Hort Innovation

Final Report

Scale and mealybug management options for lychee growers - an extension toolkit

Project leader:

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Delivery partner:

State of Queensland acting through Department of Agriculture and Fisheries (DAF)

Project code:

LY20001

Project:

Scale and mealybug management options for lychee growers - an extension toolkit (LY20001)

Disclaimer:

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Public summary

The lychee industry is focused on export markets to ensure a profitable future as domestic plantings rapidly expand. Scale and mealybug pests are commonly found in lychee orchards and are generally a minor problem for growers supplying the Australian domestic market. However, the pests present a challenge to producers targeting quarantine markets in New Zealand and the United States of America. Pre-irradiation inspections required as part of the export protocol may find scale and mealybug juvenile stages on fruit, resulting in a treatment delay until the pests are identified and able to be classified as quarantine or non-quarantine pests. An identification delay will result in fruit being diverted to the domestic market which disappoints export customers and increases downward price pressures domestically. Current management practices require improvement particularly for growers targeting export markets with quarantine protocols.

Work was undertaken over two seasons to survey lychee orchards in all Queensland growing regions and identify scale and mealybug pests to enable the compilation of a pest guide. Concurrently growers were surveyed to gather data on their knowledge and management of the pests. A spray application workshop was run in conjunction with the 2021 annual growers lychee industry growers meeting to demonstrate the importance of sprayer calibration, tractor speed and pressure settings on spray application. The information collected during the project was developed into a grower manual and informative shed poster as an extension tool for lychee growers. The project findings and management has been comprehensively promoted to industry through several mechanisms including; one on one farm visits, presentations at industry meetings, and articles in the industry magazine "Living Lychee".

A management manual and poster (tool-kit) have been developed as a working extension tool for lychee growers. Topics covered include; scale and mealybug identification, biological predators, scale pests identified during the farm surveys, current pesticide management options, post-harvest management using high pressure sprays and further information links and references. A shed poster, summarising the Toolkit has also been produced. This will be printed and mailed out to growers to act as an easy reference "best-bet" management source. The accompanying management toolkit will be available for download from the Hort Innovation and Australian Lychee Industry websites.

The toolkit will help growers understand;

- scale and mealybugs, their identification and life cycle
- the importance of biological predators
- current chemical management options, chemical labels and improved spray application and timing techniques
- the importance of ant control in managing scale
- pest scouting practices and commercial options
- post-harvest management using high pressure spray units.

Recommendations arising from the project include;

- Chemical control strategies for scale and mealybug utilised by other, similar fruit industries can act as a guide as to what the lychee industry could add to their arsenal, via the application for permits and or chemical registration
- Future RD&E may consider quantifying the outcomes of an integrated pest management program incorporating the active release of beneficial insects in conjunction with chemical control requirements.
- The lychee industry should consider supporting regular spray application and calibration training to maintain grower competencies.
- To enhance grower adoption and development key management recommendations could be regularly highlighted in the industry magazine.

Technical summary

Lychee orchards in all major production regions from the far north to south east Queensland were surveyed over two seasons for scale and mealybug pests. Pest samples were identified, by DAF entomology team members, where possible to genera and species level. Pests were categorized by family and whether they were localized or widespread within four growing regions (Mareeba, Murry Upper & Ingham, Sarina and Yeppoon, Bundaberg and Nambour). This list was

compared to previous collection records from the Queensland Primary Industries Insect Collection database.

Seven of the most commonly found and widespread scale were described and pictured to enable growers to recognize the most common scale pests in their orchards. The most commonly found scale included Indian wax scale (*Ceroplastes ceriferus),* Latina scale (*Hemiberlesia lataniae),* Lychee leei scale (*Thysanofiorina leei*), Black scale (*Parasaissetia nigra),* Olive scale (*Saissetia oleae),* Cottony cushion scale (*Icerya purchase),* and Seychelles scale *(Icera seychellarum).*

An extension bulletin "Toolkit" has been prepared which discusses pest management options including the use of biological predators and current lychee registered chemicals for domestic and USA export fruit. The bulletin includes instructions on interpreting a chemical label, concentrated versus dilute spraying and sprayer calibration. The options for ant control, common vectors of scale are also discussed. The benefits of insect scouting as a method to determine spray application are highlighted. Scale and mealybug control options in other tropical and subtropical fruit crops were highlighted as potential industry options to pursue as permits or registrations.

Finally, the post-harvest option of high pressure sprayers researched and reported in LY18000 were also highlighted.

Keywords

Lychee; scale; mealybug; pest management; beneficial insects; ant management; chemical control; export; spray application

Introduction

Scale and mealybug pests are commonly found in lychee orchards. Although generally a minor problem for growers targeting the domestic market the pests present a challenge to producers targeting quarantine markets in NZ and the USA. Pre-irradiation inspections required as part of the export protocol will often find scale and mealybug juvenile stages on fruit, resulting in a treatment delay until the pests are identified and able to be classified as non-quarantine pests.

The objective of the project was to survey orchards, out and in fruiting season, to gain an overview of the scale and mealybug problem across lychee growing regions from Mareeba to the Sunshine Coast hinterland. Identify scale and mealybug pests to family, genera or species level and record grower control practices. This information was compiled in an extension toolkit to highlight the diversity of scale and mealybug pests, their life-cycle and management options (chemical and biological) and presented in a series of workshops and articulated in the lychee industry magazine the "Living Lychee".

High pressure water sprays applied in the packing line have been found to be effective at decontaminating fruit and vegetables to enhance market access (Woolf *et al*. 2015). Recent work on the use of high pressure washing for the removal of mites on export fruit, found where scale and mealybugs are present in the orchard the high pressure wash which effectively removes 90% plus of mites may only reduce scale and mealybug infestation by 40 to 50% (Diczbalis, 2020). Hence the control of scale and mealybugs at the pre-harvest stage is an important precursor to post-harvest management.

The outcome for the lychee industry will be an improved understanding of scale and mealybug and guidelines to management options which will include an analysis/review of practices that lead to greater infield and postharvest control.

The workshops and toolkit complement the recent upgraded Lychee Field Guide produced as part of LY19001. Australian lychee growers actively promote the development of fruit exports to support industry expansion. Project outputs and outcomes are closely linked to Industry KPI's, from the Strategic Invest Plan. They include;

- Evidence of the development of further market access to the United States – *cleaner fruit passing rapidly through quarantine pre-treatment inspections*.
- Evidence of an increase in the percentage of total crop volume being exported and an increase in price per kilogram for exports – *Increased grower confidence in supplying fruit that will not be rejected during the export process will lead to an increased commitment to export markets.*
- Compliance protocols established and followed by growers – *production of fruit using approved chemical control and management options for pest management*.
- Market access priorities identified and prioritised – *This outcome of the project will* assist industry with achieving reliable and problem free exports to markets with quarantine protocols. This in-turn will lead to stabilisation of the domestic price and encourage industry growth.

Improved pre-harvest and post-harvest management will result in cleaner, pest-free fruit and give growers greater confidence to engage with the challenges associated with exporting. It is anticipated that a developing export market will be an important stimulus for industry growth.

Methodology

The project was conducted over two years incorporating the latter half of the 2020/21 season and the 2021/22 season. Scale and mealy bug surveys were conducted, in orchards in and out of season, in four major growing regions:

- Tableland/Wet tropics (Townsville north);
- Central Queensland (Mackay and Rockhampton);
- Bundaberg
- SE Queensland.

In total, sixteen orchards were sampled regularly. Samples collected were prepared for identification with details of collection sites and where the pests were found (foliage, stems, trunk and fruit). Samples were identified by the DAF GrowHelp team at times with assistance of the Queensland Biosecurity entomologists who have considerable experience in pest identification and were also able to resort to molecular methods where conventional taxonomic identification was not possible.

A grower management survey was prepared and emailed/mailed to growers via the ALGA Grower contact list. The grower survey gathered details of the grower property (location, topography, varieties grown, size of planting, surrounding vegetation type, e.t.c). Growers were asked to rate the significance of the scale and mealybug problem on their property and what other pests they experience, and the control options utilised. The outcomes of the on-farm pest surveys and the grower survey was used to examine the relationship between management and the perceived severity of the problem.

Communications with industry was undertaken *via* the industry magazine "Living Lychee" on at least two occasions during the year and at the annual lychee industry meetings held in association with the Australian Lychee Growers Association (ALGA) AGM.

A "Lychee Scale and Mealybug Management Toolkit" was written to highlight the key findings of the farm surveys and the pre-harvest and post-harvest management options available to industry. To compliment the Toolkit a Shed Poster highlighting the pest, damage caused, and action levels and pre-harvest and post-harvest management options has been produced and will be mailed out to growers.

See attached draft Toolkit and Shed-Poster for more detail.

Photos/images/other audio-visual material

Photos and images contained in the Toolkit are provided under arrangements as outlined within the Toolkit document (appendix 1).

Remaining photos with the Final Report were taken by Yan Diczbalis (yan.diczbalis@daf.qld.gov.au) on 15 September 2021.

Final report images

	Image description	**File name**
1	Spray workshop preparation. Applying UV dye at three tractor speeds (2.39, 3.00 and 5.10 km/hr) and at two operating pressures (5.5 bar and 7.5 bar).	Applying UV dye
2	Spray coverage visible during the day	Day UV spray coverage
3	Spray coverage visible at night using UV torch light	Night UV spray coverage
4	Project presentations at the 2021 growers meeting	Grower meeting Sep21
5	Lychee grower spray unit inspection and discussion	Spray unit inspection

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Results and discussion

Lychee Grower Survey Results

The results of the lychee grower survey are based on 31 anonymous responses, approximately 26% of the industry. Of the 31 responses the regional distribution was;

- 23% - Tableland/Wet tropics (Townsville north)
- 29% - Central Queensland (Mackay and Rockhampton);
- 10% - Bundaberg/Childers
- 38% - SE Queensland and northern NSW

48% or nearly half of the responses came from the Bundaberg/Childers and SE Queensland areas which are the regions that are most actively involved in exporting fruit.

Respondents grew 13 varieties of lychees with Kwai Mai Pink, Fay Zee Siu and Kaimana being the most commonly grown. 87% of respondents confirmed that scale and mealybug were present in their orchards with 59% confirming they are a management issue dependent on season or weather conditions. Pre and post flowering chemical applications were the most popular forms of control. The use of ground sprays for ant control and beneficial insects were the least utilized as forms of management and 25 % of respondents used a mix of techniques.

Grower respondents also highlighted other pests of concern, predominately leaf eating caterpillars, fruit spotting bug, flatids, macadamia nut borer and mites.

Pest management was predominately managed by self scouting (60%), with 30% of respondents applying chemicals on a calendar program. Only 10% of respondents utilized a trained pest scout and 12% utilized an integrated pest management techniques which included beneficial insects.

Most respondents had access to “tower” type air blast sprayers and 87% utilized dilute chemical application methods with 70% of respondents assuming they were achieving coverage and effectively applying pesticides. Some 47% of respondents confirmed they were achieving control of scale and mealybug pests while 33% were not achieving control and a further 20% were unsure of control.

Survey results suggested that further industry training in scale and mealybug identification and management options and pesticide application would be beneficial to growers. Most respondents (80%) wanted further information on post-harvest high pressure spray technology for fruit disinfestation.

Industry respondents indicated a preference for written information in the form of technical manuals, crop cycle management calendars or shed posters. The industry magazine “Living Lychee” was highly rated as an effective method for information transfer with 73% of respondents nominating the magazine as one of their top 3 sources of information.

Survey results were highlighted via the industry magazine and reported to growers at the 2021 growers meeting.

Lychee Field Survey Results

The tables below document the scale and mealybug identified during farm sampling over the project period (Table 1) and previous identification records from the Queensland Primary Industries Insect Collection (Table 3).

Table 1. Scale, by family, genera and species from sampling lychee orchards during the project.

		Region				
Family and species	**Common name#** (There can be multiple common or overlapping common names for the same species)	**Bundaberg & Nambour**	**Sarina & Yeppoon**	**Murray Upper & Ingham**	**Mareeba**	**Previously recorded on Lychee in Australia^**
Family Diaspididae	**Armoured scales**					
• *Chrysomphalus dictyospermi*	Dictyospermum scale	L*				
• *Hemiberlesia lataniae*	Latania scale	W				Yes
• *Thysanofiorina leei*	Lychee leei scale	W	W	W	W	Yes
Family Coccidae	**Soft scales**					
• *Ceroplastes ceriferus*	Indian wax scale	W	L		W	
• *Coccus longulus*	Long brown scale		L			Yes
• *Coccus hesperidum*	Brown soft scale	L				Yes
• *Saissetia oleae*	Olive scale#	L	L			
• *Parasaissetia nigra*	Black scale#	W	L			Yes
• *Pulvinaria psidii*	Pulvinaria scale	L				Yes
• *Prococcus acutissimus*	Banana-shaped scale				L	
Family Monophlebidae	**Giant scales**					
• *Icerya purchasi*	Cottony cushion scale				L	
• *Icerya seychellarum*	Seychelles scale	W	W	W		Yes

***L** indicates the species was localised to one farm during surveys of the region and **W** indicates the species is widespread on multiple farms in the region. #There are many common names for these species; sometimes the same common name is used for both species.

