursery or the rights manager directly to discuss this in the first instance.

Fact sheets on the most recently evaluated varieties are published on the NSW DPIRD website in the 'Rootstocks and varieties' section (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus). Many of these variety fact sheets were an outcome of Horticulture Innovation Australia (HIA) funded citrus variety evaluation research. The Citrus Australia website (https://citrusaustralia.com.au/) also publishes a range of citrus variety fact sheets.

Some variety information is exclusively published by the variety manager. It is recommended to check variety manager websites or contact individual variety managers for private variety fact sheets that are not published on the Citrus Australia or NSW DPIRD website.

The following seasonality charts (Table 5 to Table 9) provide a guide as to when orange varieties mature in southern Australia (Sunraysia on citrange rootstock). Variety managers for PBR varieties are denoted by superscripted numbers after the variety name in the seasonality chart.

Notes for the tables:

- The Riverina region is generally 2 weeks later than Sunraysia. This can vary with season and variety.
- Rootstock selection will also affect the maturity period.
- Superscripted letters or numbers refer to the variety manager (see Table 4).
- Red shading indicates red pigment fruit.

Table 5. Navel orange maturity for the Sunraysia region. For the Riverina, add 2 weeks.

	April				May				June				July				August				September				October				November			
	Week				Week				Week				Week				Week				Week				Week				Week			
Variety	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
M7[3]																																
Rayno[6]																																
Ryan[P]																																
FJ[6]																																
Newhall[P]																																
Navelina[P]																																
Fisher[P]																																
Thomson[P]																																
Leng[P]																																
Atwood[P]																																
Palmer[P]																																
Cara Cara[P]																																
Kirkwood Red[6]																																
Villa 11[6]																																
Washington[P]																					Industry standard variety, mid-season navel											
Hockney[P]																																
Benyenda[P]																																
Dolci[6]																																
Summer Gold[2]																																
Nielson[P]																																
Lane Late[P]	Industry standard variety, late navel																															
Autumn Gold[2]																																
Rohde[3]																																
Barnfield[P]																																
Clark[7]																																
Hutton[P]																																
Powell[P]																																
Chislett[3]																																
Witkrans[6]																																
Glen Ora[6]																																
Cambria[2]																																

Table 6. Common orange maturity for the Sunraysia region. For the Riverina, add 2 weeks.

	May				June				July				August				September				October				November				December				January			
	Week				Week				Week				Week				Week				Week				Week				Week				Week			
Variety	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Bintangcheng #2[P]		■	■	■	■																															
Salustiana[P]						■	■	■	■	■	■	■	■	■	■	■																				
Joe's Early[5]							■	■	■	■	■	■	■	■																						
Parson Brown[P]									■	■	■	■	■	■	■	■																				
Hamlin[P]										■	■	■	■	■	■	■	■	■																		
Pineapple[P]											■	■	■	■	■	■	■	■	■	■	■															

Table 7. Valencia orange maturity for the Sunraysia region. For the Riverina, add 2 weeks.

	August				September				October				November				December				January				February				March				April			
	Week				Week				Week				Week				Week				Week				Week				Week				Week			
Variety	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Weipe SL[6]			■	■	■	■	■	■																												
Turkey[6]				■	■	■	■	■	■																											
Benny[6]												■	■	■	■	■	■																			
McClean[6]								■	■	■	■	■	■	■																						
Gusocora[6]								■	■	■	■	■	■	■																						
McMahon SL[P]									■	■	■	■	■	■	■	■																				
Benyenda[P]										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
Ruby[6]										■	■	■	■	■	■																					
Midknight SL[P]										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Midknight Improved SL[6]										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Delta SL[P]										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Keenan[P]	Industry standard variety											■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								
DV Valencia[6]															■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			

Table 8. Blood orange maturity for the Sunraysia region. For the Riverina, add 2 weeks.

	May				June				July				August				September				October				November				December			
	Week				Week				Week				Week				Week				Week				Week				Week			
Variety	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Arnold blood[P]											■	■	■	■	■	■	■	■														
Tarocco Ippolito[P]											■	■	■	■	■	■																

Table 9. Mandarin maturity for the Sunraysia region. For the Riverina, add 2 weeks.

	April				May				June				July				August				September				October				November				December			
	Week				Week				Week				Week				Week				Week				Week				Week				Week			
Variety	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Satsuma Okitsu[P]			▒	▒	▒	▒																														
Clementine Nules[P]				▒	▒	▒	▒	▒																												
Imperial[P]							■	■	■	■	■	■	■	■	■	■	Industry standard variety, mid-season mandarin																			
Mojo[6]							▒	▒	▒	▒	▒	▒																								
Royal Honey Murcott[6]								▒	▒	▒	▒	▒																								
Early Sicily[2]									▒	▒	▒																									
Daisy[P]								▒	▒	▒	▒	▒	▒																							
Daisy LS[5]								▒	▒	▒	▒	▒	▒																							
Ruby GS[1]											▒	▒	▒	▒	▒																					
W. Murcott[P]	Industry standard variety, late-season mandarin														■	■	■	■	■	■	■	■														
Dekopon[P]															▒	▒	▒	▒	▒																	
Kinnow LS[5]																			▒	▒	▒	▒	▒	▒	▒	▒										
Murcott[P]																			▒	▒	▒	▒	▒	▒	▒	▒										

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 the 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 changes from dark green to light green–yellow
- GA to delay rind development
- Autumn copper sprays
- Cling sprays in the 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 are exceeded
- Check for 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
- 5–15 mm fruit diameter
- Assess crop load with counting frame at 12–15 mm fruit diameter (near the 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

Dr Jianhua Mo, Andrew Creek and Dr Meena Thakur, NSW DPIRD

Citrus gall wasp

Description

Size and appearance: adult citrus gall wasps (*Bruchophagus fellis*) are 2.5 mm long and shiny black (Figure 28). Larvae are hidden, feeding within the gall.

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 28). 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 (Figure 29).

Habit: most of a wasp's life is spent within the gall of a branch as a larva. Adult wasps emerge (Figure 30) 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 10).

Table 10. 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	Control							

Monitoring: check for galls in the low to middle canopy. Scattered small galls (<10 mm long) are indications of recent infestations, whereas large galls (Figure 31; >50 mm long) are indications of earlier infestations.

Monitoring tools and resources

Gall wasp monitoring video (https://www.youtube.com/watch?v=UeEWRkf8_fw) from NSW DPIRD is a useful tool for identifying early signs of galls on trees. It shows how to monitor gall wasp populations and infestation levels and highlights what equipment and steps you need for effective monitoring to take timely and appropriate management actions.

CGW emergence prediction app (https://citrusgallwasp.shinyapps.io/predict/) is an online tool that uses local weather data to forecast when adult wasps will emerge and eggs will hatch. This helps growers time their control strategies.

Management and control

Biological control: 2 naturally occurring parasitic wasps, *Megastigmus brevivalvus* (Figure 32) and *M. trisulcus* (Figure 33), parasitise CGW eggs. They do not eliminate CGW but will reduce the density and size of galls. The parasitoids are currently unavailable commercially and would take many years of augmented releases to be an effective control strategy alone. Soil-applied systemic insecticides also kill the parasitoid wasps. Surround® Crop Protectant is also likely to disrupt the parasitoid wasp activity.

Cultural: heavy hedge pruning and skirting will help control high infestations by removing large numbers of CGW. After hedging, galls need to be either mulched or burned if the timing is near adult emergence. Prune at least 56 days before expected adult wasp emergence if galls remain on the ground (under canopy) in the shade. Prune at least 28 days before expected adult wasp emergence if galls can be mechanically raked to the inter-row. The vigorous new flush after hedging is highly susceptible to CGW. Skirt pruning after egg laying can help to reduce gall wasp pressure.

Chemical: no contact foliar insecticides are registered to kill adult CGW. The residual activity of foliar insecticide is inadequate to provide effective control and is very disruptive to natural predators and parasitoids. Systemic insecticides containing clothianidin or imidacloprid applied through the irrigation system target larvae and provide adequate control. These insecticides have long residue periods. Calcined kaolin is an effective repellent for CGW during emergence, provided adequate coverage of spring flush can be maintained.

For further information, refer to Primefact 2010, *Citrus gall wasp in Southern Australia* (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/insects-diseases-disorders-and-biosecurity/inect-pest-factsheets/citrus-gall-wasp).

The chemical control for CGW is listed in Table 23 on page 60.

Figure 28. Adult citrus gall wasps laying eggs.

Figure 29. Citrus gall with bark removed, revealing citrus gall wasp cells.

Figure 30. Citrus gall wasp exit holes on mature citrus galls, with sap oozing from the openings.

Figure 31. A fully formed gall.

Figure 32. Female *Megastigmus brevivalvus* (inset: male).

Figure 33. Female *Megastigmus trisulcus* (inset: male).

Elephant weevil

Description

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

Size and appearance: immature larvae are soft and creamy–yellow. They are legless, about 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 34). 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 over reasonable distances.

Figure 34. Adult elephant weevil.

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 into the trunk exterior. A complete life cycle takes about one year. Adults emerge from September to February, with peak activity in December. They are strong fliers and feed on the bark of woody plants.

IPM

Damage and risk period: adult elephant weevil attacks young and old trees (Figure 35); 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.

Figure 35. Elephant weevil damage to young (left) and old (right) trees.

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

Heavily infested trees might have reduced fruit size and tree health. Severe infestation might cause branch or tree dieback. Healthy trees are unlikely to have significant elephant weevil damage.

Risk period: September to February (Table 11).

Table 11. 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 looks like sawdust (Figure 36). Freshly chewed bark on twigs might indicate elephant weevil presence (Figure 37).

Figure 36. Elephant weevil tunnels filled with sawdust in a young (left) and old (right) tree.

Figure 37. A young branch that has been chewed by an elephant weevil (left) and a tunnel caused by larvae 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, for example, *Beauveria bassiana* (Figure 38), can infect elephant weevil and could be part of an integrated control strategy.

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

Figure 38. 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 39) 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 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 12), but can be found all year round.

Figure 39. Adult Fuller's rose weevil.

Table 12. 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 12), 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: there is zero tolerance for quarantine export countries.

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

Management

Skirting trees and controlling weeds helps to reduce pathways for the adults 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 23 on page 60. 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.


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Katydids

Description

Size and appearance: there are several katydid species, 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 40). 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 about mid-October to November (Table 13).

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.

Figure 40. An adult citrus katydid.

Table 13. 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 young foliage, flowers and fruit (Figure 41). Fruit up to 30 mm in diameter are susceptible. The damage results in large, chalky white scars on mature fruit (Figure 42). Most citrus varieties are susceptible, however, katydids tend to cause most damage to navel oranges.

Monitoring: check fruit according to monitoring protocols (page 57) for signs of damage and scan the foliage for insects.

Natural predators: assassin bugs, praying mantises 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 41. Katydid damage to developing fruit.

Figure 42. Katydid damage to mature fruit.

Kelly's citrus thrips

Description

Size and appearance: adults are black (Figure 43), up to 3 mm long, with a small, clear band and parallel wings. Larvae are pale yellow (Figure 43) 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 (for example, 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 14). Larvae scrape the fruit rind under the calyx and where fruit touch.

Table 14. 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 44) will appear around the calyx (halo scarring) or where fruit touch. The critical period for monitoring and control is from petal fall (mid-October) to calyx closure (mid–late November), but damage can occur through to December.

Figure 43. Kelly's citrus thrips adult (black) and various larval stages. Photo: South Australian Research and Development Institute (SARDI).

Figure 44. Scurfing blemish left by Kelly's citrus thrips.

Monitoring: inspecting flowers for adult KCT will indicate a possible problem but does 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 December.

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

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 23 on page 60), but they have varying degrees of efficacy and effects on beneficial insects. Excessive use of organophosphate insecticides (for example, chlorpyrifos) 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.