Table 2. Previous lychee records from the Queensland Primary Industries Insect Collection (QDPC) of scale and mealybugs that were not detected in surveys during this project.

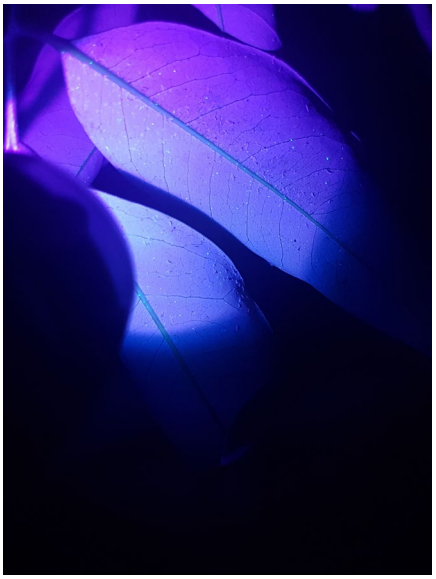
Scientific Name	Family
• *Ceroplastes rubens*	Family Coccidae – Soft scales
• *Ceroplastes sinensis*	Family Coccidae – Soft scales
• *Saissetia neglecta*	Family Coccidae – Soft scales
• *Howardia biclavis*	Family Diaspididae – Armoured Scales
• *Planococcus minor*	Family Pseudococcidae - Mealybugs

Overall, a total of 17 scale insects have been identified from lychee in Australia. Twelve of these were detected during project surveys and provide an indication of their distribution and prevalence. Five species detected in the surveys had never been detected on lychee previously. There are potentially more species of scales that may sometimes be found on lychee that were not detected during our survey or previous pest records. This could occur because they are not very abundant or are only locally abundant or because of seasonal conditions favouring certain species in some years.

The full results and outputs can be seen in the attached grower manual “Scale and Mealybug Management Toolkit” and Shed Poster.

Spray application Demonstration and Workshop





Spray workshop preparation. Applying UV dye at three tractor speeds (2.39, 3.00 and 5.10 km/hr) and at two operating pressures (5.5 bar and 7.5 bar). Spray application during the day and then at night using UV torch light.

Project presentations at the 2021 growers meeting.

Inspection of lychee grower spray unit.

Outputs

Table 3. Output summary

Output	Description	Detail
Farm visits and sampling during the project concept phase; Ingham and Murray Upper 4 November 2020	Scale and mealybug lychee orchard sampling. Project development discussions.	Project concept discussions undertaken with four orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits and sampling during the project concept phase; Yeppoon, Rockhampton and Mackay. 7-10 December 2020	Scale and mealybug lychee orchard sampling. Project development discussions.	Project concept discussions undertaken with eight orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits Bundaberg and Sunshine coast hinterland 1 Feb-4 Feb 2021	Scale and mealybug lychee orchard sampling. Sampling of high pressure wash fruit for disinfestation counts.	Project concept discussions undertaken with eight orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit. Fruit samples from high pressure sprayed fruit were collected from two orchards and pest numbers compared with not high pressure sprayed fruit. Data shared with growers.
Formation of a project reference group	A project reference group was formed and consulted at intervals during the project.	Reference group members appointed, and project issues discussed.
Farm visits Yeppoon, Rockhampton and Mackay. 8-11 June 21	Scale and mealybug orchard sampling.	Project concept discussions undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits Bundaberg and Sunshine coast hinterland. 15-18 June 2021	Scale and mealybug orchard sampling.	Project concept discussions undertaken with eight orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits Townsville to Murray Upper. 23-24 June 2021	Scale and mealybug orchard sampling.	Project concept discussions undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits and sampling Tablelands. 1-2 July 2021	Scale and mealybug orchard sampling.	Project concept discussions undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Lychee Growers Meeting and Spray Rate	Lychee producers and associated industry	Spray workshop preparation. Applying UV dye at three tractor speeds (2.39, 3.00 and 5.10 km/hr) and at two operating

and pressure demonstration. 13-16 September 2021	support and marketing personnel. Approximately 80 people.	pressures (5.5 bar and 7.5 bar). Presentations. 1. Lychee scale and mealybug management. Yan Diczbalis 2. Lychee scale insects. Andrew Manners, Yan Diczbalis and Joy Conroy. 3. Fine tuning your orchard sprayer. Allen Blair Booklet Lychee Orchard Spraying. Allan Blair, Senior Development Extension Officer, DAF. Post workshop night farm walk to observe spray patterns for the above treatments with UV torches. As a result, the host grower has changed his application practices from (3.0 km/hr at 5.5 bar) to 3.47 km/hr at 7.5 bar).
Farm visits and sampling Tablelands 3-4 November 2021	Scale and mealybug orchard sampling.	Project updates undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits and sampling Ingham and Murray Upper 10-11 November 2021	Scale and mealybug orchard sampling.	Project updates undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits and sampling Mackay, Yeppoon and Rockhampton 23-26 November 2021	Scale and mealybug orchard sampling.	Project updates undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits and sampling Bundaberg and Sunshine coast hinterland. 14-17 December 2021	Scale and mealybug orchard sampling.	Project updates undertaken with eight orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit. High pressure spray samples collected from two growers for disinfestation counts.
Farm visits and sampling Sunshine Coast hinterland. 2-4 February 2022	Scale and mealybug orchard sampling.	Project updates undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit. High pressure spray samples collected from two growers for disinfestation counts.
Farm visits and sampling Mackay, Yeppoon and Rockhampton 19-22 July 2022	Scale and mealybug orchard sampling.	Project updates undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Farm visits and sampling Tablelands 10	Scale and mealybug	Project updates undertaken with six orchard managers. Orchards sampled for scale and mealybug pests. Samples

August 2022	orchard sampling.	forward to entomology section in Brisbane for identification and collation. Results utilized to build the pest list as presented in the Lychee scale and mealybug toolkit.
Presentations at Lychee Growers meeting Mareeba 12-14 September 2022	Lychee producers and associated industry support and marketing personnel. Approximately 120 people.	Project presentations. See appendix for contents. 1.Lychee Scale and Mealybug Management. Yan Diczbalis and Andrew Manners 2. Management options for mealybug. Lara Senior, Entomologist DAF. 3. Phytosanitary Irradiation. Peter Leach and Lara Senior 4. Mite and insect disinfestation of lychee fruit using high pressure water sprays. Yan Diczbalis, Andrew Manners and Massimo Bianco.
Farm visits and project discussions, Mackay. Yeppoon, Rockhampton and Sunshine Coast hinterland 21-25 November 2022	Scale and mealybug orchard sampling.	Project updates undertaken with ten orchard managers. Orchards sampled for scale and mealybug pests.
Shed poster. August 2022 – Feb 2023.	A shed poster designed for lychee growers and staff to summarise the scale and mealybug management pre and post harvest.	The poster will be made available on the ALGA and Hort Innovation websites for lychee producers. 150 hard copies of each will be printed and posted to lychee orchards registered with ALGA.
Toolkit manual. August 2022 – Feb 2023.	A grower toolkit (manual) for lychee producers.	The manual will be made available on the ALGA and Hort Innovation websites for lychee producers. 150 hard copies of each will be printed and posted to lychee orchards registered with ALGA.

Outcomes

Table 4. Outcome summary

Outcome	**Alignment to fund outcome, strategy and KPI**	**Description**	**Evidence**
Pesticide application practice change	**Outcome 3** Extension and capability **Strategy:**1 Deliver communication and extension capability **KPI:** Measurement of practice change	Spray application workshop presentation and Post workshop night farm walk to observe spray patterns for the above treatments with UV torches.	As a result, the host grower has changed his application practices from (3.0 km/hr at 5.5 bar) to 3.47 km/hr at 7.5 bar). This practice change filters on to grower neighbours and grower group.
Improved understanding of identification and management of scale and mealybug pests in lychee orchards and the need for disinfestation for export fruit.	**Outcome 2** Increased profitability. **Strategy:** 1. **KPI:** Development of pest and disease management strategies that mitigate	Growers surveyed on their understanding and management of scale and mealybug pests. Industry participants have an improved understanding of scale and	Feedback from producers and questions in regard to management options which are now highlighted in the grower toolkit.

Improved spray coverage.	crop loss in collaboration with growers	mealybug pests and management options.	
	Outcome 1: Demand Creation **Strategy:** 2 and 3 **KPI:** Growth in export markets and development of an export strategy	Toolkit manual completed and being published. Distributed via direct mailout and available on website. Development and publication of the Scale and Management Toolkit and associated Shed Poster.	Drafts submitted.
	Outcome 3: Improve capability **Strategy:** Deliver communication and extension capability. **KP**I: Grower contact	Project presentations at the two main industry grower meetings in September 2021 and September 2022. Present results at annual grower meetings and publish project findings in the industry magazine "Living Lychee".	Meeting agendas. Participant list. Grower testimonial.

Monitoring and evaluation

Table 5. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
Has the project achieved its outcomes of producing a Scale and Mealybug Management Toolkit?	Yes, Toolkit and shed poster prepared and ready for publication.	The toolkit and shed poster are static documents and are currently beneficial. However, all documents require reviews and updates with the passage of time. The chemistry (registered and permitted) sections will need regular updates to keep in line with APVMA registrations and permits.
Is the project relevant to the industry and HI?	Yes, the industry requested the project and HI produced a call for applications.	All projects outputs and outcomes require updates with the passage of time.
Has industry been involved in the process? Has the engagement process been sufficient?	Yes, the industry has been closely involved with the project through the PRG and regular liaison with lychee growers in Queensland. Grower engagement has been a project priority. Regular grower visits in all producing regions followed up by regular updates via the industry magazine “Living Lychee” and presentations at the grower annual meetings.	Industry involvement and engagement is a continuous process. Ideally and where resources allow project outputs need to be reviewed and industry updated.
Has the project been completed in the allocated time frame?	No, a short extension of two months was requested.	Preparation of management toolkits and posters requires time inputs beyond the project personnel resources. Additional time to ensure project completion is appreciated.

Recommendations

1. The project toolkit and associated shed poster are highly recommended reading for all lychee producers considering or currently involved in producing lychees for export to quarantine markets.
2. The published registered and permitted chemical list would ideally be available “on-line” to allow for any changes of permits or registered products for lychee.
3. Chemical control strategies for scale and mealybug utilised by other, similar fruit industries can act as a guide as to what the lychee industry could add to their arsenal, via the application for permits and or chemical registration
4. Future RD&E may consider quantifying the outcomes of an integrated pest management program incorporating the active release of beneficial insects in conjunction with chemical control requirements.
5. The lychee industry should consider supporting regular spray application training to maintain grower competencies.
6. To enhance grower adoption and development key management recommendations could be regularly highlighted in the industry magazine.

Refereed scientific publications

N/A

References

Diczbalis, Y (2020). Mite and insect disinfestation of lychee fruit using high pressure water sprays. Hort Innovation Final Report LY18000.

Woolf, A. et al. (2015). Advances in application of high pressure washing to enhance market access. Acta Horticulturae 1105:385-390

Intellectual property

No project IP or commercialisation to report

Acknowledgements

Co-Investors: This project would not have been possible without the investment from Hort Innovation, the Lychee Industry and DAF.

Project Steering Committee: Thanks to the project steering committee members who gave freely of their time to guide the project team. In particular Jill Houser, Executive Officer Australian Lychee Growers Association.

Growers: Growers from all lychee producing regions contributed to the grower survey. Similarly, many producers made their orchards available for lychee pest surveys.

QDAF: The following kindly shared their expertise with the project team; Dr Ian Newton, Stef De Faveri, Richard Piper, Dr Lara Senior and Dale Bennet.

Attachments

1. Lychee scale and mealybug management shed poster
2. Lychee scale and mealybug management Toolkit
3. Lychee Orchard Spraying guide
4. Image files

Lychee SCALE AND MEALYBUG PESTS. Superfamily Coccoidea

What are they?

- Scale insects are a group of insects within the superfamily *Coccoidea.*
- There are over 20 families of scale; including soft scale (family *Coccidae*), mealybugs, (family *Pseudococcidae*) and hard armoured scales (family *Diaspididae*).
- All scale are sap suckers and there is a large amount of diversity in the group.
- Approximately 15 species have been found in lychee in Queensland, with a few common ones shown below. ***Refer to your Scale and Mealybug Toolkit and Field Guide for details.***
- First instar nymphs (that hatch from eggs or are live born) are called crawlers and can move on the tree. Ants can also act as vectors and tend the scale so that they can feed from the honeydew secretions produced.


Indian Wax Scale


Lychee leei Scale on leaves and fruit


Black Scale


Olive Scale on fruit and stems

Damage

- Direct physical damage to infested fruit, twigs and leaves is minor on lychee. However, if severe infestations occur they can cause twig and stem dieback and leaf deformation of new growth.
- Scale covered fruit are unsaleable, and contamination of fruit with honeydew encourages sooty mould growth.
- The presence of scale on fruit may delay or fail export protocols for growers exporting to NZ and the USA.

Action level

- Chemical control: Best control occurs at the crawler stage. Check 20 trees spaced throughout the lychee block. Control when 5% or more of 5 sample leaves, stem or fruit are infested with 5 or more scale. ***Refer to the Lychee Field Guide for more information.***

Pre-harvest scale management

Refer to your Scale and Mealybug Toolkit for details.