Light brown apple moth

Description

Size and appearance: young larvae (caterpillars) are pale yellow–green. 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). Females have a wingspan of about 18 mm, making them larger than the males.

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 45 and Figure 46). When disturbed, the larvae will wriggle vigorously backwards. Larvae can also be found on fallen fruit and some broadleaf weeds.

Figure 45. A mature light brown apple moth larva on a leaf with webbing. Inset: an early instar larva on a young fruit with calyx removed.

Figure 46. Light brown apple moth damage to a fruitlet.

Figure 47. 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 15) and occasionally in early autumn and winter. Halo scarring (Figure 47) in small fruit can appear in spring and winter. Larvae can bore into mature fruit.

Monitoring: check fruit according to monitoring protocols (page 57) for signs of damage. Use pheromone traps to monitor moth flights to better time control sprays.

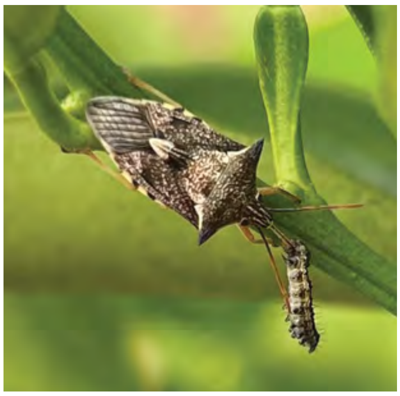


Figure 48. Predatory shield bug.

Natural predators: *Trichogramma* wasps parasitise moth eggs; other parasitic wasps and flies parasitise moth larvae. Important predators include the predatory shield bug, *Oechalia shellenbergii* (Figure 48), lacewing larvae and spiders. Various pathogens, including *Bacillus thuringiensis* (Bt), can also be used.

Management

Consider spraying only if monitoring indicates an unacceptable number of LBAM larvae. Select chemical options that preserve beneficial insect populations in the orchard. Some broad-spectrum insecticides can be used if monitoring indicates other pests also require treatment. Commercial pheromone mating-disruption products are available for area-wide LBAM management (refer to Table 23 on page 60).

Table 15. 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			

Mealybugs

Description

Size and appearance: mealybugs are oval-shaped, soft-bodied insects that are 3–4 mm long and covered with white, mealy wax. They are often found between touching fruit, under the calyx (Figure 49) or in the 'navels' of oranges (Figure 50).

Figure 49. Long-tailed mealybug under the calyx.

Figure 50. Long-tailed mealybug inside an orange navel.

There are several species of mealybugs. The long-tailed mealybug (*Pseudococcus longispinus*) is the predominant species in the Riverland, Sunraysia and Riverina regions. The citrophilus mealybug (*Pseudococcus calceolariae*) is mainly found in the Riverland and Sunraysia regions.

The tail filaments of the long-tailed mealybug are as long as or longer than the body (Figure 51). When squashed, the body fluid is pale yellow. The tail filaments of the citrophilus mealybug are much shorter and thicker than long-tailed mealybug (Figure 52) and the body fluid is claret-red.

Other mealybugs include the citrus mealybug, spherical mealybug, and *Rastrococcus* mealybug. The latter 2 are currently found in Queensland and coastal NSW only. Cottony cushion scale also looks superficially similar to mealybugs.

Life cycle: there are 3 to 4 generations a year. Long-tailed mealybug females produce around 200 live crawlers over 3 weeks that they deposit under their bodies. Crawlers are pink and less than 1 mm in size. Citrophilus mealybug lays up to 500 eggs in a cottony egg sac. These hatch in a few days to become crawlers.

Spring generations settle onto fruit in late November and early December (Table 16). They generally settle in sheltered sites such as the fruit calyx or inside the navel and between touching fruit and leaves. Mealybugs can overwinter as adults.

Figure 51. Long-tailed mealybug adult. Photo: Baker and Huynh (2016).

Figure 52. Citrophilus mealybug adult. Photo: Baker and Huynh (2016).

Table 16. Risk and monitoring period for mealybug activity.

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

IPM

Damage: mealybugs feed on sap and excrete honeydew, which encourages the growth of sooty mould (Figure 53) and other fungi. Sooty mould spoils the appearance of fruit. Other fungi can grow on the honeydew and cause fruit rot. Mealybugs are a quarantine pest of concern for some countries.

Monitoring: use a 10× hand lens to check fruit for mealybugs fortnightly from November. After December, monitor monthly until fruit maturation. Examine under the calyx and in autumn, also check the navel end of oranges. It is beneficial to monitor and detect early stages before fruit are heavily infested or marked with sooty mould.

Natural predators: parasitic wasps, lady beetles and lacewings.

Figure 53. Sooty mould caused by mealybugs.

Figure 54. Two-spotted lady beetles are mealybug predators.

Management

Cultural: use alternate row slashing to enhance beneficial insect numbers. Manage ant colonies, as ants will actively defend pests from natural predators. Understanding the habits of the ant species causing the problems will help with managing the ants.

Biological: mealybugs can be managed by natural predators such as lacewing larvae, the cryptolaemus lady beetle, and the tiny two-spotted lady beetle (Figure 54). Mealybugs are also attacked by several parasitoid species. Natural predators are very effective as they can get inside the tree canopy and tight places where mealybugs live. Lacewing larvae and the cryptolaemus lady beetle are commercially available. *Cryptolaemus montrouzieri* is an Australian native and a very effective biocontrol agent (Figure 55).

Chemical: mealybugs are difficult insects to manage using pesticides alone. Consult your pest control specialist for registered chemical control options. Make considered chemical choices to protect natural predators. Insecticides mixed with oil can provide effective control in medium-level infestations (refer to Table 23 on page 60).

Figure 55. *Cryptolaemus montrouzieri* adults.

Queensland fruit fly

Description

Size and appearance: adult Queensland fruit flies (QFF) are about 6–8 mm long and reddish-brown with yellow markings (Figure 56). 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.

Figure 56. Dorsal view of adult Queensland fruit fly.

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 17). Valencias are at higher risk than navels because fruit maturation occurs in the warmer months (spring and summer) when fruit flies are most active.

Table 17. 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.

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. Refer to page 53 for more information on QFF and Table 23 on page 60 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

Size and appearance: the first stage starts as yellow crawlers (Figure 57) that are about 0.5 mm in diameter, then whitecaps (Figure 58) before turning reddish–brown (Figure 59) and growing to 0.5–2.0 mm in diameter. Females are round and males are elongated. Adult males are yellow and have wings (Figure 60).

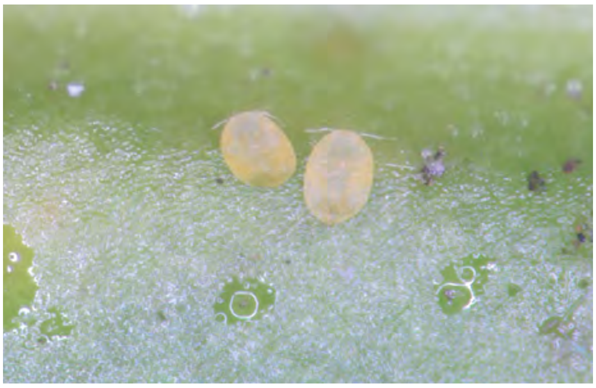


Figure 57. Red scale crawlers.

Figure 58. White cap stage beside a male red scale pupa.

Figure 59. Various stages of red scale.

Figure 60. Male red scale.

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 for scale according to monitoring protocols (page 57) from November to December (Table 18), then monthly until harvest. Before spraying, randomly collect 20 fruit from each block and examine the relatively large mature female scale insects for parasitism.

Table 18. 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.

Natural predators: lacewing larvae and scale-eating lady beetles. The most common parasitoids are *Aphytis* spp. and *Comperiella bifasciata* wasps (Figure 61). *Aphytis* spp. wasps prefer to parasitise second instar scale insects; up to 80% of female scale insects can be parasitised.

Management

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

HMO requires a high-volume application (for example, medium-sized trees might need 5,000–8,000 L/ha). Medium-volume spray machines (that is, air-blast) might not provide satisfactory results. Other chemical options (refer to Table 23 on page 60) could be applied with a medium-volume spray machine.

Figure 61. An adult *Comperiella* spp. parasitic wasp. Photo: Qld Department of Primary Industries (QDPI).

Early season (December) control should be applied to high infestations or sites with a history of recurring scale insect. If red scale insects are present and parasitism is low between October and March, consider releasing *Aphytis* spp. wasps.

For more information, a great webinar is available on the DPIRD website as part of the IPDM project output on sustainably managing red scale (https://www.youtube.com/watch?v=jad28TH8f2g).

Another useful resource is the red scale emergence timing tool on the NSW DPIRD website (https://redscale.shinyapps.io/predict/). This tool helps predict crawler emergence for optimal timing of chemical applications or Aphytis spp. wasp releases based on male flight peaks.

Soft brown scale

Description

Size and appearance: soft brown scale insects are flat, oval, 3–4 mm long, yellow–green or yellow–brown (Figure 62) and often mottled with brown spots. Female scale insects darken with age.

Life cycle: there are 3–4 generations a year in the southern regions. One generation takes about 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 scale insects are found on leaves, twigs (Figure 63) and occasionally fruit. Most infestations are found in young or recently reworked trees.

Figure 62. Mature soft brown scale.

Figure 63. 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 19). Focus monitoring on boundary rows (dusty trees), young trees and recently reworked trees.

Monitoring: check fruit according to monitoring protocols (page 57) for signs of damage.

Natural predators: numerous parasitic wasps.

Table 19. 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 be controlled. Refer to Table 23 on page 60 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 64). Adults are green, 15–20 mm long and have a prominent spine on each shoulder (Figure 65).

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 (SCB) mainly attack lemons and some mandarin varieties, but grapefruit and oranges can also 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 64. Spined citrus bug nymphs at various stages.

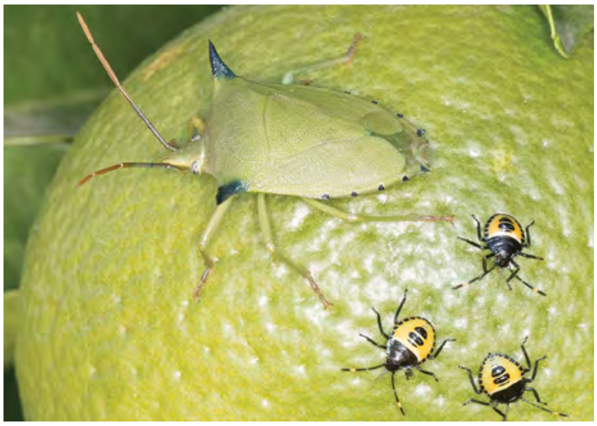


Figure 65. Spined citrus bug adult and nymphs.

IPM

Damage and risk period: November to harvest (Table 20). Adults and nymphs feed on fruit by sucking, causing rind lesions, dried out fruit segments and fruit drop.

Table 20. 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 for damage according to monitoring protocols (page 57). Collect and rear eggs to hatching to check for parasitism.

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 bugs and numerous predatory wasps.

Management

Regular monitoring and prompt control are critical 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 selective insecticides to provide effective control (refer to Table 23 on page 60).

Further reading on insect pests

Baker G and Huynh M. 2016. Identifying mealybugs on inland Australian citrus. South Australian Research and Development Institute fact sheet, https://www.pir.sa.gov.au/__data/assets/pdf_file/0007/285532/Identifying_Mealybugs_on_Inland_Australian_Citrus_Fact_Sheet.pdf

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.

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 (*Bactrocera tryroni,* QFF) ensures producers can develop, maintain and enhance domestic and international market access.

Queensland fruit fly (Figure 66) 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 67) 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 are most at risk when fruit starts to mature (that is, from colour break). Immature green fruit are not preferred, but 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 (for example, splitting, hail damage) are available, fruit fly damage is more likely.

Figure 66. Queensland fruit fly on citrus.

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

Effective orchard quarantine practices that prohibit fruit from being moved into the orchard are essential. 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 67. 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. Any 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 68). It has slightly different markings from the Newman fly and Island fly (Figure 69 and Figure 70).

Queensland fruit fly is also different from the small dark brown *Drosophila* spp. flies (also called vinegar or ferment flies) that loiter around ripe and decaying fruit. While *Drosophila* spp. 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, becoming yellowish when fully grown (Figure 72). When fully fed, the larva pupates (Figure 73), 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 68. Queensland fruit fly (*Bactrocera tryoni*) has horizontal 'GT' stripes (blue circle), a yellow band on the abdomen and clear wings.

Figure 69. 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 70. Island fly (*Dirioxa pornia* Walker) has wings that are distinctly mottled with black. It is mainly found in female traps.

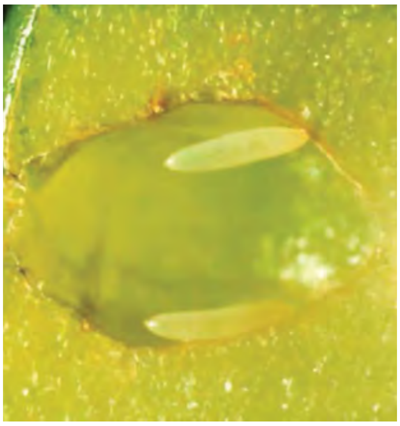


Figure 71. Queensland fruit fly eggs (about 1 mm).

Figure 72. Queensland fruit fly larvae (6–8 mm).

Figure 73. Queensland fruit fly pupae (6–8 mm).

Fruit fly stings

Fruit are most susceptible from the start of colour break (April to May). Actively managing QFF throughout the season ensures low numbers during high-risk periods. Over-ripe fruit (that is, missed during harvest) is highly susceptible.

The egg-site punctures in the fruit are commonly referred to as 'stings' (Figure 74). 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 fruit, although stung, do not develop larvae, but the stung fruit sometimes fall. Larvae can successfully develop in most citrus varieties including fruit on *Citrus (Poncirus) trifoliata* rootstock.

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.

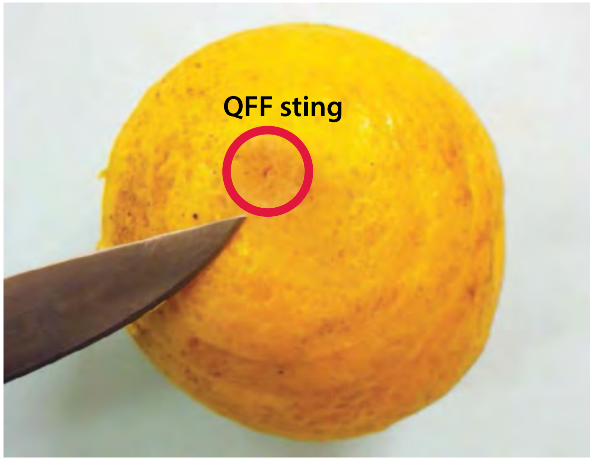


Figure 74. Fruit stung by Queensland fruit fly often get secondary fungal infections such as sour rot, brown rot or blue and green moulds.

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 rejected fruit properly.

Several chemicals are registered for controlling QFF in citrus (refer to Table 23 on page 60). 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 effectiveness of the baiting. Fruit should still be routinely checked for fruit fly damage.

The current recommendation is to place one trap 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 (that is, at the corners of the orchard) and look for alternative hosts (for example, 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 consider offering to remove the trees, then 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 (for example, near a neighbouring unmanaged backyard tree).

If the block becomes heavily infested, refer to the APVMA website (https://portal.apvma.gov.au/pubcris) for treatment options. Make sure you discuss treatment plans with your packing shed manager before applying them; a cover spray on mandarins might disqualify a post-harvest 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 flies. 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 is controlled in all other host plants
- all late hanging fruit missed during harvest is removed
- all fallen fruit are picked up and properly disposed of; do not send damaged or fallen fruit to the packing shed
- good orchard hygiene is maintained.

Bait spraying

Apply 15–20 L of bait spray per hectare (following 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 (refer to Figure 75), 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.

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

Figure 75. 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.

Resources

Monitoring and baiting

Andrew Jessop discusses all things Queensland fruit fly (https://www.youtube.com/watch?v=sMKohgWsPqo&t=3s)

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)

Queensland fruit fly with Dan Papacek (https://www.youtube.com/watch?v=6nzPM7mUfiU&t=4s)

Fruit fly programs

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

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

Acknowledgements

The original edition of this article was written by Sandra Hardy and Andrew Jessup.

Integrated pest management

Food safety, environmental accountability and increasing insect resistance to pesticides are vital issues facing modern horticultural industries. Adopting integrated pest management (IPM) helps overcome these issues and encourages sustainable production. IPM is based on managing the relationships between various 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 (for example, 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 using a protocol (page 57) and keeping good records are fundamental to knowing what is happening in the orchard. A monitoring protocol involves 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 by avoiding 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 essential 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 23 on page 60 and Table 24 on page 65) 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 and green lacewings (Figure 76) are general predators commonly seen in citrus orchards. They prey on aphids, moth eggs, small larvae, scale insects 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 prey debris they carry on their backs (Figure 77). Brown lacewing larvae are not disguised and have clear pincers at the front for attacking prey. Green lacewing eggs are white and attached 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 76. A green lacewing adult.

Lady beetles

Cryptolaemus and *Diomus* lady beetles (Figure 78) are mealybug predators. Both the adult and larvae feed on mealybugs and soft brown scale.

Rhyzobius lophanthae is a commercially available scale insect-eating lady beetle (Figure 79) 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 and assassin bugs, are also common in orchards where IPM is practised, including the 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 that eat 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 scale insects and unmated females. The tiny yellow wasps (Figure 80) 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 insect, which then parasitises other scale insects, continuing the cycle of biological control.

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

Figure 77. A green lacewing larva disguised by the prey debris it carries on its back.

Figure 78. An adult *Diomus notescens* on a citrus leaf.

Figure 79. Both the larvae (left) and adult (right) of the lady beetle (*Rhyzobius lophanthae*) are important scale insect predators.

Figure 80. *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 scale insects. One larva develops in each scale insect. *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 81). 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 to release in the orchard.

The minute two-spotted lady beetle is another naturally occurring predator of two-spotted mites.

Figure 81. 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, either by failing to detect pests that later cause significant fruit damage or overestimating the presence of a pest and unnecessarily applying pesticides. Pesticide use can adversely affect beneficial insects and lead to secondary pest flare-ups, which 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 21). Choose representative trees (that is, healthy trees) throughout the whole block. A practical strategy is to walk down rows and select trees randomly along the row (Figure 82). If pest flare-ups are detected in only one part of the block, further monitoring can help determine the extent of the damage and provide the opportunity to spray only the affected area. This will save time and money and minimise the negative effects of 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 inspect it 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 21. 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 82. A suggested pattern to use while walking throughout the block for monitoring.

Creature feature: the mealybug destroyer

Rob Weppler, Riverina IPM Pty Ltd

Cryptolaemus montrouzieri is a small ladybird beetle (Figure 83) that feeds on mealybugs, soft scales, and cottony cushion scale. It is commonly found in Australian citrus orchards where these pests are a problem. It is also an effective predator of a range of soft scale pests on other plants.

In citrus, Cryptolaemus often shows up only after its prey has reached levels greater than many growers are willing to tolerate. However, once it shows up, the prey population is usually completely controlled. It is unclear how much they help to regulate pest populations at low densities. To maintain low densities of pests, internal parasitoids are also required.

Cryptolaemus is native to Australia, but has also been imported to many other citrus-growing nations as an effective biological control agent. It was imported to California during 1891–92, but entomologists subsequently realised that Cryptolaemus was not over-wintering in sufficient numbers to give adequate control of citrus mealybugs, so they began a mass rearing program to augment the natural population each spring. At its height in the 1920s, 15 public and private organisations were producing Cryptolaemus beetles. Orange County alone constructed 22 buildings for this purpose and produced millions of beetles per week.

Insectaries around the world still rear Cryptolaemus as a voracious predator of mealybugs and soft scales (Figure 84). A single larva can consume up to 250 mealybugs. In Australia, Cryptolaemus is available to purchase from Bugs for Bugs in Queensland.

Natural enemies, including Cryptolaemus, can completely control severe outbreaks of citricola and soft brown scale in citrus and long-tailed mealybug in greenhouse eggplant. Cryptolaemus is an Australian legend, along with the Vedalia beetle, that continues to help citrus growers around the world.

Figure 83. *Cryptolaemus montrouzieri* adult. Photo: Rob Weppler, Riverina IPM Pty Ltd.

Figure 84. *Cryptolaemus montrouzieri* larva feeding on soft scale. Photo: Rob Weppler, Riverina IPM Pty Ltd.

More information about Cryptolaemus and integrated pest management in citrus is available on the NSW DPIRD website (https://www.youtube.com/watch?v=93_GdsB4_cY&pp=ygUTaXBtIGNpdHJpY29sYSBzY2FsZQ%3D%3D).

Insecticide chemical tables

Common citrus pests and their growing periods

Table 22. When to monitor common citrus pests.

			Cell division		Cell expansion							
	Bud break / Leaf expansion	Flowering	Flowering	Fruit set/ drop		Golf ball		Colour break	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 leaf-miner												
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 23) can change at 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 in this document.

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.

Table 23. Insect pests and chemical controls registered for use in NSW (correct on 3 November 2025), 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 Ant Bait
Aphids	Dimethoate	1B	❸	7	Dimethoate® 400
	Malathion	1B	❸	3	Fyfanon® 440 EW
	Pirimicarb	1A	❶	2	Pirimor® WG
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
Australian plague locust	Dimethoate	1B	❸	7	Dimethoate® 400
Bronze orange bug	Carbaryl	1A	❸	3	Bugmaster® Flowable (oranges and lemons only)
	Dimethoate	1B	❸	7	Dimethoate® 400
	Malathion	1B	❸	3	Fyfanon® 440 EW
Brown field slug	Metaldehyde	5	❶	7	Snail Trail Snail and Slug Pellets
Citrophilous mealybug	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Buprofezin	16	❶	28	Applaud®
	Sulfoxaflor	4C	❷	1	Transform Isoclast®
Citrus butterflies	Malathion	1B	❸	3	Fyfanon® 440 EW
Citrus butterflies (larvae)	Carbaryl	1A	❸	3	Bugmaster® Flowable (oranges and lemons only)
Citrus gall wasp	Calcined kaolin	na	❶	0	Surround® WP Crop Protectant
	Clothianidin	4A	❷	140	Samurai®
Citrus leaf-eating weevil	Bifenthrin	3A	❸	0	Talstar® 100 EC
Citrus leaf-miner	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Botanical oil	Spray adjuvant	❶	0	Eco-oil®
	Clothianidin	4A	❷	140	Samurai®
	Paraffinic oil	Spray adjuvant	❶	1	Biopest®
	Petroleum oil	Spray adjuvant	❶	1	Banole® EC
	Spinetoram	5	❷	1	Success® Neo
Citrus mealybug	Acetamiprid + pyriproxyfen	4A + 7C	❸	14	Trivor®
	Buprofezin	16	❶	28	Applaud®
	Spirotetramat	23	❶	21	Movento® 240 SC (suppression only)
	Sulfoxaflor	4C	❷	1	Transform Isoclast®
Citrus nematode	Cadusafos	1B	❷	0	Rugby® 100G