- Monitor for scale activity.
- There are a number of biological predators that will help manage scale. Avoid use of broad spectrum chemicals.
- Controlling ants in the orchard will help minimise the spread of scale.
- Chemical control: Match spray applications to the crawler stage which occurs in spring and early summer.
- Utilise chemicals which have the least impact on beneficial predator insects. ***Refer to your Scale and Mealybug Toolkit for details.***
- Prune canopies and calibrate spray equipment to increase the efficiency of spray penetration.
- **If exporting to the USA please check your Toolkit for USA - Australia registered chemicals!**

Chemical control

1. Apply ant baits (between flush to flowering and flowering to harvest)
2. Apply Dimethoate or Sulphur (USA) to control erinose mite and assist with scale management (at the start of flush and start of flowering)
3. Apply Trivor® (Australia) Applaud® (USA) to target crawler and juvenile scale (mid flowering & early fruit set)
4. Apply high volume summer oil cover spray (after pruning)

Biological control

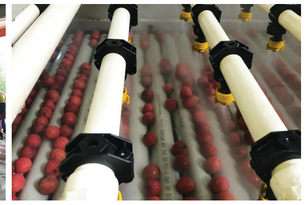
5. Strategic release of parasitic wasps, lacewings and ladybirds (late flowering to fruit set & prior flush commencing, at least 3 weeks after Dimethoate was applied)

12 MONTH CALENDAR *(not to scale)*

NB. *Numbers and symbols in the graph refer to the control measures listed on the left*

Post-harvest scale management

- A high pressure washer will help clean fruit and remove unwanted surface pests.
- Recommended for growers sending fruit to quarantine export markets (NZ and USA).
- Install a high pressure wash system in your packing line. ***Refer to your Scale and Mealybug Toolkit for details.***



Australian Lychee Growers Assoc. ALGA

Hort Innovation Strategic levy investment | LYCHEE FUND

Queensland Government

Lychee Scale and Mealybug Management Toolkit

Queensland Government

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Queensland Government

Lychee Scale and Mealybug Management Toolkit

Queensland Department of Agriculture and Fisheries; Management Guide

Supporting Organisations

Hort Innovation
Strategic levy investment

LYCHEE FUND

Australian Lychee ALGA Growers Assoc.

Foreword

The lychee industry in Australia, specifically Queensland, continues to expand as new plantings of newer varieties introduced in the mid 2000's are planted and harvested. The domestic market is strengthening as lychees become a summer favourite fruit. However, a prosperous future for the Australian lychee industry is linked to the industry's ability to export a substantial proportion of our produce.

Two of our major export markets, New Zealand and the United States of America, are quarantine markets. Pre-irradiation inspections required as part of the export protocol require that fruit are pest free prior to treatment. If mites or insects, including scale and mealybugs are found on fruit, this will result in a treatment delay until the pests are identified and able to be classified as non-quarantine pests. This generally results in fruit being diverted to the domestic market.

The Australian Lychee industry in association with Hort Innovation has supported research, conducted by DAF Queensland, to ensure that fruit bound for export markets are pest free prior to packing. This involves a combination of pre-harvest and post-harvest practices. This "Toolkit" and the associated packhouse poster is the synthesis of work supported by the industry to better manage scale and mealybug pests in lychee orchards. The toolkit will help growers understand;

- scale and mealybugs, their identification and life cycle
- the importance of biological predators
- current chemical management options for Australia and the USA
- chemical labels and improved spray application and timing techniques
- the importance of ant control in managing scale
- pest scouting practices and commercial options
- post-harvest management using high pressure spray units.

The Australian Lychee Growers Association and the industry's management committee commends the researchers and their teams as well as the support of individual producers for their efforts in detailing and sharing solutions to improving export opportunities.

Derek B. Foley

Derek Foley
President
Australian Lychee Growers Association

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Introduction

The lychee industry has committed to increasing exports as the key to industry expansion and development. The industry, currently valued at $34.4 M has established an export market valued at $7.4 M or 20% of gross value of product. Key markets are Hong Kong, New Zealand, USA and sundry smaller importers in the Middle East, Singapore, Canada, and some Pacific nations.

Mites, scales and mealybug and other insect pests are commonly found in lychee orchards. The pests cause little direct damage to trees and fruits unless badly managed. However, they do present a challenge to producers targeting quarantine markets in the USA and NZ. Pre-irradiation inspections required as part of the export protocol require that fruit are pest free. If mites or insects, including scale and mealybugs are found on fruit, this will result in a treatment delay until the pests are identified and able to be classified as non-quarantine pests. If pests are found, this generally results in fruit being diverted to the domestic market.

Recent work (Diczbalis 2020), funded by Hort Innovation and the Lychee Industry research and development levy, investigated the use of high pressure washing for the removal of mites on export fruit. The project found that post-harvest high-pressure washing effectively removed 90% plus of mites but only reduced scale and mealybug by 40 to 50%.

This management “toolkit” is the culmination of a two-year project to identify scale and mealybug pests and their distribution in lychee producing regions. The toolkit is designed to offer lychee producers information on identification of scale and mealybug pests as well as management options. The export of pest free fruit requires pre-harvest and post-harvest management. This document in combination with the Lychee Field Guide gives growers the tools to reduce pest loads and enhance the export of fruit to quarantine markets.

Scale and mealybug identification

What are scales and mealybugs?

Scale and mealybugs refer to a large group of insects within the super family *Coccoidea*. There are over 20 families of scale including soft scales (family *Coccidae*), mealybugs (family *Pseudococcidae*) and hard armoured scales (family *Diaspididae*).

For small, blob like insects there is a great deal of variation in their biology. Many species do not have functional legs and are sedentary and once attached to the plant; they do not move. However, some species can move throughout their lifecycle. Some species are parthenogenetic (that is they can reproduce without mating) while some species are hermaphroditic (individuals have both male and female reproductive organs). In some species males are part of the life cycle and where they do occur, they look very different from females and are rarely seen. They have wings and superficially they are similar to gnats and whiteflies.

Feeding mechanism

Scale and mealybugs do not chew plant parts; they are sap suckers similar to aphids. They possess a stylet (sharpened straw) that they insert into the plant's vascular system to draw out liquids from the phloem (plant food conducting vessels). Heavy infestations can compromise plant health and/or fruit quality. Most soft bodied scale and mealybugs produce honeydew as they feed. Honeydew is scale insect excretion but is very sweet, being made up of plant sap. Hence ants will farm the scale and position them on the plant and may defend them from attack by predators and parasites. For this reason, a section on management of ants is included in this toolkit.

Difference between scales and mealybugs

All mealybugs are scale insects from one family (Pseudococcidae). Therefore, all mealybugs are scales, but not all scales are mealybugs.

Mealybugs have a white cottony and or waxy body with no hard covering. They often have waxy extensions around their edges or rear of the insect. Mealybugs produce an ovisac to hold and protect their eggs. Most mealybugs can move throughout their lifecycle. Some scale insects from other families can appear very similar to mealybugs when they are white, cottony and can also move throughout their lifecycle.

Scale insects that are not mealybugs have quite a lot of variability in their appearance. They may be smaller or larger than mealybugs. Many scales appear like barnacles clinging to the host plant and do not move. Soft scales are often covered with a waxy coating, and they produce honeydew while feeding. Hard or armoured scales have a hard wax coating and are generally circular and domed in shape. They do not produce honeydew.

There are invariably many exceptions to these general descriptions. If you are experiencing difficulties managing scale insects and it appears as though one species is the main problem, it may be worthwhile having it identified[1].

Scale and mealybug identification

Identification of mealybug and scale, members of the Superfamily *Coccoidea*, to genus and species level is complex and, in most instances, requires the input from specialist taxonomists. There is increasing reliance on using genetic methods of identification, however at times the best we can offer is identification to family level. Plants and insects are scientifically identified at a range of levels. The use of the acronym; "**Parrots Can Only Fly Going South**" is an excellent way of remembering the different levels or hierarchies (Phylum, Class, Order, Family, Genus and species). Insects are in the Kingdom Animalia.

[1] https://www.daf.qld.gov.au/business-priorities/biosecurity/plant/health-pests-diseases/grow-help-australia-sample-submission-form

Table 1 Scale and mealybug scientific classification

P	Phylum	Arthropoda
C	Class	Insecta
O	Order	Hemiptera
F	Family (Superfamily)	*Coccoidea* breaking further down to the currently recognised 23 families. Most of the samples identified in lychee are in the families *Diaspididae* (armoured scales); *Coccidae* (soft scales); *Monophlebidae* (cottony cushion scales) and *Pseudococcidae* (mealybugs).
G	Genus	e.g. *Icerya*
S	Species	*seychellarum* (See page 31 of your Lychee field guide for a picture).

In short, the identification of mealybugs and scales is a complex task. From a grower perspective, scale and mealybug are a problem regardless of the scientific identification.

Scale and mealybug life cycles

Scales hatch from an egg and typically develop through at least two nymphal instars (growth stages) before maturing into a reproductively active adult. At maturity, females produce eggs that are usually hidden under their bodies, although some species lay their eggs externally under prominent cottony or waxy covers. Eggs hatch into tiny crawlers (mobile first instar nymphs), which are yellow to orangish in most species. Crawlers walk over the plant surface, are moved to other plants by wind or ants, or are inadvertently transported by people or birds. Crawlers settle down and begin feeding within a day or two after emergence. Each instar may appear substantially different from the previous one giving the impression that multiple species of scales are present. There is a great deal of information on scale insects and mealybugs online through university extension services out of the USA and elsewhere, e.g., University of California[2].

Generalized life cycle

Armoured Scale

- The eggs are laid underneath the waxy covering and hatch in one to three weeks.
- The newly hatched scales (crawlers) move about over the plant until they locate a suitable location to feed, often succulent new growth. They insert their piercing-sucking mouthparts into the plant, begin feeding and will not move as they develop.
- Individuals that become females lose their legs and antennae during the first moult. They moult a second time before reaching maturity, and do not pupate.
- The cast skins (exuviae) are incorporated in the scale cover, often giving them a target like appearance.
- Male scales go through two additional moults and pupate underneath the wax. Adult males are tiny, two-winged, gnat-like insects without mouthparts.
- In some armoured scales the adult stage is reached in six weeks, and there are several generations per year.

[2] https://ipm.ucanr.edu/PMG/PESTNOTES/pn7408.html

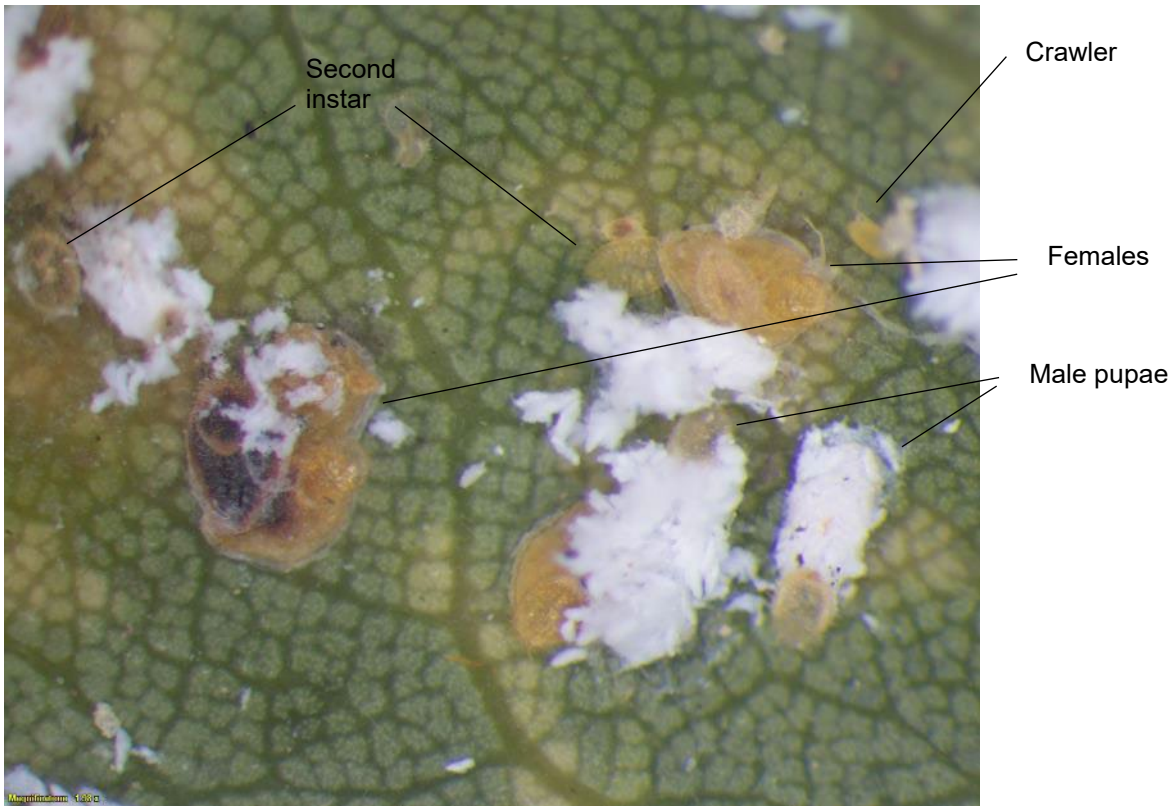


Image 1 All life stages of scale insects can occur in a very small area. Pictured here is *Thysanofiorinia leei* nymphs, females and pupal males.

Soft Scales and Mealybugs

- The life cycle is similar to the armoured scales except some soft scales require one year to reach maturity.
- In the females of the soft scales the antennae and legs are not lost but are reduced to such an extent that they cannot move. Some species of soft scales can move slowly. Mealybugs, however, have well developed legs and can move substantial distances.
- The wax when secreted, usually forms a sac at the rear end of the body enclosing the eggs, and the scale on the back of the insect becomes much thickened, forming a fluffy mass.
- Mealybug life cycles are completed rapidly and require approximately 30 days at 27˚C.

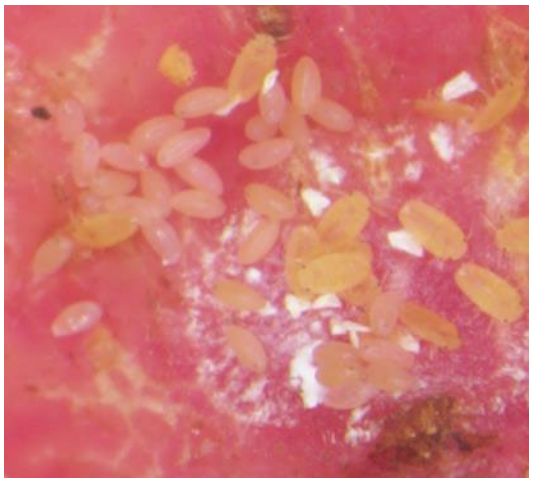


Image 2 Eggs and crawlers of *Parasaissetia nigra*; these can appear very similar across a wide range of scale insect species.

Image 3 Second and third instar nymphs of *S. oleae* (left), *P. nigra* (middle), and *Coccus hesperidum* (right).

Image 4 Mature females of *S. oleae* (left) and *P. nigra* (right).

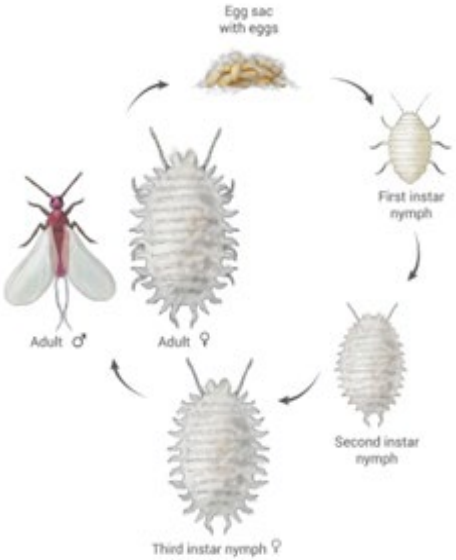


Image 5 Mealybug life cycle – *Planococcus citri* (https://www.koppert.com/challenges/pest-control/mealybugs-and-scales/citrus-mealybug/

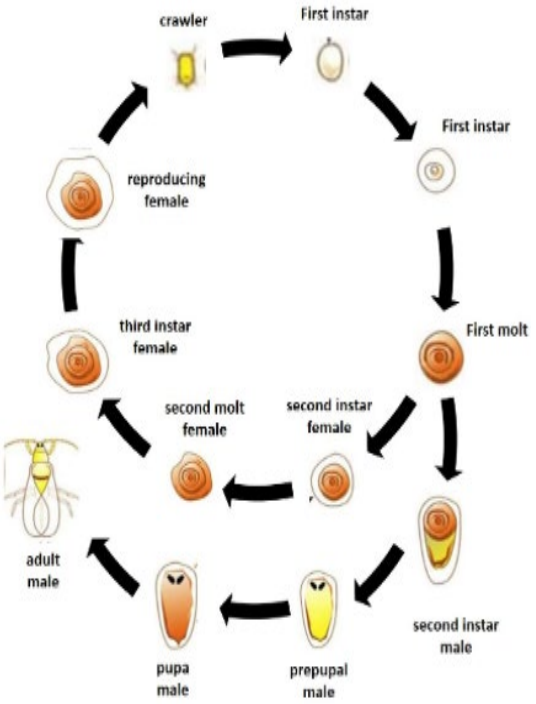


Image 6 Typical armoured scale life cycle (https://www.kingquenson.com/Company_News/Scale-Insects.html)

Scale and Mealybug identified from farm samples collected during the project.

Table 2 Scale, by family, genera and species from sampling lychee orchards during the project.

		Distribution in each region*				
Family and species	**Common name#** (There can be multiple common or overlapping common names for the same species)	**Bundaberg & Nambour**	**Sarina & Yeppoon**	**Murray Upper & Ingham**	**Mareeba**	**Previously recorded on Lychee in Australia^**
Family Diaspididae	**Armoured scales**					
• *Chrysomphalus dictyospermi*	Dictyospermum scale	L				
• *Hemiberlesia lataniae*	Latania scale	W				Yes, SEQ
• *Thysanofiorina leei*	Lychee leei scale	W	W	W	W	Yes, Weipa to SEQ
Family Coccidae	**Soft scales**					
• *Ceroplastes ceriferus*	Indian wax scale	W	L		W	
• *Coccus longulus*	Long brown scale		L			Yes, Mareeba
• *Coccus hesperidum*	Brown soft scale	L				Yes, Tully
• *Saissetia oleae*	Olive scale#	L	L			
• *Parasaissetia nigra*	Black scale#	W	L			Yes, Cairns, Bundaberg
• *Pulvinaria psidii*	Pulvinaria scale	L				Yes: SEQ, Yeppoon, Mareeba
• *Prococcus acutissimus*	Banana-shaped scale				L	
Family Monophlebidae	**Giant scales**					
• *Icerya purchasi*	Cottony cushion scale				L	
• *Icerya seychellarum*	Seychelles scale	W	W	W		Yes, Innisfail

*L indicates the species was localised to one farm during surveys of the region and W indicates the species is widespread on multiple farms in the region.
#There are many common names for these species; sometimes the same common name is used for both species.
^Indicates that the species had been previously recorded on lychee.

Table 3 Previous lychee records from the Queensland Primary Industries Insect Collection (QDPC) of scale and mealybugs that were not detected in surveys during this project.

Scientific Name	Common name	Family	Collection Locations
Ceroplastes rubens	Red wax scale	Family Coccidae – Soft scales	SEQ
Ceroplastes sinensis	Chinese wax scale	Family Coccidae – Soft scales	SEQ
Saissetia neglecta	Caribbean black scale	Family Coccidae – Soft scales	Sarina
Howardia biclavis	Burrowing scale	Family Diaspididae – Armoured Scales	Mareeba, Cairns
Planococcus minor	Passionvine mealybug	Family Pseudococcidae - Mealybugs	Innisfail

Overall, a total of 17 scale insects have been identified from lychee in Australia. Eleven of these were detected during project surveys and provide an indication of their distribution and prevalence. Five species detected in the surveys had never been detected on lychee previously in Australia. It is likely that there are more species of scales that may sometimes be found on lychee that were not detected during the survey. It is also possible that some species detected have a wider distribution than detected during the project. It is also possible that some species detected have a wider distribution than indicated here.ve a wider distribution than indicated here. This could occur because they are not very abundant, are only locally abundant or because conditions during the surveys were not favourable for them.

Latania Scale - *Hemiberlesia lataniae*

Originally native to Europe, but now widely present in many temperate and tropical regions of the world. Latania scale have a wide host range (120 plant families) which includes many fruit crops, palms, sugarcane and ornamentals. It is an economic pest of kiwi, avocado, olive, mango and tea overseas. They can be present on all parts of the plant and have variable colour and shape often depending on the plant part on which they feed. This species may not produce males and can complete its lifecycle in 7-10 weeks.

Surveys showed that it was present across multiple farms in Southeast Queensland (Bundaberg and Nambour surveys). Overseas, this species has been shown to have 2 generations per year in the USA, 3 generations in Egypt and 4 generations in Israel. It is worth assuming that it can have at least 4 generations per year in Queensland.

Damage includes loss of vigour, deformation of infested plant parts, chlorotic leaves and stem dieback, depending upon the level of infestation.

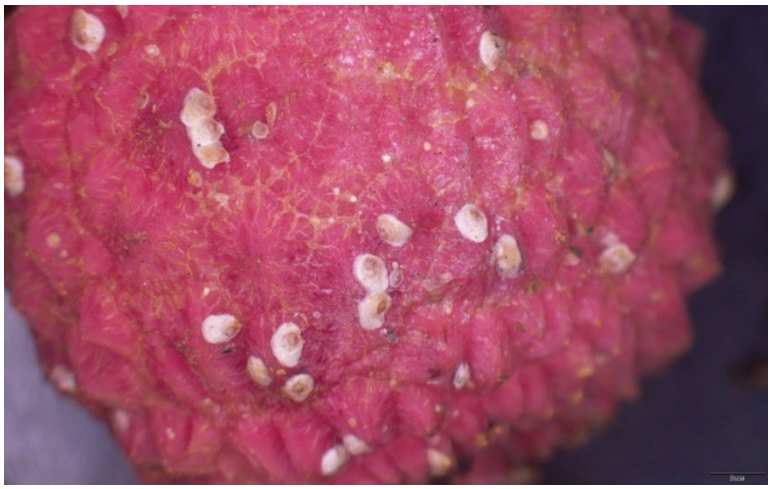


Image 7 Latania scale, nymphs and adults (females). Females are the relatively large individuals, nymphs are smaller.

Lychee leei Scale - *Thysanofiorinia leei*

It is a known pest of lychee overseas and widely spread throughout lychee production regions in Australia. Heavy infestations can occur on the trunk and up into the canopy and generally on the underside of the leaf. During the season, the scale can be found on panicles, fruit stalks and on fruit. Its small size and “cotton fluff” appearance belies the nature of the armoured (hard) scale.

This species was by far the most common and widespread scale insect detected during these surveys, being the only species present in high numbers in all regions of Queensland. It is only known to occur on two host plant species, lychee and rambutan (family Sapindaceae). Damage includes leaf chlorosis, leaf drop, stem and limb dieback (at very high-level infestations).

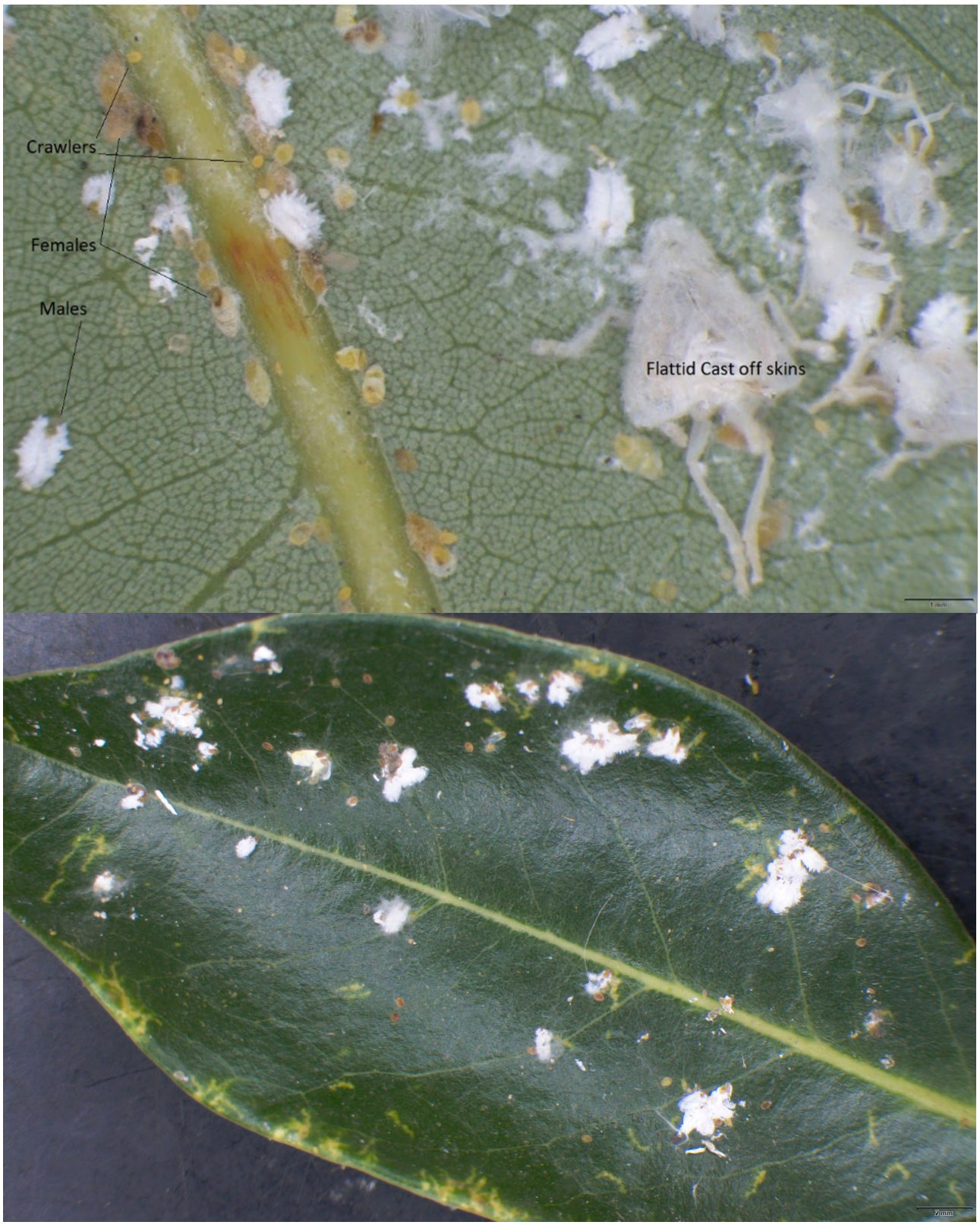


Image 8 Lychee leei scale. Males are fluffy, nymphs are small, and females are relatively large and flat.