Table 23. Insect pests and chemical controls registered for use in NSW (correct on 3 November 2025), page 2 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
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
Fruit spotting bug	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Sulfoxaflor	4C	2	1	Transform Isoclast®
Fruit-piercing moth	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
Fuller's rose weevil	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
	Clothianidin	4A	2	140	Samurai®
	Cyantraniliprole	28	2	0	Exirel®
	Gamma-cyhalothrin	3A	3	28	Trojan® (oranges and lemons only)
	Isocycloseram	30	3	14	Vertento®
	Lambda-cyhalothrin	3A	3	28	Karate Zeon® (oranges and lemons only)
Greenhouse thrips	Pyrethrins	3A	2	1	PyGanic®
Helicoverpa (budworms, earworms)	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®
	Isocycloseram	30	3	14	Vertento®
	Spirotetramat	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Transform Isoclast®
	Thiamethoxam	4A	2	49	Actara®
Lesser Queensland fruit fly (male)	Spinosad	5	1	0	Naturalure® Fruit Fly Bait Concentrate
Light brown apple moth	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Bacillus thuringiensis (Bt)	11	1	0	Dipel® DF
	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
	Cyantraniliprole	28	2	0	Exirel®
	Isocycloseram	30	3	14	Vertento®
	Methomyl	1A	3	2	Nufarm Methomyl 225
	Methoxyfenozide	18	1	1	Prodigy®
	Spinetoram	5	2	1	Success® Neo
	Tebufenozide	18	1	1	Mimic® 700 WP
	Tetra-decenyl acetate + tetra-decadienyl acetate	Pheromone	1	0	Splat LBAM HD-O™ mating disruption agent
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

Table 23. Insect pests and chemical controls registered for use in NSW (correct on 3 November 2025), page 3 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Long-tailed mealybug	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Buprofezin	16	1	28	Applaud®
	Sulfoxaflor	4C	2	1	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
Mealybug (*Pseudococcidae* spp.)	Orange oil	na	1	0	PREV-AM® Contact Insecticide, Miticide and Fungicide
Migratory locust	Dimethoate	1B	3	7	Dimethoate® 400
Mite, broad mite	Abamectin	6	3	7	Vertimec® Pro
	Paraffinic oil	Spray adjuvant	1	1	Bioclear®
Mite, brown citrus mite	Mancozeb	M3	2	0	Penncozeb® 750 DF
	Mancozeb + zinc	M3	2	0	Manic® WG Fungicide Plus
Mite, brown citrus rust mite	Abamectin	6	3	7	Vertimec® Pro
	Paraffinic oil	Spray adjuvant	1	1	Bioclear®
	Sulfur	M2	1	0	Thiovit® Jet Microgranule
	Zineb	5	1	7	Barmac Zineb
Mite, citrus bud mite	Mancozeb	M3	2	0	Penncozeb® 750 DF
	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
	Mancozeb	M3	2	0	Penncozeb® 750 DF
	Mancozeb + zinc	M3	2	0	Manic® WG Fungicide Plus
	Orange oil	na	1	0	PREV-AM® Contact Insecticide, Miticide and Fungicide
	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	Thiovit® Jet Microgranule
	Zineb	5	1	7	Barmac Zineb
Mite, Oriental spider mite	Etoxazole	10B	1	7	ParaMite®
	Orange oil	na	1	0	PREV-AM® Contact Insecticide, Miticide and Fungicide
Mite, two-spotted mite	Orange oil	na	1	0	PREV-AM® Contact Insecticide, Miticide and Fungicide
Orange fruit borer	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)

Table 23. Insect pests and chemical controls registered for use in NSW (correct on 3 November 2025), page 4 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Queensland fruit fly	4-(p-acetoxyphenyl)-2-butanone + malathion	1B	1	0	Searles® Fruit Fly Wick (bait toxicant)
	Abamectin (bait)	6	1	7	Vertimec® Pro
	Dimethoate	1B	3	7	Dimethoate® 400
	Malathion (cover spray)	1B	3	3	Fyfanon® 440 EW
	Malathion (bait)	1B	1	3	Fyfanon® 440 EW
	Pyrethrins	3A	3	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
	Spinosad	5	1	0	Naturalure® Fruit Fly Bait Concentrate
Rutherglen bug	Malathion	1B	3	3	Fyfanon® 440 EW
	Pyrethrins	3A	2	1	PyGanic® (clean-up spray)
Scale (*Coccoidea* spp.)	Orange oil	na	1	0	PREV-AM® Contact Insecticide, Miticide and Fungicide
Scale, black (brown olive) scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Pyriproxyfen	7C	2	7	Admiral® Advance
Scale, citricola scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Sulfoxaflor	4C	2	1	Transform Isoclast®
Scale, cottony cushion scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Pyriproxyfen	7C	2	7	Admiral® Advance
Scale, pink wax scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
	Malathion	1B	3	3	Fyfanon® 440 EW
	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	Transform Isoclast®
Scale, purple (mussel) scale	Malathion	1B	3	3	Fyfanon® 440 EW
	Spirotetramat	23	1	21	Movento® 240 SC
Scale, red scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Buprofezin	16	1	28	Applaud®
	Clothianidin	4A	2	140	Samurai®
	Imidacloprid	4A	2	140	voodoo guard® soil insecticide
	Malathion	1B	3	3	Fyfanon® 440 EW
	Paraffinic oil	Spray adjuvant	1	1	Biopest®
	Petroleum oil	Spray adjuvant	1	1	D-C-Tron® Plus
	Pyriproxyfen	7C	2	7	Admiral® Advance
	Spirotetramat	23	1	21	Movento® 240 SC
	Sulfoxaflor	4C	2	1	Transform Isoclast®
Scale, soft brown scale	Acetamiprid + pyriproxyfen	4A + 7C	3	14	Trivor®
	Malathion	1B	3	3	Fyfanon® 440 EW
	Spirotetramat	23	1	21	Movento® 240 SC

Table 23. Insect pests and chemical controls registered for use in NSW (correct on 3 November 2025), page 5 of 5.

Insect pest	Active ingredient(s)	Group	IPM	WHP (days)	Example trade name
Scale, 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	Transform Isoclast®
	Sulfur	M2	2	0	Barmac wettable sulphur fungicide and miticide
Scale, white wax scale	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
	Paraffinic oil	Spray adjuvant	1	1	Biopest®
	Petroleum oil	Spray adjuvant	1	1	D-C-Tron® Plus
Slugs	Iron	na	1	0	Protect-us™ Mineral Snail and Slug Killer
	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 and Slug Killer for Agricultural use
	Metaldehyde	5	1	7	Snail Trail Snail and Slug Pellets
	Silicate salts + copper complex	na	1	0	Socusil® Snail Repellent
Spined citrus bug	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
	Malathion	1B	3	3	Fyfanon® 440 EW
Spur-throated locust	Dimethoate	1B	3	7	Dimethoate® 400
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
Treehoppers	Malathion	1B	3	3	Fyfanon® 440 EW
Whitefly	Orange oil	na		0	PREV-AM® Contact Insecticide, Miticide and Fungicide
Wingless grasshopper	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)
	Dimethoate	1B	3	7	Dimethoate® 400
Yellow peach moth	Carbaryl	1A	3	3	Bugmaster® Flowable (oranges and lemons only)

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 24) 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.

Table 24. Active ingredients of insecticides registered for managing insects in NSW (correct on 3 November 2025), 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)
	❶	Queensland fruit fly (bait)	Vertimec® Pro
Acetamiprid + pyriproxyfen (4A + 7C)	❸	Black (brown olive) scale, citricola scale, citrophilous mealybug, citrus leaf-miner, 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®
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 (na)	❶	Citrus leaf-miner	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
Calcined kaolin (na)	❶	Citrus gall wasp	Surround® WP Crop Protectant
Carbaryl (1A)	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 (oranges and lemons only)
Clothianidin (4A)	❷	Citrus gall wasp, citrus leaf-miner, Fuller's rose weevil, red scale	Samurai®
Cyantraniliprole (28)	❷	Fuller's rose weevil, Kelly's citrus thrips, light brown apple moth	Exirel®

Table 24. Active ingredients of insecticides registered for managing insects in NSW (correct on 3 November 2025), page 2 of 3.

Active (Group)	IPM	Insect pest	Example trade name
Dimethoate (1B)	3	Aphids, Australian plague locust, bronze orange bug, migratory locust, Queensland fruit fly, spur-throated locust, thrips (see Kelly's citrus thrips), wingless grasshopper	Dimethoate® 400
Etoxazole (10B)	1	Oriental spider mite	ParaMite®
Gamma-cyhalothrin (3A)	3	Fuller's rose weevil	Trojan® (oranges and lemons only)
Imidacloprid (4A)	2	Red scale	Voodoo Guard® Soil Insecticide
Iron (na)	1	Snails, slugs	Protect-us™ Mineral Snail and Slug Killer
Iron-EDTA complex (na)	1	Snails	Multiguard® Snail & Slug Killer for Agricultural use
Isocycloseram (30)	3	Fuller's rose weevil, Kelly's citrus thrips, light brown apple moth	Vertento®
Lambda-cyhalothrin (3A)	3	Fuller's rose weevil	Karate Zeon® (oranges and lemons only)
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
Mancozeb (M3)	2	Brown citrus mite, citrus bud mite, citrus rust (Maori) mite	Penncozeb® 750 DF
Mancozeb + zinc (M3)	2	Brown citrus mite, citrus bud mite, citrus rust (Maori) mite	Manic® WG Fungicide Plus
Metaldehyde (5)	1	Slugs, snails	Snail Trail Snail and Slug Pellets
Methomyl (1A)	3	Light brown apple moth	Nufarm Methomyl 225
Methoxyfenozide (18)	1	Light brown apple moth	Prodigy®
Orange oil (na)	1	Citrus rust (Maori) mite, mealybug (*Pseudococcidae* spp.), Oriental spider mite, scale (*Coccoidea* spp.), two-spotted mite, whitefly	PREV-AM® Contact Insecticide, Miticide and Fungicide
Paraffinic oil (spray adjuvant)	1	Broad mite, brown citrus rust mite, citrus red mite, citrus rust (Maori) mite	Bioclear®
	1	Citrus leaf-miner, pink wax scale, red scale, white wax scale	Biopest®
Petroleum oil (spray adjuvant)	1	Citrus leaf-miner	Banole® EC
	1	Citrus rust (Maori) mite, pink wax scale, red scale, white wax scale	D-C-Tron® Plus
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
	2	Black (brown olive) scale, cottony cushion scale, red scale	Admiral® Advance
Silicate salts + copper complex (na)	1	Snails	Socusil® Snail Repellent

Table 24. Active ingredients of insecticides registered for managing insects in NSW (correct on 3 November 2025), page 3 of 3.

Active (Group)	IPM	Insect pest	Example trade name
Spinetoram (5)	2	Citrus leaf-miner, *Helicoverpa* (budworms, earworms), light brown apple moth	Success® Neo
Spinosad (5)	1	Queensland fruit fly	Naturalure® Fruit Fly Bait Concentrate
Spirotetramat (23)	1	Kelly's citrus thrips, pink wax scale, purple (mussel) scale, red scale, soft brown scale, white louse scale (citrus snow scale)	Movento® 240 SC
	1	Citrus mealybug	Movento® 240 SC (suppression only)
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)	Transform Isoclast®
Sulfur (M2)	2	Brown citrus rust mite, citrus bud mite, citrus rust (Maori) mite	Thiovit® Jet Microgranule
	2	White louse scale (citrus snow scale)	Barmac Wettable Sulphur Fungicide and Miticide
Tebufenozide (18)	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.

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.

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 85). Symptoms can develop in the orchard or post-harvest. 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 usually only causes decay when the rind has been damaged by other factors such as cold (Figure 86) or sunburn. Foggy and moist conditions throughout winter provide ideal conditions for the fungus to develop. Fungal spores are spread by rain splash. Post-harvest anthracnose development can occur when fruit are harvested late (over-ripe) or held too long in storage.

Management: annual pruning after harvest removes deadwood and reduces the risk of symptoms developing in the orchard. Applying a protective copper spray before autumn rain will reduce anthracnose in the orchard.

Growers can consider applying a second copper spray if the fruit will be harvested late in the season. For more information, refer to Primefact 757, *Using copper sprays to control diseases in citrus* (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/content/crop-management/orchard-management-factsheets/copper-sprays).