Image 9 High magnification of male pupae (left) and dissected male revealed from within pupa (right).

Dictyospermum scale - *Chrysomphalus dictyospermi*

Widespread overseas, dictyospermum scale has a wide host range (over 80 plant families), including many fruit tree crops, palms, ornamental trees and shrubs. It is sometimes noted as an economic pest of citrus overseas. Surveys here only found it on lychee in SEQ on one farm, but it is likely to be present on other hosts across much of Queensland. They can be found on foliage and growing tips, fruit and flowers. They can complete 3-4 generations per year.

Image 10 Dictyosperma scale on lychee fruit.

Mining Scale - *Howardia biclavis*

Mining scale has a wide distribution across North and South America, Europe, Asia and Australia; however, it is mainly tropical. It was not detected on lychee in surveys here but was previously recorded on lychee around Mareeba and Cairns. Like many scales, it has a wide distribution across many fruit tree crops, other tree species, shrubs and herbaceous plants. It has been reported as an economic pest of many ornamental plants in Florida, a coffee pest in Brazil and Puerto Rico, and tea in various countries.

This species does not burrow into plant tissue. Crawlers are thought to move into cracks in the bark. As the scale grows it forces its way under the epidermis of the plant giving the appearance that it burrows.

Image 11 Mining scale on Fig. Photo by John A. Davidson, Univ. Md, College Pk, Bugwood.org

Black Scale - *Parasaissetia nigra*

Common in Australia and widely distributed throughout the world with a wide host range including fig, guava, macadamia and many ornamental plants (from over 100 plant families). Surveys in Queensland found it to be widespread in SEQ and was detected at one farm in the Sarina/Yeppoon surveys.

Sooty moulds often develop on honeydew deposits on surfaces near groups; heavy infestation of the leaves and stems may result in partial defoliation. Even in the absence of sooty moulds, nearby surfaces often become sticky to the touch and ants may be attracted by the sugary deposits. High infestations may result in leaf reduction in fruit set and loss of vigour. This species is thought to be all female and may complete its lifecycle in 6-9 weeks, depending on temperature and the host plant.

This species is very difficult to distinguish from other species of *Parasaissetia* and *Saissetia*.

Image 12 Black scale adults

Olive Scale - *Saissetia oleae*

Originally from South Africa the olive scale is distributed worldwide. It was detected at only two farms in Queensland, one in SEQ and one in Sarina/Yeppoon surveys. It has a wide host range including citrus, avocado, olive, tropical fruit and landscape plants (from at least 80 plant families). Where present in lychee, it can be found on branches, fruiting panicles and fruit. Parasitised adults were commonly observed. In Florida, biological control is considered the best method of management.

It is known to have one or two generations per year depending upon temperature; optimal growth occurs at about 21°C. Females can lay a large number of eggs under their body (1000-4000 eggs). It is adversely affected by hot, dry conditions and tend to colonise shaded, humid parts of the plant in hotter climates.

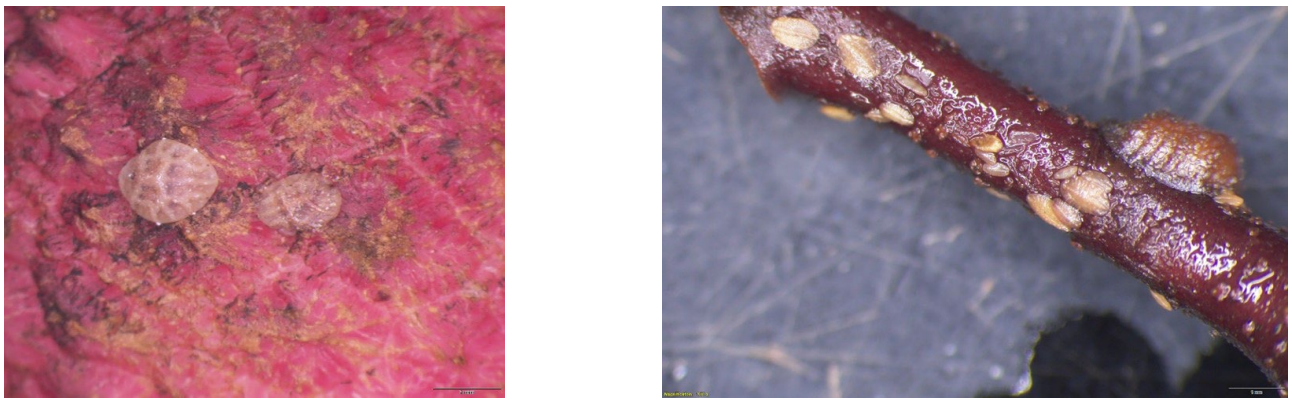


Image 13 Olive scale. Large nymphs (left) – note distinct ‘H’ in body sculpturing. Adult and smaller nymphs (right).

Caribbean black scale - *Saissetia neglecta*

Caribbean black scale is mainly distributed in North and South America, China and Australia. It was not detected in surveys here but had been detected from lychees in Sarina previously. It has been reported from many plant species across more than 30 plant families including various fruit tree crops, other trees, shrubs and herbaceous plants. They are very similar in appearance to olive scale and black scale.

Brown soft scale – *Coccus hesperidum*

Brown soft scale has a wide distribution across tropical and temperate countries. It has one of the largest host ranges of soft scale species (over 130 plant families) across fruit tree, ornamental trees, shrubs and herbaceous plants. In surveys here it was only detected in SEQ on one farm but has previously been recorded in Tully. It is very similar in appearance to other dark brown scale insects. Damage is typical of other scales, and it has at least 3-5 generations per year

Image 14 Brown soft scale appear very similar to other round, brown, convex scales. Photo by Lesley Ingram, Bugwood.org

Long brown scale – *Coccus longulus*

Long brown scale is widely distributed overseas but is mainly a pest in warmer climates. It has a wide host range (over 50 plant families) including various fruit trees, other trees, ornamental plants and many species in Fabaceae. In surveys here it was found at one farm in the Sarina/Yeppoon area and has previously been recorded on lychee in Mareeba. It is potentially a pest across all lychee growing regions.

Image 15 Long brown scale immature individual (about 1-2mm), adults can be up to 7mm long.

Banana-shaped scale – *Prococcus acutissimus*

Banana-shaped scale has a distribution that is mainly in Asia and South Pacific Islands. It was detected on lychee from only one farm during current surveys in Mareeba. It has a wide host range, but not nearly as wide as many other scales (only plants from about 30 plant families) including fruit trees, ornamental trees and shrubs. It is not known to be a serious pest of any tree crops. As the name suggests, it is a long and thin (up to about 6mm long and 1-2mm wide), slightly curved species that is brown.

Image 16 Banana shaped scale (left); upturned with crawlers underneath (right).

Pulvinaria scale – *Pulvinaria psidii*

Pulvinaria scale has a distribution that is largely tropical and sub-tropical. In Australia, surveys only detected the scale on one farm in SEQ, but it has been previously recorded in Yeppoon and Mareeba. It has a wide host range (from over 70 plant families), including many fruit trees, other trees and ornamental shrubs and herbaceous plants. It is similar in appearance to other species in the genus and other species that are yellow to greenish yellow. They grow to be about 2-3mm long and have 2-3 generations per year overseas.

Females produce egg batches that are white and fluffy around their body. It is recorded as a pest of mango in Egypt and can reduce quantity and quality of fruit.

Image 17 Pulvinaria scale nymphs. Photo by United States National Collection of Scale Insects Photographs, USDA Agricultural Research Service, Bugwood.org

Red wax scale - *Ceroplastes rubens*

Red wax scale has a wide distribution across Asia, Africa, Europe and Florida (USA). It has a wide host range (from over 80 plant families) including many fruit trees, other trees and shrubs. It is a major pest of citrus in Australia and overseas. It is known to have 2 generations per year in Queensland and NT. Damage is relatively minor caused from black sooty mould growing on honeydew. Red wax scale was not detected in our surveys but was previously detected on lychee in SEQ.

As the name suggests, adults are pink or pale red and have a waxy covering over them that is quite distinctive in appearance. Nymphs are similar in colour but smaller. They grow to be about 3.1mm in diameter. They are similar in appearance to Indian wax scale, except that it is red/pink.

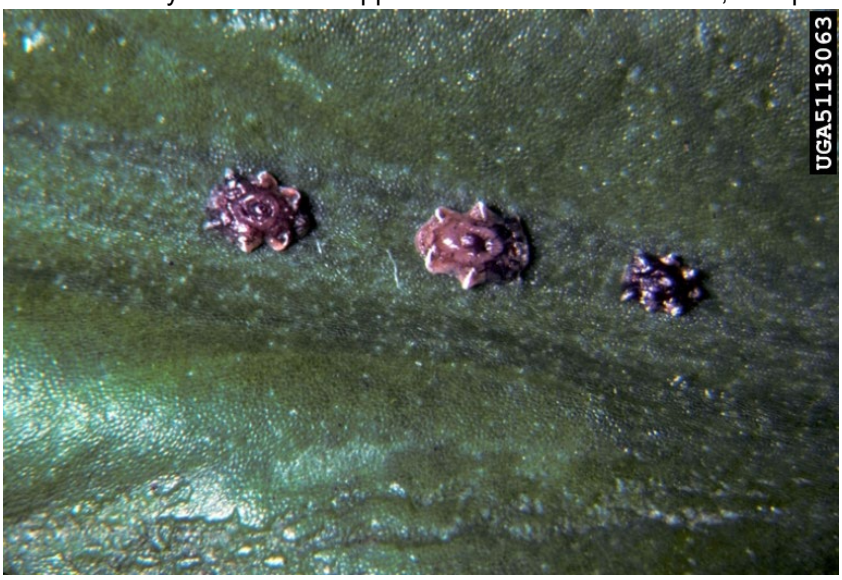


Image 18 Red wax scale. Photo by United States National Collection of Scale Insects Photographs, USDA Agricultural Research Service, Bugwood.org

Chinese wax scale - *Ceroplastes sinensis*

This scale is distributed across both tropical and temperate climates in Asia, Europe, South and North America and Australia. It has a wide host range, (from about 60 plant families) from many fruit trees, other trees and shrubs. It is also known to be a pest of citrus in Australia. In surveys here it was not detected but it has been previously found on lychee in the Kingaroy region.

It is very similar in appearance to both red wax scale and Indian wax scale, having a thick waxy covering and can be slightly pink or white to dirty grey in colour. They are relatively large with adults being 5-10mm in diameter. Refer to NZ factsheet[3] for more details on their biology and many photographs.

Indian wax scale - *Ceroplastes ceriferus*

Widely spread throughout the world, the Indian wax scale can be found in all east coast lychee production regions but was predominately found in SE Queensland (Bundaberg to Nambour). It was mainly found in large numbers on branches near the tops of the tree and occasionally found near fruit panicles. The scale is often parasitised by wasps. Dead and parasitised individuals are difficult to detect without pulling them off the branch and inspecting with magnification.

This species has many potential host plants including many shrubs and trees including, eucalyptus, coffee, citrus, figs, gardenia, magnolia, avocado, viburnum and many others. They produce honeydew that supports the growth of sooty mould and may be attended by ants. Heavy infestations may cause leaves to yellow and drop prematurely or cause branch dieback in very heavy infestations.

Image 19 Indian wax scale. Bottom photos of parasitised individuals; the blue coloured insect is a parasitic wasp that failed to emerge from the scale insect.

Cottony cushion scale - *Icerya purchasi*

Native to Australia, the scale is now widespread throughout the world and frequently associated with citrus production. It is able to survive cool and warm climates. In surveys here it was only detected in NQ from one farm but is likely to occur throughout Queensland. It has a wide host range (from over 80 plant families) occurring on fruit trees, other trees, shrubs and herbaceous plants.

[3] https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Chinese-wax-scale---Ceroplastes-sinensis.html

This scale is a hermaphrodite (being both male and female) and is able to self-fertilise, though males sometimes occur, and individuals may sometimes mate. Nymphs are bright or dark red-orange and may secrete some white wax and can move short distances. They grow to about 5mm in length. Adults produce more white wax and can sometimes be completely covered. They also produce a large white ovisac under their body, causing their body to tilt upwards. They can have 2-4 generations per year depending on climate and host plant. For more details on their biology and many photos refer to the NZ factsheet[4] on this species. The scale can at times be confused with Seychelles scale.

Image 20 Cottony cushion scale.

Seychelles scale - *Icera seychellarum*

This scale is widespread in Australia (NSW, NT and Qld), throughout the Pacific and many places overseas. In surveys here, it was found to be widespread in all growing areas accept Mareeba, where it was not detected. It is likely to be present on the Atherton Tablelands given that it is present in Ingham, it just wasn't detected during these surveys. The scale occurs on leaves, stems, twigs and fruit. It is more common on stems or on the underside of leaves near the midribs. The scale is found in association with ants due to its production of honeydew and the resulting sooty mould.

All stages of this scale have well developed legs and can walk short distances. Nymphs are orangey/yellow, but may sometimes be red, and gain yellow-waxy 'fluff' as they develop and become larger. Adults are substantially larger than nymphs and are white and yellow and almost always female. Superficially, they are similar in appearance to mealybugs. This is a very large species; individuals can grow to be about 1cm in length.

They have a wide host range from at least 60 families of plants including many fruit tree crops, ornamental plants and many trees, shrubs and herbaceous plants. High populations can cause yellowing and premature leaf drop, stem dieback and potentially may even cause tree death under extreme situations.

Image 21 Seychelles scale. Nymphs (left) and adult (right).

[4] https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Cottony-cushion-scale---Icerya-purchasi.html

Passionvine mealybug - *Planococcus minor*

Passionvine mealybug is the only species of mealybug that has been recorded on lychee in Australia. It was not detected in surveys but was recorded from lychee around Innisfail. It is found in North and South America, Asia and many South Pacific Islands and Australia. It has a wide host range (over 70 plant families) including fruit trees, other trees, shrubs and herbaceous plants. It is a common pest on many host plants including cacoa, grapes, passionfruit and others. Damage can include reduced yield, fruit quality and stunted growth and leaf loss. Black sooty mould also will grow on honeydew.

Eggs are laid in a batch at the end of females. Immatures are pinkish or white and oval shaped. As they mature they become covered in a white, powdery, waxy secretion. They can be up to 4mm in length. All stages can walk, but they tend to only move short distances.

Image 22 Passionvine mealybug infestation with many egg batches. Photo by Joel E. Miles, Office of Environmental Response and Coordination, Bugwood.org.

Current Management Options

This section of the toolkit highlights current lychee approved pesticides, spray application and pest management information.

Pesticides approved for use in lychee.

Current pesticide management options are listed in Table 4. The content of the table represents the state of knowledge at the time of publication. Before proceeding with chemical applications ensure you are aware of the registration and permits applicable to controlling pests in lychee. For each example chemical Trade Name, the table links to information on pesticide type its chemical group, active ingredient/s, pests managed, whether the chemical is registered or covered by a permit, method of application, use recommendations, effect on beneficial insects, the withholding period and if the chemical is approved for USA exports. The action is also listed indicating contact (C), translaminar (T – products that go across the leaf, but are not truly systemic), or systemic (S).

The information pertaining to the effect of the chemical on beneficial insects uses information from Koppert (https://www.koppert.com/news-information/side-effects-database/) and Biobest (https://www.biobestgroup.com/en/side-effect-manual) side effects databases; L = low toxicity, M = moderate toxicity, H = high toxicity. Residual information is the length of time that the product will have a negative effect on beneficial insects and mites. **Toxicity and residual information are a guide only.**

Table 4 Lychee Pest and Disease Registered and Permitted Chemicals as of February 2023.

Green shaded cells specific to scale and mealybug control. Yellow shaded cells indicate chemicals approved for USA exports.
* = permit or registered specific for control
# = permit for use on another insect but also effective for scale control (please refer to label).
^ Method of application F = foliar application, D = Soil drench
UN = This insecticide has not be allocated a mode of action group because the way the product works is not known sufficiently.

Disclaimer: This information is not a replacement for APVMA Permits and Labels. Please reference these before use. Reference using the Australian Pesticide and Veterinary Medicines Authority (APVMA) website https://portal.apvma.gov.au/home Click: Product Search or Permit Search and enter lychee or litchi

Example trade name	Pesticide Type & Chemical Group	Active Ingredient/s	Action	Pests	Registered or Permit*	Method of Application^	Application recommendations/ Comments	Effect on beneficials^^	WHP (days)	USA Approved

Example trade name	Pesticide Type & Chemical Group	Active Ingredient/s	Action	Pests	Registered or Permit*	Method of Application^	Application recommendations/ Comments	Effect on beneficials^^	WHP (days)	USA Approved
Insecticides/Miticides – specifically for scales and mealybugs										
Applaud®*	Insecticide Group 16	440 g/L buprofezin	T	Scale (*Coccidae*, *Diaspididae* & *Ericoccidae*); Mealybugs (*Pseudococcidae*) and Flatids	PER8801	F	2 sprays 14 to 21 days apart when nymph and crawlers present.	L-M – 0-3 weeks residual	14	Yes
Apparent Sulfur®*	Fungicide/Miticide (group M2) Insecticide (UN Group	800 g/kg sulphur	C	Erinose Mite and white louse scale (*Unaspis citri*)	PER91169	F	Apply before growth flush and after 14-21 days until all new growth damage free. Avoid petroleum oil within a month of sulphur application (before and after).	Probably L-M – 1-2 weeks residual	No WHP	Yes
Sacoa summer insecticide® plus other registered products*	Insecticide UN	815-861 g/L petroleum oil	C	Green Shield Scale (*Pulvinaria psidii),* Soft Green Scale (*Coccusviridis*) and Soft Scale (*Coccidae*)	PER91168	F	Apply from before panicle emergence to when fruit is 15 mm in diameter. High volume. No more than 4 sprays per season with a minimum of 21 days apart. Avoid overlaps of Sulphur and oils within 1 month of each other.	L-M – 0-1 week residual	1	Yes
Trivor*	Insecticide Groups 4A/7c	186 g/L acetamiprid + 124 g/L pyriproxyfen	S + T	Fruit Spotting bug, Fruit Fly, Mealybugs and Scale, Flatids	PER89943	F	Apply at crawler stage, spring or early summer. Max 2 applications 14 + days apart. Do not apply during flowering. Do not apply more than 1.6 L/ha per season	Probably M-H – 2-3 weeks residual	28	No

Example trade name	Pesticide Type & Chemical Group	Active Ingredient/s	Action	Pests	Registered or Permit*	Method of Application^	Application recommendations/ Comments	Effect on beneficials^^	WHP (days)	USA Approved
Natrasoap	Insecticide UN		C	Aphids, thrips, mealybug, two-spotted mite, spider mite, whitefly	Registered	F	Apply to point of run-off, when first noticed. Apply during cooler temperatures, reapply 5-7 days as required.	M – H – probably low residual	No WHP	No
Insecticides/Miticides – for mites and insects										
Bugmaster®	Insecticide Group 1A	500 g/L carbaryl	C	Castor oil looper, loopers, Mac Nut Borer, Yellow peach moth, Swarming beetles	Registered	F	Apply at first signs of pests and repeat as necessary. For non-Flowering and fruiting trees	H – 4+ weeks residual	0 days when applied as directed.	No
Reylon Dimethoate 400® + other registered	Miticide/ Insecticide Group 1B	400 g/L dimethoate	S	Erinose Mite	Registered	F	Established Trees: Apply before growth flush and after 14-21 days until all new growth damage free	H – 4+ weeks residual	7	No
Dipterex® or other registered products	Insecticide Group 1B	500 g/L trichlorfon	C	Flatid Planthopper, Flower eating caterpillars, Loopers, Yellow Peach moth, Suppression ONLY: Fruit spotting bug, Green Vegetable Bug, Lychee Stink Bug	PER14743	F	Apply only when pest present. Do not apply more than 6 applications per year. Do not use at >5 times dilute concentration rate. Do not spray while bees are foraging.	M-H – 2+ weeks residual	7	No

Example trade name	Pesticide Type & Chemical Group	Active Ingredient/s	Action	Pests	Registered or Permit*	Method of Application^	Application recommendations/ Comments	Effect on beneficials^^	WHP (days)	USA Approved
PyGanic Organic Insecticide®	Insecticide Group 3A	13 g/L pyrethrins	C	Insects (including beneficial predators) that may be present.	Registered for Sub-Tropical Fruit inedible peel including Avocado, Banana, Kiwifruit, Litchi (lychee), Mango and Pineapple.	F	For preharvest removal of insects, including beneficial predators in the crop that may be present prior to harvest. Apply to the crop prior (3-12 hours) to harvest to remove most insects prior to packing. Do not over-wet fruit to avoid spray marking. Ensure spray penetrates the fruit panicle and apply at 750 to 1000L/ha with high pressure.	H – Probably 8+ weeks	1	YES (?)
Bulldock®	Insecticide Group 3A	25 g/L Beta-cyfluthrin	C	Fruit spotting bug, Elephant Beetle, Swarming Leaf Beetle, Flatids, Yellow Peach Moth	PER80374	F	Max 4 applications per year with a min of 21 days between sprays	H – Probably 8+ weeks	7	No
Transform®#	Insecticide Group 4C	220 g/L sulfoxaflor	S	Fruit Spotting Bug	PER85397	F	2 applications per year with a min of 14 days between sprays	Probably L-H - unknown residual	7	No
Sivanto Prime 200 SL®	Insecticide Group 4D	200 g/L flupyradifurone	S	Banana and Fruit spotting bug, green and mango planthopper	Registered	F	Apply to runoff when threshold of insects is reached, use higher rate at times of higher pest pressure. Apply a maximum of two applications per 12-month period and do not reapply within 14 days of the first spray. Do not exceed 1 L of product per	Probably L-M – unknown residual	3	No

							hectare per application. Concentrate spraying is not appropriate.			
Example trade name	**Pesticide Type & Chemical Group**	**Active Ingredient/s**	**Action**	**Pests**	**Registered or Permit***	**Method of Application^**	**Application recommendations/ Comments**	**Effect on beneficials^^**	**WHP (days)**	**USA Approved**
Entrust organic Insecticide®	Insecticide Group 5	240 g/L spinosad	T	Fall Army Worm	PER89870	F	Target eggs and newly hatched larvae. No more than 4 applications in a season	L-H, depending on species, 1 week residual	Not required	Yes
Success Neo®	Insecticide Group 5	120 g/L spinetoram or 250 g/L spinetoram	T	Fall Army Worm - Permit. Registered for Flower eating caterpillar, leaf rollers and yellow peach moth, red banded thrip (RBT) and sorghum caterpillar	PER89241 and Registered	F	Target eggs and newly hatched larvae. No more than 4 applications in a season	M-H – at least 2 week residual	Not required when used as directed	Yes
Vertimec Pro®; Barmac, Titan, Cropro etc	Miticide/ Insecticide Group 6	18 g/L abamectin	T	Two spotted mite and Erinose mite	Registered	F	Apply when pests first appear during spring /summer. Max of 2 applications at least 28 days apart. Add wetter 0.2% HORT SPRAY OIL 200 mL/100L. Recommended spray volumes of 1,000 to 1,500 L/ha	L-H – 1-2 week residual. Variable results across species.	7	Yes
Distance Plus Ant Bait®	Insecticide Group 7C	(a.i. 5g/kg pyriproxyfen)	T	Ant activity	Registered	D	Pyripoxyfen is an insect growth regulator that disrupts the reproductive life cycle of ants. Apply early spring or summer at first signs of ant activity. Do not exceed 3 applications per year and maintain a	Probably L-M – 1-2 weeks residual	Not applicable	Yes?

							minimum of 3 months between treatments.			
Example trade name	**Pesticide Type & Chemical Group**	**Active Ingredient/s**	**Action**	**Pests**	**Registered or Permit***	**Method of Application^**	**Application recommendations/ Comments**	**Effect on beneficials^^**	**WHP (days)**	**USA Approved**
Mimic 700 WP®	Insecticide Group 16A	700 g/kg tebufenozide	C, I	Macadamia Nut Borer	Registered	F	Apply 2 sprays 6 and 12 weeks prior to harvest. This product is an insect growth regulator that is primarily an ovicide (stops eggs from hatching). It may have some activity on small larvare.	L-M – probably very low residual	14	No
Prodigy®	Insecticide Group 18	240 g/L methoxyfenozide	C, I	Permit: Mango Shoot Looper; Registered for Mac Nut Borer	PER91798 and Registered	F	Permit: 3 applications pre fruit set at 14 day intervals Registered: Spray as pest numbers reach threshold levels. Target eggs and relatively small immature insects.	L - probably 1-2 weeks residual	14	Yes
Fungicides										
Octave WP®	Fungicide Group 3	462 g/L prochloraz	S	Pepper Spot	PER80369	F	Apply only during flowering and fruit set. Do not apply to developing fruit. No more than 2 applications at 21–28-day intervals. Use maximum spray volume of 2,000 L/ha	L-M – probably 1-2 weeks residual	28	No
Luna Sensation®	Fungicide Groups 7&11	250 g/L fluopyram + 250 g/L trifloxystrobin	S + T	Pepper Spot	Registered	F	Begin spray application at early fruit development, 14 to 21 days apart, as part of a program. Maximum 3 applications and do not exceed 2 L/ha per year.	Probably L-M – unknown residual	3	No