Figure 85. Anthracnose can appear as a tear-staining pattern on the rind.

Figure 86. 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 87 and Figure 88). Affected fruit usually colour prematurely and drop.

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

Management: applying recommended registered fungicides early during fruit development can reduce disease incidence. Well-pruned trees have better air circulation and spray penetration, resulting in lower spore populations. Where practical, delay harvesting susceptible varieties to allow infected fruit to drop first.

Figure 87. Black core rot in a mandarin.

Figure 88. 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 initially appear as 1–2 mm, red, circular lesions on the rind (Figure 89). Continued disease development later in the season can lead to large, brown to black, irregularly shaped, sunken lesions. Infected fruit and leaves might drop.

Figure 89. Citrus black spot early stages.

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

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

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 90). Spots are usually 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.

Figure 90. Brown spot symptoms on mandarin.

Cause: the *Alternaria alternata* fungus.

Management: extended wet weather from early spring to autumn can lead to foliar and fruit damage. Heavy dew is 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.

Chimeras

Symptoms: abnormally shaped, textured or coloured leaves and/or fruit (Figure 91).

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 91. Chimera can cause abnormally shaped, textured or coloured fruit.

Citrus viruses and viroids

Symptoms: affected trees can exhibit stunted growth (Figure 92), reduced production and fruit quality, tree decline or death. Other symptoms can include stem pitting (Figure 93), gumming (Figure 94) and bark peeling (Figure 95). Different diseases affect different citrus scions and rootstocks. Infected trees can be symptomless but still spread disease to susceptible varieties.

Cause: viruses are small infectious agents that can only replicate inside living cells, whereas viroids are the smallest form of infectious agents that 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 the citrus tristeza virus, which is spread by aphids.

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 solution (1.25% available chlorine).

Figure 92. Stunted growth in an orange tree (left) caused by citrus exocortis viroid.

Figure 93. Stem pitting in a grapefruit tree caused by citrus exocortis viroid.

Figure 94. Fine pits and gumming caused by orange stem pitting strains of citrus tristeza virus.

Figure 95. Severe bark peeling in an orange tree caused by citrus exocortis viroid.

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 cause ringbark and kill trees.

Cause: *Phytophthora* spp. 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 96).

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 (for example, copper) can reduce infection. Manage ant colonies in the orchard to reduce spore movement into the canopy.

Figure 96. An ant nest with collar rot.

Copper spray injury

Symptoms: usually the exposed (outward-facing) surface of the fruit shows signs such as stippling (Figure 97) or darkening of existing blemishes (Figure 98).

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 copper rates. 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 97. Minor copper phytotoxicity spray injury, the outward-facing side of the fruit shows signs of stippling.

Figure 98. Extensive copper phytotoxicity spray injury results in darkened blemishes on the outward-facing side of the fruit.

Creasing (albedo breakdown)

Symptoms: creasing is also known as albedo breakdown. It is often a seasonal issue that can reduce pack-outs and increase the risk of fruit breakdown during transit. Fruit with albedo breakdown has a weak rind that is susceptible to cracking (Figure 99). 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 100). 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 pre-harvest 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 101).

Calcium sprays can also help, but research indicates that multiple sprays (that is, 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 during January and early February.

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

Figure 99. The rind separation from albedo breakdown.

Figure 100. Typical albedo breakdown in a navel orange.

Figure 101. Severe creasing in an over-ripe mandarin.

Thorough spray coverage is essential, especially for the shaded parts of the fruit, which tend to exhibit worse symptoms than the unshaded side.

Frost injury

Symptoms: frosted fruit can have rind scald (Figure 102 and Figure 103) and dry fruit sacs (Figure 104). Severely damaged fruit usually drop. Young, frost-damaged trees can suffer bark splitting and foliage death. A moderate frost with cold wind can cause foliage to curl and bleach, as indicated by brown blotches (Figure 105).

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 an 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, refer to Primefact 1576, *Frost damage in citrus* (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/731630/frost-damage-in-citrus-D4-Edited-final-D3.pdf).

Figure 102. Frost injury to a navel orange.

Figure 103. Chill injury to Star Ruby grapefruit.

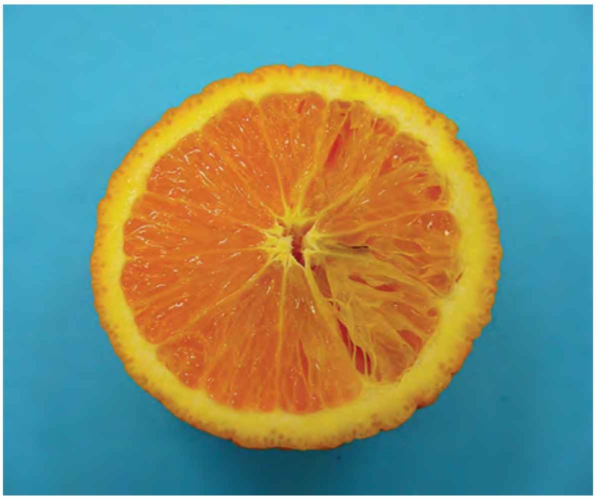


Figure 104. Dry fruit sacs in a navel orange.

Figure 105. 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 106) and matching, slightly raised, pale brown blisters form on the undersides (Figure 107); 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 106. Greasy spot symptoms on a citrus leaf.

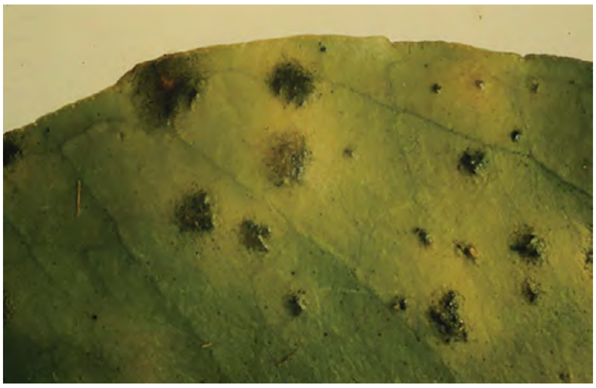


Figure 107. Greasy spot lesions on the underside of a citrus leaf.

Incompatibility

Symptoms: incompatibility between the scion and rootstock is usually associated with declining tree health; the rootstock can outgrow the scion (Figure 108). Trees can also die prematurely.

Cause: some scions are incompatible with certain rootstocks. Known incompatibilities include Imperial mandarin on *Citrus (Poncirus) trifoliata* (Figure 109), Eureka lemon on C. trifoliata and navelina orange on C35 rootstock.

Management: use compatible stock and scion combinations or separate incompatible varieties using an interstock.

Figure 108. Incompatibility with Imperial mandarin on trifoliate orange stock.

Figure 109. 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 110), twigs and fruit (Figure 111). Initially they are grey to pink and darken over time. Affected growth is usually 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 110. Lemon scab symptoms on a leaf. Photo: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org.

Figure 111. The irregular raised lesions on the 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 112). 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.

Cause: *Phomopsis citri* produces fungal spores on dead twigs during wet periods, which spread to young leaves (Figure 113) 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 112. Small raised melanose spots.

Figure 113. Melanose lesions on citrus leaves.

Oleocellosis and water marks

Symptoms: darkened spots on the fruit rind (Figure 114).

Cause: the phytotoxic action of peel oil released onto the rind causes oleocellosis in the field. Foggy, wet conditions can cause the rind to become turgid (swollen or distended) and more prone to rupturing oil glands during harvest. When turgid fruit is suddenly exposed to low temperatures, peel oil can be released on unharvested fruit. Rough handling of the fruit during harvest or post-harvest 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 115). Ensure pickers wear gloves. Do not harvest after rain or early on winter mornings when the fruit is cool and wet.

Figure 114. Oleocellosis watermarks on navel fruit without gibberellic acid applied.

Figure 115. Handling oleocellosis can appear a few days after harvest.

Citrus diseases and disorders

Phytophthora brown rot

Symptoms: leaf infections appear as dark brown, spreading blotches (Figure 116). Infected fruit develops a rapidly spreading, brown rind discolouration (Figure 117). 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 be controlled.

Figure 116. Left, the dark brown spreading blotches are leaf symptoms of brown rot. Right, a lemon from a tree infected with phytophthora brown rot.

Figure 117. Phytophthora brown rot on oranges.

Phytophthora root rot

Symptoms: feeder roots on affected trees die off quicker than they are replaced (Figure 118). Above ground, trees will show signs of stress, such as leaf yellowing and twig dieback, because their depleted root system cannot support the canopy (Figure 119).

Cause: *Phytophthora* spp. species oomycetes (water moulds) cause root decay. Waterlogged, poorly drained soil creates ideal conditions for phytophthora root rot.

Management: the disease is best managed using resistant or tolerant rootstocks, such as *Citrus (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 118. Left: dead feeder roots on a seedling infected with phytophthora. Right: active feeder roots from a healthy tree.

Figure 119. Leaves often turn yellow and drop from trees affected by phytophthora root rot.

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 120). 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 (for example, 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 120. Sooty mould grows on the sticky honeydew excreted by sap-sucking insects on the leaves and fruit.

Septoria spot

Symptoms: septoria spot starts as small, light brown depressions on the rind (Figure 121). The spots can enlarge, merge and darken as the fruit ripens (Figure 122). Small black fruiting bodies can form in the sunken lesions (Figure 123). 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 are still green. The disease remains latent for several months, with symptoms from 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 121. Septoria symptoms first show as small, light brown depressions on the rind.

Figure 122. Septoria symptoms after harvest.

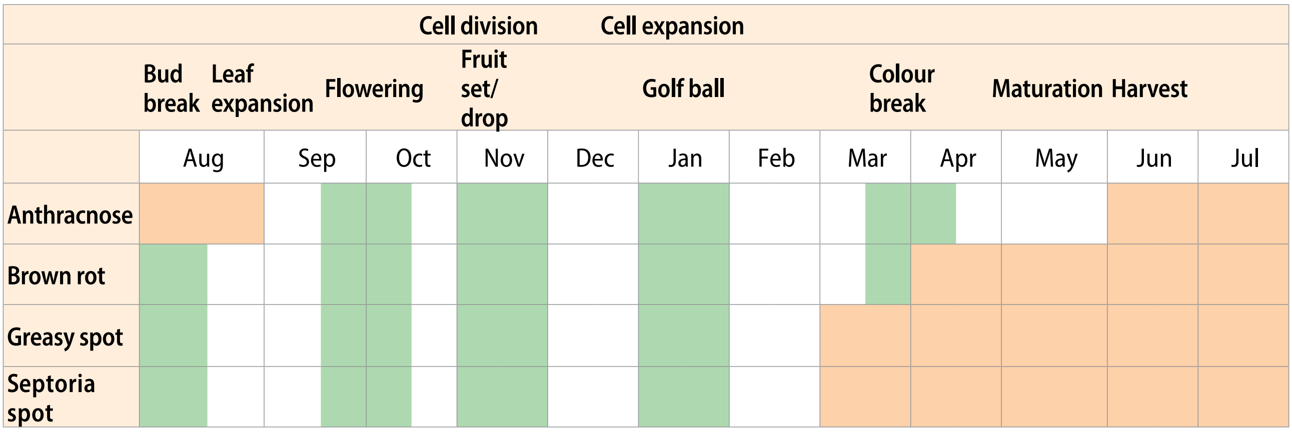
Figure 123. Advanced septoria spot with small black fruiting bodies in the lesions.

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 25. Common citrus diseases and growing periods.



Denotes phenology   Denotes disease activity

Diseases and chemical controls

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

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Table 26. Diseases of citrus and chemical controls registered for use in NSW (correct on 3 November 2025), 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	Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750 WG
	Copper hydroxide + mancozeb	M1 + M3	0	Mankocide® DF
	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 Liquid
	Mancozeb	M3	0	Dithane Rainshield Neo Tec®
	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, Oxydul® DF (both mandarins only)

Table 26. Diseases of citrus and chemical controls registered for use in NSW (correct on 3 November 2025), page 2 of 2.