Example trade name	Pesticide Type & Chemical Group	Active Ingredient/s	Action	Pests	Registered or Permit*	Method of Application^	Application recommendations/ Comments	Effect on beneficials^^	WHP (days)	USA Approved
Cabrio WG Fungicide® + other registered products	Fungicide Group 11	200 g/kg or 250 g/L pyraclostrobin	T or S, unclear	Pepper Spot	PER80367	F	Use as a preventative fungicide only. Do not apply more than 3 foliar applications per year. After 2 applications (10-14 days apart) follow with a fungicide from an alternate chemical group.	Probably L-M – unknown residual	3	No
Switch Fungicide®	Fungicide Groups 9&12	375 g/kg cyprodinil + 250 g/kg fludioxonil	S + C	Pepper Spot	PER88197	F	Apply a maximum of four foliar applications per season in 1000L/ha, using an air blast sprayer at a minimum retreatment interval of 7-14 days. Make the first application during early flowering and repeat 7-14 days later if conditions remain favourable for disease development. After two applications alternate with another fungicide with a different mode of action for two applications.	L-H depending on species - unknown residual	14	Yes
Copper E.g. Nordox 750 WG®	Fungicide Group M1	(750 g/kg) - cuprous oxide 100g /100L or cupric hydroxide (500 g/kg) 100 g/100L	C	Pepper Spot	PER13660	F	Apply every 4 weeks from one month prior to panicle emergence, minimum 2 weeks apart. Avoid use of copper during flowering and fruit set.	L-H depending on species – unknown residual	1	Yes

Example trade name	Pesticide Type & Chemical Group	Active Ingredient/s	Action	Pests	Registered or Permit*	Method of Application^	Application recommendations/ Comments	Effect on beneficials^^	WHP (days)	USA Approved
Mancozeb®	Fungicide Group M3	750 g/kg mancozeb	C	Pepper Spot	PER13659	F	Apply on a 3-to-4-week schedule. Use high volume spray equipment (1,000 L/ha). *No tolerance for this product for export to the USA.*	L-M – 0-2 weeks depending on species.	7	No
Plant Growth Regulators										
Prep 720 Growth Regulator® or other registered products	Growth regulator	720 g/L ethephon	NA	Flush Management	PER81753	F	No more than 2 sprays per season. Apply to young (<10 cm) flush. Full coverage or spot spraying. Add Kendeen 20 Surfactant at 120 mL/100L	Unknown	No WHP	No
Tops®	Growth Regulator	100 g/kg triclopyr	NA	Fruit Set	Registered	F	Apply when majority of fruit is 15-20 mm in length. Only 1 application/season. Use a non-ionic wetter	Unknown	No WHP	No

Green shaded cells specific to scale and mealybug control. Yellow shaded cells indicate chemicals approved for USA exports.

* = permit or registered specific for control
# = permit for use on another insect but also effective for scale control (please refer to label).
^ Method of application F = foliar application, D = Soil drench
UN = This insecticide has not been allocated a mode of action group because the way the product works is not known sufficiently.

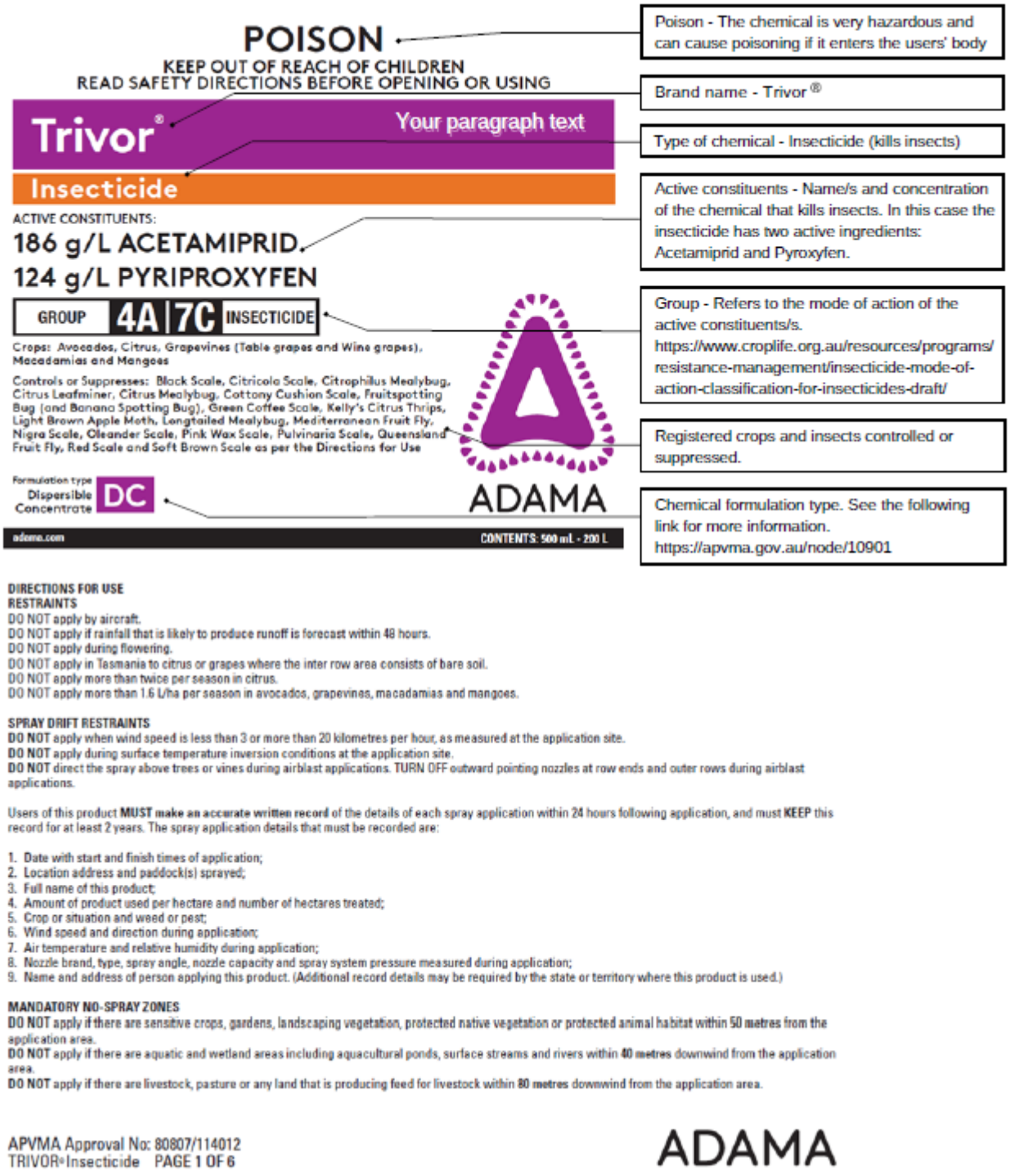
Table 5. Insecticides for use against scale insects on nursery stock, including lychees. Action C = contact, T = translaminar, S = systemic. Toxicities to beneficials uses information from Koppert and Biobest side effects databases; L = low toxicity, M = moderate toxicity, H = high toxicity. Residual information is the length of time that the product will have a negative effect on beneficial insects and mites. Toxicity and residual information are a guide only. Registrations and permits listed here are correct as of February 2023.

Example product	Mode of action group	Active ingredient	Registration information	Action	Toxicity to beneficials
Diazol	1B	Diazinon	Nursery plants against all scale insects (selected states, most labels do not include Qld).	C	M-H – 2-3 weeks residual
Conquer	4A	Imidacloprid	Non-bearing plants against mealybugs, soft scales and sap-sucking bugs (which technically includes all scale insects).	S	H – 2-3 weeks residual
Insegar	7B	Fenoxycarb	PER91816 for nursery stock against all scale insects (including mealybugs).	T	L-H – 1-3 weeks residual
Pyxal	7C	Pyriproxyfen	All nursery stock against all scales	T	L-M – 1-2 weeks residual
Applaud	16	Buprofezin	PER91816 for nursery stock against all scales and mealybugs	T	L-M – 0-3 weeks residual
Movento	23	Spriotetramat	PER91816 for nursery stock against all scale insects (including mealybugs). For use as foliar or drench application.	S	L-M – 0-1 week residual
Mainman	29	Flonicamid	All non-bearing, nursery stock against mealybugs only.	S	L – 0-1 week residual
Natrasoap	UN	Potassium salts of fatty acids	Fruit and nut trees and potted plants against mealybugs only.	C	M – H – probably low residual
Various	UN	Petroleum oil	PER91816 for nursery stock against all scale insects (including mealybugs).	C	L-M – 0-1 week residual

Interpreting a chemical label

Chemical labels contain detailed information about the pesticide that is registered or permitted to be used on your crop. In essence it is a “legal document” which under legislation must be observed by the user, this includes the booklet.

See the label for Trivor below as an example:



DIRECTIONS FOR USE
RESTRAINTS
DO NOT apply by aircraft.
DO NOT apply if rainfall that is likely to produce runoff is forecast within 48 hours.
DO NOT apply during flowering.
DO NOT apply in Tasmania to citrus or grapes where the inter row area consists of bare soil.
DO NOT apply more than twice per season in citrus.
DO NOT apply more than 1.6 L/ha per season in avocados, grapevines, macadamias and mangoes.

SPRAY DRIFT RESTRAINTS
DO NOT apply when wind speed is less than 3 or more than 20 kilometres per hour, as measured at the application site.
DO NOT apply during surface temperature inversion conditions at the application site.
DO NOT direct the spray above trees or vines during airblast applications. TURN OFF outward pointing nozzles at row ends and outer rows during airblast applications.

Users of this product **MUST make an accurate written record** of the details of each spray application within 24 hours following application, and must **KEEP** this record for at least 2 years. The spray application details that must be recorded are:

1. Date with start and finish times of application;
2. Location address and paddock(s) sprayed;
3. Full name of this product;
4. Amount of product used per hectare and number of hectares treated;
5. Crop or situation and weed or pest;
6. Wind speed and direction during application;
7. Air temperature and relative humidity during application;
8. Nozzle brand, type, spray angle, nozzle capacity and spray system pressure measured during application;
9. Name and address of person applying this product. (Additional record details may be required by the state or territory where this product is used.)

MANDATORY NO-SPRAY ZONES
DO NOT apply if there are sensitive crops, gardens, landscaping vegetation, protected native vegetation or protected animal habitat within **50 metres** from the application area.
DO NOT apply if there are aquatic and wetland areas including aquacultural ponds, surface streams and rivers within **40 metres** downwind from the application area.
DO NOT apply if there are livestock, pasture or any land that is producing feed for livestock within **80 metres** downwind from the application area.

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TRIVOR® Insecticide PAGE 1 OF 6

ADAMA

Please read the label carefully and follow rate instructions. If the chemical is not registered but you are aware of a permit to use on lychee, then follow the instructions on the permit. See below the example for use

of Trivor in lychee for the control of Fruit Spotting Bugs, Fruit Fly (Mediterranean and Queensland) and Mealybugs and Scale Insects.

Table 6 Permit to allow minor use of a registered AGVET chemical product for control and suppression of various insect pests in assorted tropical and sub-tropical fruits. Permit Number PER89943 (In force from 29 January 2021 – 31 January 2024)**.**

Products to be used:
TRIVOR INSECTICIDE (APVMA No. 80807)
Containing: 186 g/L ACETAMIPRID and 124 g/L PYRIPROXYFEN as the only active constituents.

Lychee	Fruit Spotting Bugs (*Amblypelta nitida* and *Amblypelta lutescens*)	20 – 40 mL/100 L or 400 – 800 mL/ha	Apply when monitoring indicates fruit spotting bug are becoming active in the crop. Use the higher rate if high fruit spotting bug pressure is expected and for longer residual control Apply as a foliar application by airblast sprayer, boomspray or equivalent. Apply spray dilute to the point of run-off; use sufficient water to obtain thorough and uniform coverage. DO NOT apply more than 2 applications per season. DO NOT apply less than 14 days after the initial treatment. DO NOT apply more than 800 mL/ha per application.