Disease	Active ingredient(s)	Group(s)	WHP (days)	Example trade name(s)
Lemon scab	Copper ammonium acetate	M1	1	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 oxychloride	M1	1	Coppox WG, Oxydul® DF
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Liquid
Lichens	Sulfur	M2	0	InnoSulph® 800 WG
Melanose	Copper ammonium acetate	M1	1	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 oxychloride	M1	1	Coppox WG, Oxydul® DF
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Liquid
	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®, Foli-r-fos, HortiPhos
Phytophthora root rot	Phosphorous acid	P07	0	Agri-fos®, Foli-r-fos, HortiPhos
Phytophthora stem rot/canker	Copper ammonium acetate	M1	1	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 Liquid
Septoria spot	Copper cuprous oxide	M1	1	AG Copp 750 WG
	Copper oxychloride	M1	1	Coppox WG, Oxydul® DF
Sooty blotch (smoky blotch)	Copper ammonium acetate	M1	1	Liquicop
	Copper ammonium complex	M1	1	Copperguard®
	Copper cuprous oxide	M1	1	AG Copp 750 WG
	Copper oxychloride + copper hydroxide	M1	1	Airone® WG (Lemons)
	Copper sulfate	M1	1	Cuprofix® Bordeaux, Tribasic Liquid
	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 27). Always read the label.

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Table 27. Active ingredients of fungicides registered in NSW for managing citrus diseases (correct on 3 November 2025).

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)	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, phytophthora stem rot/canker, septoria spot, sooty blotch (smoky blotch)	AG Copp 750 WG
Copper hydroxide + mancozeb (M1 + M3)	Black spot	Mankocide® DF
Copper hydroxide/cupric hydroxide (M1)	Black spot, lemon scab, melanose, phytophthora stem rot/canker	Blue Shield®
Copper oxychloride (M1)	Black spot, lemon scab, melanose, phytophthora brown rot, septoria spot	Coppox WG, Oxydul® DF
	Brown spot	Coppox WG, Oxydul® DF (both mandarins only)
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 Liquid
Mancozeb (M3)	Black spot	Dithane Rainshield Neo Tec®
Mancozeb + zinc (M3)	Black spot	Manic® WG Fungicide Plus
Phosphorous acid (33)	Phytophthora collar rot, phytophthora root rot	Agri-fos®, Foli-r-fos, HortiPhos
Propineb (M3)	Black spot	Antracol® 700 WG
Sulfur (na)	Lichen, 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 citrus diseases

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 appear 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 on fruit that are over-ripe 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 protective 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 over 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 was seen in the Riverina, where weakened rind tissue is invaded by *Colletotrichum gloeosporioides* (the fungus that causes anthracnose; Figure 124). Wet seasons and foggy mornings have exacerbated these issues. Varieties that hang on the tree for longer (that is, 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 dead wood within the tree canopy. 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 124. Tear staining on fruit where injured cells are invaded by *Colletotrichum gloeosporioides* (the fungus causing anthracnose).

Fungicides

Copper formulations

Some copper formulations and their particle sizes are listed in Table 28.

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 28. Some Australian copper formulations and their particle sizes. Note, particle size of the active ingredient depends upon the individual manufacturer's milling process.

Active ingredient	Median particle size (microns)
Copper hydroxide	0.15–2.50
Copper oxychloride	1.40
Cuprous oxide (AG Copp 750 WG)	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 125).

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 critical factor affecting product effectiveness is the formulation's particle size and how well it sticks to the plant surface (that is, 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 (for example, fruit expansion)
- excessive spray application volumes resulting in run-off and/or stripping of copper from leaf and fruit surfaces.

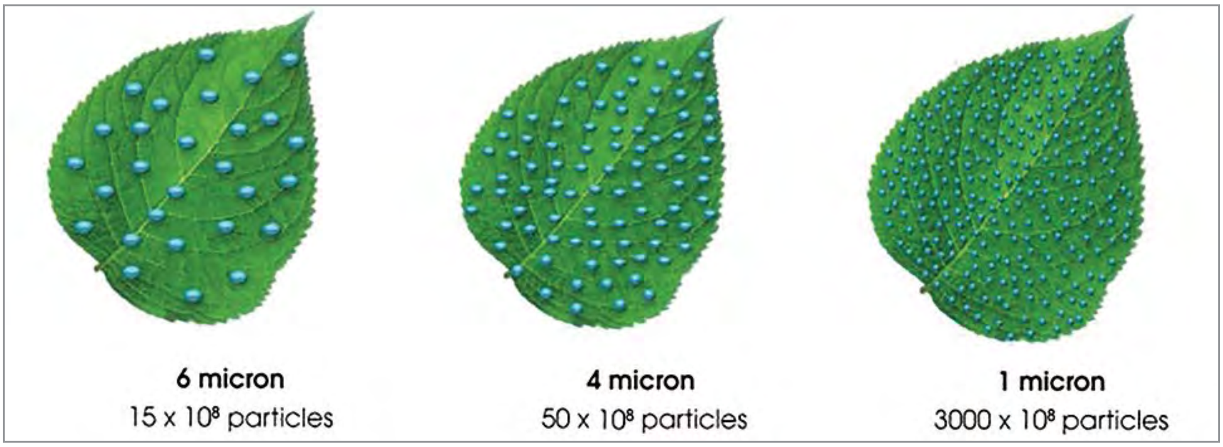

Figure 125. Leaf coverage improves with smaller particles of copper fungicide.

Effect of water pH

Most copper products are formulated to be almost insoluble in water with a pH of 7.0. As the water pH decreases, the solubility of the copper fungicide increases, and more copper ions are released. If the water or spray solution is too acidic (that is, 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 29). For example, copper hydroxide has fairly high solubility and activity but is not very persistent under wet coastal conditions.

Table 29. 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: 7 Worlds Ag.

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 126 and Figure 127).

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 usually be applied safely 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 blemishes. 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 126. Copper damage to citrus leaves, causing leaf stippling.

Figure 127. Copper stippling on a lemon.

Copper should be applied with sufficient water volumes to provide good coverage but not to cause excessive run-off (Figure 128). 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 129).

Figure 128. Excessive water rates result in spray run-off, wasted spray, contaminated soil and environmental problems. Photo: Citrus Research International.

Figure 129. Fruit stippling caused by excessive copper residues or the release of excessive amounts of copper ions.

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

Citrus leaves and fruit are sometimes difficult to wet, as the leaves are waxy and the fruit are 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 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 (for example, 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 (that is, 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 protective 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 (for example, 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 recommended by the manufacturer.
- The pH of the water used for applying copper should be greater than 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.

Brodrick HT (1970) Investigations into blemishes in citrus fruit, part IV, accentuation of blemish marks by copper fungicide sprays. *South Africa Citrus Journal*, 441: 27–29.

Rae DJ, Beattie GA, Watson DM, Liu ZM and Jiang L (1996) Effects of petroleum spray oils without and with copper fungicides on the control of citrus leaf-miner *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae). *Australian Journal of Entomology*, 35(3): 247–251, https://onlinelibrary.wiley.com/doi/pdf direct/10.1111/j.1440-6055.1996.tb01398.x

Schutte GC (1997) Rind stippling on Valencia oranges by copper fungicides used for control of citrus black spot in South Africa. *Plant Disease*, 81(8): 851–854, https://doi.org/10.1094/PDIS.1997.81.8.851

Timmer LW and Zitko SE (1996) Evaluation of copper fungicides and rates of metallic copper for control of melanose on grapefruit in Florida. *Plant Disease*, 80(2): 166–169, https://www.cabidigitallibrary.org/doi/full/10.5555/19961004028

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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 130), yield loss and even death in some scion and rootstock combinations, while 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 131). 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 replanted.

A Hockney navel orange planting at Dareton research station shows the effect of using infected budwood (Figure 132). 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 (that is, 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, you need to know what is in your budwood. More information is available from Primefact 704, *Dwarfing citrus trees using viroids* (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 130. Stunted trees in an orchard caused by a severe strain of citrus exocortis viroid from untested budwood propagation.

Figure 131. Symptoms of bark scaling induced by a severe strain of citrus exocortis viroid.

Figure 132. Left: Hockney navel on Troyer citrange, planted in 2005, using high-health-status budwood.
Middle: Hockney navel on Troyer citrange, planted in 2002 using low-health-status budwood.
Right: Hockney navel on C35, planted in 2002, using low health status budwood that was viroid-infected.

Post-harvest diseases and disorders

John Golding, Research Horticulturist, NSW DPIRD

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 133). 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 is often inevitable during harvest and handling.

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 134), 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 for blue and green mould

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

Figure 133. Green mould.

Figure 134. Blue mould.

Sour rot

Symptoms

Sour rot produces a very soft, watery appearance on the peel (Figure 135) 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 post-harvest fungicides registered for controlling post-harvest sour rot. Some fungicides are not suitable for some export markets, making it more difficult to control the disease.

Figure 135. Sour rot.

Post-harvest

Citrus disorder

Stem-end breakdown

Rind disorders can be very difficult to diagnose and even harder to prevent. There are often sporadic but severe occurrences of peel tissue breakdown around the stem end in late-season oranges and mandarins. The market can have a low tolerance to this disorder.

Typical symptoms of stem-end breakdown include drying of the peel around the button (calyx), where there can be a characteristic ring of unaffected peel that is directly next to the button (Figure 136). Research has shown that this non-affected area has no stomata and high levels of wax, which contribute to the lack of water loss and therefore no symptoms. The dried out cells around this area become sunken and sometimes turn brown, and then become a site for decay infection.

Stem-end breakdown was observed in late navel oranges and W. Murcott mandarins, particularly later in the season, in all southern growing regions and was related to the unusually hot and dry conditions in spring and summer.

The fruit can sometimes show these symptoms at harvest, but they often develop after packing and storage. There are several pre-harvest and post-harvest factors that can be managed to reduce the risk of stem-end breakdown.

In the orchard

- Ensure the fruit are not stressed before harvest, that is, keep up the irrigation, especially during hot, dry times in spring.
- Maintain rind health; some recommendations from overseas suggest a gibberellic acid (GA) spray can delay fruit ageing and reduce this disorder.

At harvest

- Avoid harvesting fruit in hot, dry conditions (high temperatures, low humidity and windy), or soon after unseasonal hot, dry weather.
- Clip-harvest fruit. Clipped fruit will be less stressed and can have up to 50% less stem-end breakdown than snap-picked fruit.
- To reduce water loss in the fruit after harvest, keep the fruit as cool (and humid) as possible. Store

picked fruit in the shade, or in larger bin stacks to reduce water loss and stress. Use a bin cover to ensure the fruit is kept as cool and 'stress-free' as possible.

- In warm, dry conditions, only pick what can be processed in the packing house within a day. Do not store or delay processing of susceptible fruit. If harvested fruit is to be stored, even temporarily, then ensure the appropriate post-harvest fungicides are applied and keep the fruit cool with high humidity before processing.

In the packing house

- Process the fruit without delay, that is, ensure the post-harvest wax is applied as soon as possible.
- Cool the fruit promptly and maintain low (but non-chilling) temperatures with high humidity throughout storage, transport, and marketing.
- Excessive brushing during packing can increase water loss and increase the development of stem-end breakdown. Recommendations from Florida suggest keeping the brush speeds below 100 rpm and using automatic wipeouts to prevent fruit from sitting idle on the brushes.

Figure 136. Typical symptoms of stem-end breakdown in navel oranges (left) and Tangold (right). Note the potential for decay infection in the affected peel (top middle in navels).

Reference

Ritenour M and Dou H (2023) Stem-end rind breakdown of citrus fruit. *Publication #HS936*, University of Florida IFAS, https://doi.org/10.32473/edis-hs193-2003.

Post-harvest fungicide use

Post-harvest fungicide use is essential to control fruit decay caused by fungi such as *Penicillium italicum* (causes blue mould) and *Penicillium digitatum* (causes green mould) during storage and transport. However, fungicide use is just one tool that is needed for effective post-harvest decay management. Controlling post-harvest decay also relies on:

1. Carefully harvesting and handling fruit to minimise physical injuries such as punctures, abrasions and cuts. Many rots rely on damage (wounds) to the skin for entry and infection.
2. Ensuring good hygiene and sanitation in the packing house and coolroom. Lower numbers of decay-causing spores will reduce the risk of resistance developing. Frequently sanitising all plant and equipment is critical to reduce spore loads that could transfer to fruit.
3. Using sanitisers in wash water to kill post-harvest decay spores and to manage food safety.
4. Using appropriate fungicides and following label directions.
5. Keeping the fruit in the coolroom.
6. Monitoring the levels of spores and fungicide resistance in the packing house. Also, develop strategies to manage any potential technical resistance to ensure fungicide application is effective.

The current post-harvest fungicides that are registered and available for use on citrus in Australia are listed in Table 30.

For updates on changes to these post-harvest fungicides, please check the APVMA Public Chemical Registration Information System Search (PubCRIS) database (https://portal.apvma.gov.au/pubcris). The APVMA website is an excellent resource to find the most up-to-date details, including product name, registering company, active constituents and product category for not only registered post-harvest chemicals, but all agricultural chemicals. Always check to see if the fungicide is registered for use.

Post-harvest fungicides

Table 30. A summary of current post-harvest fungicides[1] (correct on 3 November 2025).

Active ingredient(s)	Example trade names[2]	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®	Blue mould, green mould, sour rot	Multi-site activity (Guanidine)	M7
Imazalil	Magnate®, Fungaflor®	Blue mould, green mould	DMI (demethylation inhibitors; imidazole)	3
Imazalil and pyrimethanil	Philabuster®, Pyxis®	Blue mould, green mould	DMI and anilinopyrimidine	3 and 9
Ortho-phenylphenol	Ortocil®	Blue mould, green mould, sour rot	Multi-site activity	M
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)	Tecto®, Vorlon®	Blue mould, green mould, and activity on stem end rot (*Phomopsis citri*)	Benzimidazole	1

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

Ensuring fungicides are within maximum residue limits

Post-harvest fungicide selection should not only be based on efficacy and practical use within the packing line, but also on where the fruit is going to be sold. The fungicide must also meet the in-market maximum residue limit (MRL) requirements. For fruit to be sold on the domestic market, all registered post-harvest fungicides can be used and meet MRL requirements when used according to the label. For export markets, some post-harvest fungicides that are registered in Australia are not registered in the export market. For example, the use of guazatine is not allowed in some export markets. For an up-to-date summary of the export MRLs, please consult the Citrus Australia MRL listings (https://citrusaustralia.com.au/growers-industry/export-information-mrls/). Regularly test your fruit for residues to ensure it meets MRLs. This should be done using a qualified laboratory to ensure your fruit meet all market access requirements.

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Common citrus weeds

Steven Falivene and Anthony Cook (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 webpage (https://weeds.dpi.nsw.gov.au/) or phone app (Figure 137).

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 137. 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 138). The mature plant can be up to 30 mm tall, with spikelets (flower stalks) containing 3–9 flowers (Figure 139). Seeds are 4–6 mm long, 1 mm wide and straw coloured. This weed is sometimes confused with perennial ryegrass (*Lolium perenne*).

Figure 138. 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. Refer to Table 31 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 105). 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 leaves.

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 139. 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 140) from a woody taproot.

Leaves consist of 4–8 pairs of opposite oblong leaflets (Figure 141). It germinates in summer and becomes established quickly (within 2–4 weeks). Flowers are small (8–15 mm in diameter) and bright yellow (Figure 142).

Caltrop flowers from spring to autumn. The fruit consists of a woody burr with 4 long, hard, sharp, rigid spines (Figure 143), which are easily spread by boots, tyres and animals. Some seeds can survive for up to 7 years.

Figure 140. A thick stand of caltrop.

Figure 141. A caltrop seedling.

Figure 142. Caltrop has a small yellow flower.

Figure 143. 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 the spread.

Feathertop Rhodes grass

Chloris virgata

Feathertop Rhodes grass (Figure 144 and Figure 145) 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 105).

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

Figure 144. A stand of feathertop Rhodes grass.

Figure 145. 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 146) 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 146. A seed head of flaxleaf fleabane.

Control

For best results, fleabane should be sprayed when it is <50 mm in diameter (Figure 147). Many herbicides can control the weed up to this stage, but once it has reached the bolting stage, that is, when the stem has elongated (Figure 148), not many herbicides will 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 100.

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 147. Flaxleaf fleabane at the rosette stage.

Figure 148. 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 149). 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 150). 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 149. Khaki weed can spread its seed around orchards in a similar way to caltrop.

Figure 150. 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 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 151) 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 (for example, 5 years).

Figure 151. Wireweed is a sprawling plant.

Control

It is easier to control wireweed when it is young (Figure 152). 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 102.

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 152. A wireweed seedling. Photo: Trevor James, AgResearch NZ.

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Further information

Davey C (2024) Flaxleaf fleabane and feathertop Rhodes grass management. *GRDC update paper*, https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2024/07/flaxleaf-fleabane-and-feathertop-rhodes-grass-management

Grains Research and Development Corporation (GRDC, 2020) Common weeds of grain cropping, https://grdc.com.au/resources-and-publications/all-publications/common-weeds-of-grain-cropping-the-ute-guide

Weed Management Unit (2009) Tribulus: caltrop and yellow vine. *Primefact 723*, NSW Department of Primary Industries, www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/318563/Tribulus-caltrop-and-yellow-vine.pdf

Managing weeds

Steven Falivene and Anthony Cook (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 between 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 (for example, 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 (for example, 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 (for example, organic production) it can be a viable option. Mulching the under-tree row with large quantities of organic materials such as straw (Figure 153), 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 153. 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 154). They last for 7–10 years, which is 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 155). 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 154. Plastic mulch and sturdy tree guards protect trees from herbicide overspray.

Figure 155. 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 herbicide 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. Refer to Herbicide overspray and maximum residue limits on page 103 for more information.

Orchard herbicides can be grouped into 3 broad categories (refer to Table 31 on page 108):

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 mode of action Group 1. 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 will help protect them from herbicides and other sources of damage. Consult herbicide product labels for specific recommendations.

Important: 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 essential because changing environmental conditions (for example, temperature and rain) can significantly affect knockdown and pre-emergent programs. Every site needs a customised herbicide program. The following points should help when developing a herbicide program:

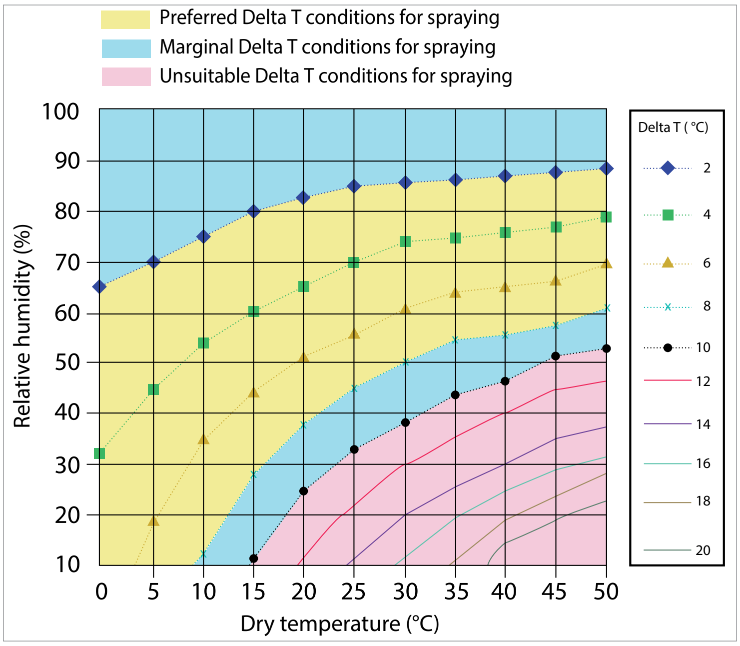


Figure 156. Delta T chart. Source: Bureau of Meteorology.

- Always spray during ideal Delta-T conditions (Figure 156).
- The most hazardous condition for herbicide spray drift is an atmospheric inversion, which usually occurs during clear skies from sunset and sunrise. Do not spray under inversion conditions.
- As a suggestion, use 100 L/ha for systemic products (for example, 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 herbicide spike, such as oxyfluorfen or carfentrazone, to a registered knockdown herbicide might further improve control.

- Paraquat (Group 22) 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. Refer to Common citrus weeds on page 94 for more information.
- Fleabane is difficult to control because of its hairy leaves and resistance to Group 9 herbicides. Higher volume coverage and double-knock techniques can be used (for example, 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 (for example, fleabane). However, it might take 4–6 weeks to provide a good brownout. A follow-up spray with a knockdown herbicide (for example, 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 157) and only use a shrouded herbicide unit (Figure 158). Refer to the NSW DPIRD website for a video of a shrouded herbicide unit (https://www.youtube.com/watch?v=OPYZLK5hRyc).

Figure 157. Skirting trees using a circular saw cutter bar mounted on the forks of a tractor.

Figure 158. 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 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 105.
- 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, for example, 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 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, for example, 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 156 on page 102) 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). Refer to Table 31 on page 108 and the product label to determine the MOA group.

Glyphosate (Group 9) 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 102 and Common citrus weeds on page 94.

Glyphosate-resistant ryegrass is present in orchards and vineyards throughout 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:

- use 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
- look for surviving weeds after spraying and preventing them from setting seed
- use as many weed control techniques as practical (that is, cultivation and hand hoe) and do not rely solely on herbicides
- use a double-knock technique when appropriate (for example, applying a different herbicide 1–2 weeks later)
- spraying during the appropriate weather conditions such as low wind and suitable Delta T conditions (refer to Figure 156 on page 102)

- 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
  - modifying the droplet size for good coverage and reduced spray drift.

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

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.

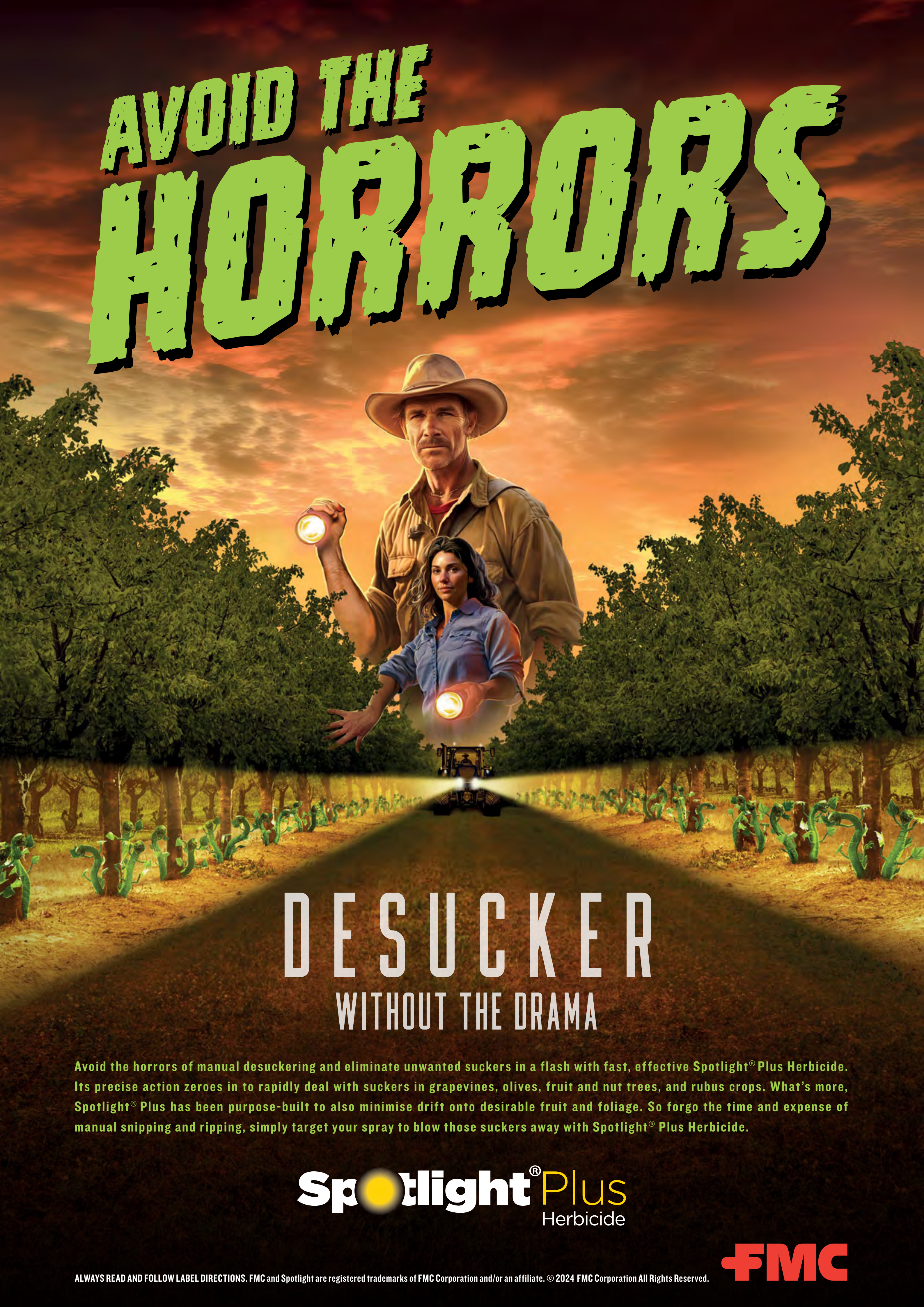
There are 2 types of tests available: a quick test and a seed test. The quick test involves live seedlings being sent away for re-potting and spraying. Once the plants have fully recovered, they are sprayed with the herbicides of your choice. Results are usually reported between 4 and 8 weeks later. 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 that it cannot test for pre-emergent herbicides, as the plants have already emerged.

A seed test requires the 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 about 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.


AVOID THE HORRORS
DESUCKER
WITHOUT THE DRAMA
Avoid the horrors of manual desuckering and eliminate unwanted suckers in a flash with fast, effective Spotlight® Plus Herbicide. Its precise action zeroes in to rapidly deal with suckers in grapevines, olives, fruit and nut trees, and rubus crops. What's more, Spotlight® Plus has been purpose-built to also minimise drift onto desirable fruit and foliage. So forgo the time and expense of manual snipping and ripping, simply target your spray to blow those suckers away with Spotlight® Plus Herbicide.
Spotlight® Plus
Herbicide
FMC
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Herbicide chemical table

Before using any herbicide (Table 31), always check and follow all label instructions.

Table 31. Herbicides and their uses.

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

WHP = withholding period.

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 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 risk 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 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, for example, navel oranges
- property address and a clear delineation of the area where the pesticide was applied
- type of equipment used to apply the pesticide for example, knapsack, air-blast sprayer, boom spray
- full name of the product or products (for example, 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.

Globally Harmonised System of classifying and labelling chemicals

The Globally Harmonised System (GHS) is an international system for classifying hazards and communicating 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 (that is, 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
Bruce Browne, Farm Chemicals Officer, Biosecurity and Food Safety
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 Queensland fruit fly website (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)
Mildura Fruit Company (https://www.mildurafruits.online/)
National Farmers' Federation (www.nff.org.au)
NSW Farmers' Federation (www.nswfarmers.org.au)
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

Agriculture Victoria (https://agriculture.vic.gov.au/)
NSW Department of Primary Industries and Regional Development (https://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 Primary Industries (https://www.dpi.qld.gov.au/)
SA Primary Industries and Regions (www.pir.sa.gov.au)
SafeWork NSW (www.safework.nsw.gov.au)
WA Department of Primary Industries and Regional Development (https://www.dpird.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 Department of Primary Industries and Regional Development (https://www.dpi.nsw.gov.au/agriculture/horticulture/citrus)
Queensland Government (https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/crops/fruit-veg)
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 – horticulture (https://www.dpird.wa.gov.au/businesses/plant-and-crop-farming/horticulture/)

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)
bagMUSTER (https://www.bagmuster.org.au/)
ChemClear (www.chemclear.com.au)
drumMuster (https://www.drummuster.org.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)
NSW 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 website (www.dpi.nsw.gov.au/agriculture/horticulture/citrus). These are regularly updated and new publications added.

NSW DPIRD citrus contacts

Research

Dr Dave Monks Research Horticulturist
Dareton Primary Industries Institute
Silver City Highway, Dareton, NSW 2717
P: 03 5019 8431
E: dave.monks@dpird.nsw.gov.au

Dr Meena Thakur Research Horticulturist
Entomology
Yanco Agricultural Institute
2198 Irrigation Way East, Yanco, NSW 2703
P: 02 6951 2612
E: meena.thakur@dpird.nsw.gov.au

Dr Mahmud Kare Research Horticulturist
Dareton Primary Industries Institute
Silver City Highway, Dareton, NSW 2717
P: 0419 154 090
E: kare.mahmud@dpird.nsw.gov.au

Dr Nerida Donovan Citrus Pathologist
Elizabeth Macarthur Agricultural Institute
Woodbridge Road, Menangle, NSW 2568
P: 02 4640 6232
E: nerida.donovan@dpird.nsw.gov.au

Dr Tahir Khurshid Research Physiologist
Dareton Primary Industries Institute
Silver City Highway, Dareton, NSW 2717
P: 03 5019 8433
E: tahir.khurshid@dpird.nsw.gov.au

Development and communication

Andrew Creek Citrus Development Officer
Yanco Agricultural Institute
2198 Irrigation Way East, Yanco, NSW 2703
M: 0428 934 952
E: andrew.creek@dpird.nsw.gov.au

Steven Falivene Citrus Development Officer
Dareton Primary Industries Institute
Silver City Highway, Dareton, NSW 2717
P: 03 5019 8405 M: 0427 208 611
E: steven.falivene@dpird.nsw.gov.au

Post-harvest

Dr John Golding Research Horticulturist
Central Coast Primary Industries Centre
The University of Newcastle
North Loop Road, Ourimbah, NSW 2258
P: 02 4348 1926
E: john.golding@dpird.nsw.gov.au

Dr Sukhvinder Pal (SP) Singh Research Horticulturist (Food Safety)
Central Coast Primary Industries Centre
The University of Newcastle
North Loop Road, Ourimbah, NSW 2258
P: 02 4348 1935 M: 0420 593 129
E: sp.singh@dpird.nsw.gov.au

Dave Monks

Meena Thakur

Mahmud Kare

Nerida Donovan

Tahir Khurshid

John Golding

SP Singh

Andrew Creek

Steven Falivene


Resources

Farms of the

FUTURE

NSW GOVERNMENT

Grow with Agtech

Farm businesses across NSW are facing challenges every day — including water management, connectivity issues, livestock monitoring, or the weather.

The Farms of the Future program connects you with practical solutions to these pain points, helping you run a more efficient, productive, and sustainable farm.

Learn about Agtech and connectivity solutions
Build a tailored Agtech plan for your property and priorities.

See it live
Visit Agtech Alley & Demonstration Hubs to see real-farm results in person or in a virtual reality headset.

Compare options
Research products in the Agtech Toolbox (sensors, connectivity, software).

Get hands-on help
Connect with our Agtech specialists in the training room or at an event to refine your Agtech plan.

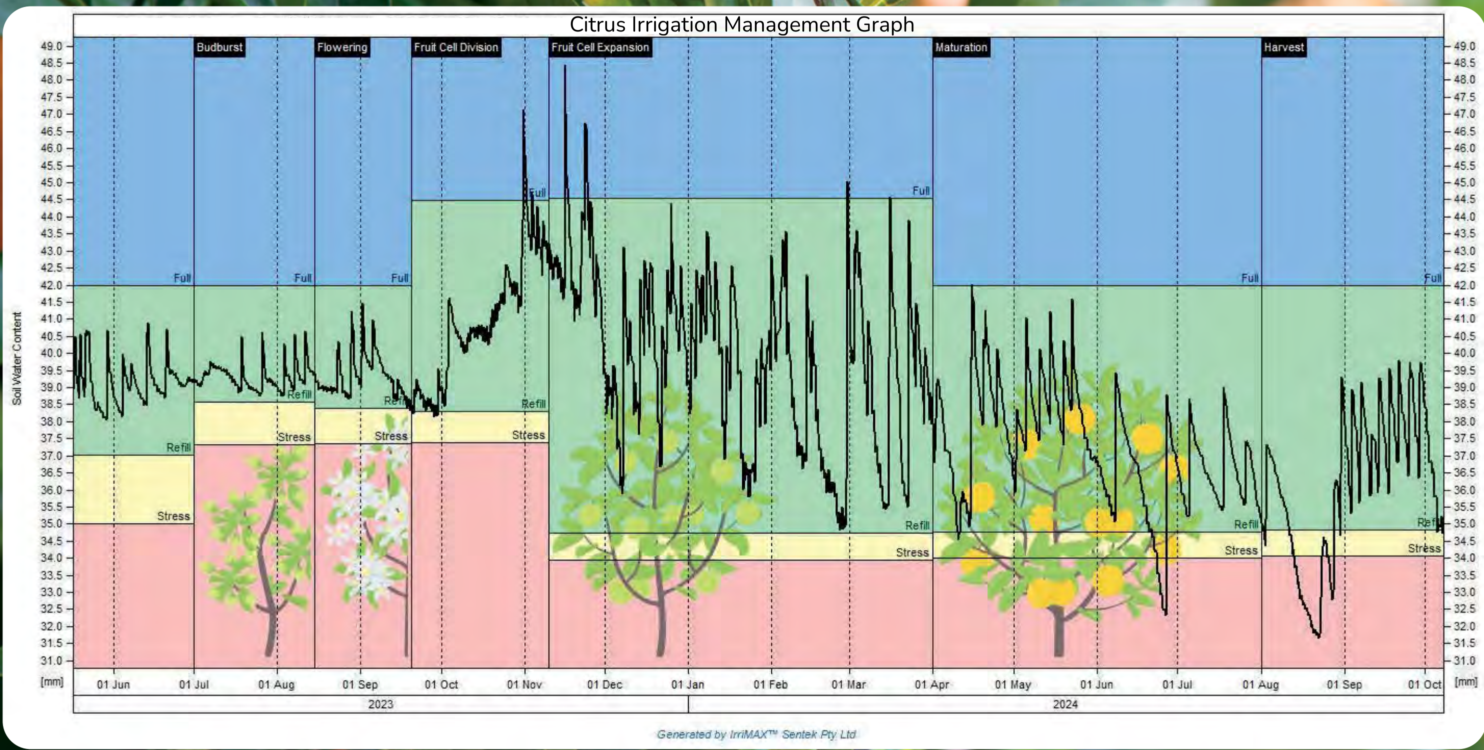
Subscribe for
events and training

A Smarter Way to Tackle Your Farm's Pain Points

Agtech Toolbox: www.agtech.dpi.nsw.gov.au

Citrus Irrigation Monitoring by Sentek

- Monitor water use through Phenological Stages to maximise plant Water Use Efficiency
- Measure the soil data to optimise plant yield and production costs
- Develop a citrus irrigation system customised to your operation



Sentek

sentek@sentek.com.au

+61 8366 1900

www.sentektechnologies.com