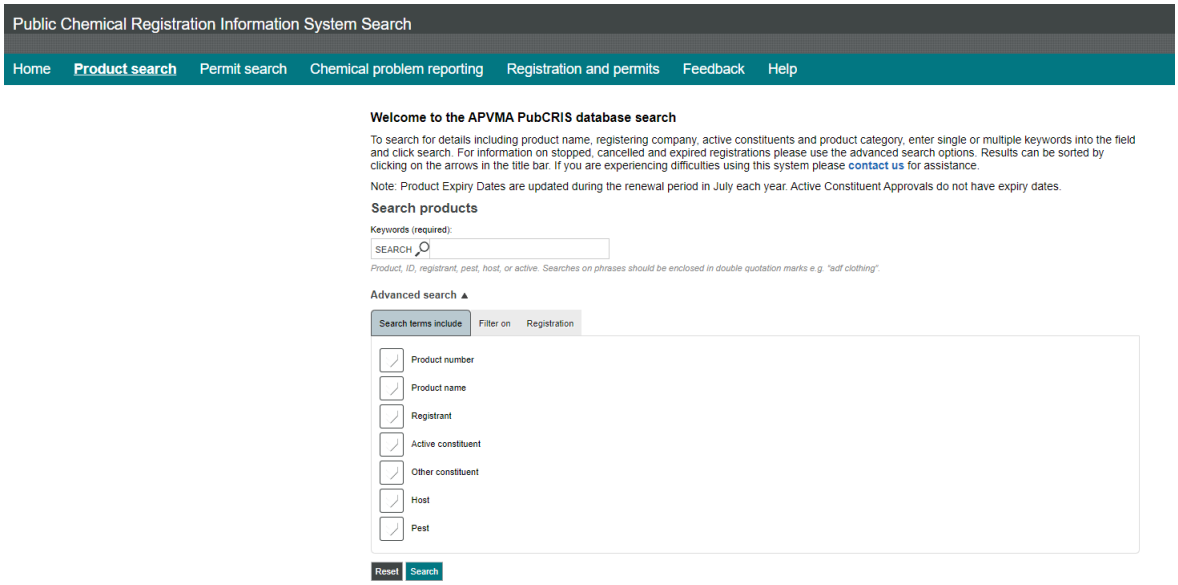
Crop	Pest	Rate	Critical Use Comments
Lychee	Mediterranean Fruit Fly (*Ceratitis capitata*) Queensland Fruit Fly (*Bactrocera tryoni*) Suppression only.	40 mL/100 L or 800 mL/ha	Apply when monitoring indicates fruit fly activity. Apply as part of a broader program involving other products for control of fruit fly, appropriate pest monitoring and farm hygiene. Apply as a foliar application by airblast sprayer, boomspray or equivalent. Apply as a dilute (high volume) spray to the point of runoff, ensuring thorough coverage of fruit and foliage. Concentrate spraying is not recommended when targeting fruit fly as thorough coverage is critical. DO NOT apply more than 2 applications per season. DO NOT apply less than 14 days after the initial treatment. DO NOT apply more than 800 mL/ha per application. Apply in rotation with insecticides from a different mode of action using a 7 day spray interval.
	Mealybugs (Pseudococcidae) Scale Insects (Coccoidea)		Apply when monitoring indicates the onset of crawler release as part of a monitoring and spray program for the management of mealybugs and scale. Do not target applications on populations that are well- established where mature adult insects dominate the population. Apply as a foliar application by airblast sprayer, boomspray or equivalent. Apply spray dilute to the point of run-off; use sufficient water to obtain thorough and uniform coverage. DO NOT apply more than 2 applications per season. DO NOT apply less than 14 days after the initial treatment. DO NOT apply more than 800 mL/ha per application.

If you are a member of the Australian Lychee Growers Association (ALGA) you will be kept up to date with registered and permitted chemicals for use on Lychee, the current chemical permit and label list can also be accessed on the member section of the ALGA website on https://australianlychee.com.au. Alternatively, Hort Innovation provides a monthly update of all permits (all crops) issued. This can easily be found on https://www.horticulture.com.au/.

The most authoritative and the ultimate site for details on Registered chemicals and permits for lychee is the Australian Pesticide and Veterinary Medicines Association (APVMA) website https://apvma.gov.au/.

1. “Click” on the Registration and Permits Tab
2. “Click” on Search registered chemical products and permits

3. “Click” on the PubCRIS database link for registered chemicals or the Permits database link for Permits (On this page there are also instructions for how to use the databases).
4. The links take you directly to the relevant database.



5. Enter Lychee in the search box and “click” on the green search box. You can select a narrower search by selecting one of the boxes below the search term.
6. This will take you to all chemicals “registered” for use on lychee which include Herbicides, Insecticides, Fungicides, Miticides, and Plant Regulators.
7. Follow a similar process when searching for Permits.

Concentrated versus dilute spraying

Dilute spraying

When dilute spraying, the chemical rate (mL or grams per 100L) taken from the label is mixed in the spray tank and the foliage is sprayed to the ‘point of run-off’. Spraying to this point will optimise the amount of product applied, avoid wastage and reduce possible unwanted contamination of the environment. When dilute spraying, higher total water volumes are used during the season in comparison to concentrate spraying and a wider range of droplet sizes is produced by spray equipment. Spray volumes are also increased through the season to closely match canopy growth.

“Point of runoff” – is defined as the point at which spray starts to run off the surface of a leaf or fruit but this can be difficult to identify. Complications arise because not all parts of the canopy being sprayed will have the same coverage at any one time. In most cases, outer leaves closest to the sprayer nozzles will capture more droplets than leaves in the centre of the tree. Calibrating and setting up the sprayer to even out the coverage throughout the canopy is extremely important.

Concentrate spraying

Concentrate spraying refers to the application of agrochemical using a water volume that is less than ‘point of run-off’. The same amount of chemical (per hectare) is sprayed that would have otherwise been applied if dilute spraying had been used. To achieve this, the amount of agrochemical in the spray tank needs to proportionally increase as the volume of water decreases. Spray volumes used for concentrate spraying are assessed to ensure good coverage. As the canopy grows during the season, water volumes are increased to ensure coverage is maintained as foliage area increases. Sprayer air characteristics should be matched with water volume (and droplet size) to ensure sufficient coverage at lower water volumes.

Generally, label recommendations suggest that to calculate concentrate spray concentrations, use the dilute spray volume and rate to “run off” as a guide. If your trees require 1,500 L/ha to achieve runoff and your dilute spray concentration is 50 mL/100 L you will require 750 mL of chemical per hectare. However, if you are “concentrate” spraying and applying a volume of 500 L/ha then your spray application rate is calculated accordingly.

- 1,500 L/ha divided by 500 L/ha = 3
- Concentrate spray rate = 50 mL/ha (dilute spraying) x 3 = 150 mL/100 L
- Spray application rate = 750 mL of chemical per ha

Dilute and concentrate sprays can be applied by most spray equipment used in orchard.

If a pesticide label states that it can be applied at 20 mL/100 L or at a 400 ml/hectare that means if using “20 ml/100 L” you could apply up to 2,000 L of water per ha.

However, applying at 2,000 L/ha would be over-kill if the canopy/leaf area only requires 1000 L/ha to apply to “run off”.

This is well explained in the excerpt from Viti-Notes (https://www.awri.com.au/wp-content/uploads/spray_application_rate_per_hectare.pdf) below.

> *“Moving away from a single rate per hectare using a fixed spray volume per hectare is comparable to painting different sized houses with equal quantities of paint. By not taking into account the differences in surface area, the coverage cannot be the same. In the vineyard there is a risk of under-dosing large canopies or over-dosing small canopies if a common volume is used. The single rate per hectare has now mostly disappeared from labels for products used in viticulture. Instead of a chemical rate per hectare (e.g. 3kg/hectare) chemical labels will have a rate per 100 litres of water (e.g. 300g/100L). As a result growers need to determine the amount of water (Litres/hectare) needed to spray their vines to the point of run-off. Viticulturists can now use the new chemical labels to match chemical rates to the size of their vine canopies. This will result in adjusting and increasing chemical rates as the canopy grows over the season. Using the ‘rate per 100 litres’ together with good target accuracy should result in a constant dose being applied as vines grow.”*

If you only need 1000 L/ha to spray to runoff then your application rate per hectare will be 200 mL/ha, half of the allowable maximum.

Residue studies to determine MRLs are conducted using rates higher than that required to manage the problem and the rate of chemical breakdown is managed.

The excerpt below is from the Permit for Trivor® PER89943. The per hectare rate (800 mL/ha) would allow up to 2,000 L/ha of mix to be applied at the rate of 40 mL/L. If a grower has determined that they only require 600 L/ha to apply chemical to runoff then the application rate per ha will be 240 mL/ha, well under the allowable application of chemical to stay within the MRL. The rate per hectare is the maximum rate that should be used to stay within the MRL’s considering withholding periods etc. and any additional information as per Permit 89943 - DO NOT apply more than 1.6 L/ha per season. That is 1.6 L of chemical (active ingredient).

Table 7 Permit instructions for use of Trivor® in lychee

Crop	Pest	Rate	Critical Use Comments
Lychee	Plant Hoppers (Fulgoroidea) Leafhoppers (*Empoasca* spp.)	40 mL/100 L or 800 mL/ha	Apply when numbers exceed local pest thresholds as part of a monitoring and spray program for the management of leaf hoppers. Apply as a foliar application by airblast sprayer, boomspray or equivalent. Apply spray dilute to the point of run-off; use sufficient water to obtain thorough and uniform coverage. DO NOT apply more than 2 applications per season. DO NOT apply less than 14 days after the initial treatment. DO NOT apply more than 800 mL/ha per application.

Sprayer Calibration

Applying pesticides or foliar nutrients to your orchard with a poorly calibrated and maintained sprayer is a waste of money and time.

Introduction

- In managing pests and diseases in your orchard you potentially will apply hundreds of dollars of chemical per hectare over the year
- Tree size and foliage density can vary from season to season and as the trees develop
- Most modern chemicals require precise application to be effective
- Growers need to minimise off-target spraying and environmental pollution and save money

Reason for Calibrating

- Pesticides and foliar nutrients need to be applied at the label/permit rate
- You need to know the application rate and ensure it is applied correctly
- Actual application rate may vary due to nozzle wear, wheel slippage, faulty pressure gauges, tractor speedometer error
- Spray patterns can vary from one side to the other, particularly on sloping and uneven ground

Factors affecting application rate

- Ground speed
- Sprayer operating pressure
- Nozzle flow rate/s
- Nozzle alignment
- Spray pattern
  - Your spray pattern is influenced by your groundspeed, operating pressure nozzle flow rates and nozzle alignments. This pattern can be checked using water sensitive paper and/or fluorescent dye.

There are several excellent online resources to assist with this process.

Orchard sprayer calibration and testing makes a difference. Request a copy from the ALGA of the Lychee Orchard Spraying Manual prepared by Allan Blair. The statement below comes from a lychee grower after a calibration exercise using UV sensitive dye and spray runs at different speeds and operating pressures.

We have just returned from a check on the orchard that we have sprayed. We went on the cherry picker and found a significant improvement "in spray coverage through the canopy" where I have driven at 3.74km/h and sprayed at 7.5bar in comparison to my current "practice" speed of 3.0km/h at 5.5bar.
Coverage is better and there are also less drops on the ground.
I have made some calculations and I think that I will be applying around 2.2L/tree which is less than the 2.45L/tree currently applying at 3.0km/h. Still the coverage looks better to me. Must be because of the increase in pressure to 7.5bar.
This equals around 1000L/ha. Once I start spraying again, I may adjust the pressure a bit higher to complete the orchard with 9 tanks x 700L = 6300L over 5.5ha = 1145L/ha over 476 trees = 2.4L/tree.

Ant Control

Ants are abundant in orchards. If you take the time to sit under a lychee tree you will see the mulch and soil surface around the tree full of insect activity with ants busy moving between the soil, tree trunk and upper branches. Ants have a symbiotic relationship with scale and mealybugs, they tend the adults, aid in the spread of juvenile scale and actively attack and feed on scale parasites and predators and feed on the honeydew that the scales produce. Ant control can assist with scale management.

There are no biological predators of ants, hence control activities are limited to exclusion, baiting and ground sprays.

Exclusion

Tree skirting, trunk banding with sticky barriers and controlling ground cover under the trees are the main ways of excluding ant movement into the trees. Skirting and ground cover control under trees are generally part of normal orchard management. Trunk banding with sticky barriers is time consuming and not appropriate for large orchards but certainly would be a consideration for smaller orchards taking a minimum chemical or organic approach.

There are a range of sticky ant barriers on the market. They should not be directly applied to the trunk as they can cause ring barking. They are recommended to be applied to the outer surface of a plastic tape which encircles the trunk or major branches. Ants do not require a thick coating of sticky gel to be an effective barrier. Be aware that plastic tapes left on the trunk or branches for extended periods can be problematic. Plastic tapes should not be left longer than several months on the tree.

Ant Baits

A variety of ant baits are available. The baits that will be most effective depend on the species of ants present as some ants prefer sugar baits and others prefer protein baits. Providing both may be beneficial; monitor the efficacy and modify as required. Baits generally contain a mix of food or ant attractant and a toxic or growth regular agent. But few are directly registered for use on lychee. The important thing about an ant bait is that it should not be so toxic as to kill individual ants quickly before they have had a chance to return to the nest to transfer the toxicant to the colony at large. A few potential baits that can be used are.

- Distance Plus Ant Bait – a.i. 5g/kg Pyriproxyfen a group 7C insecticide is registered for use in plantations and orchards including olives, citrus and tropical fruits and tree nuts. The active ingredient Pyriproxyfen is a mimic of a natural insect hormone. It is a type of insect growth regulator that affects mostly young insects and eggs. The product is recommended to be applied in early spring or summer at the first sign of ant activity and signs that they are actively foraging. This is generally the same time when scale crawlers are on the move.
- A simple home-brew bait, but well tested, incorporates the household cleaner and laundry detergent booster, Borax (Sodium Tetraborate) as the toxicant. Small quantities of Borax, a relatively harmless compound, are taken back to the nest by an army of ant workers. It may take time but eventually this action can reduce in size or kill out the colony. Best to find out what the main species of ants in your orchard are attracted to, sugar or protein.
  - Bugs for Bugs recipe for Borax bait is 3 cups of water + 1 cup of sugar with 4 teaspoons of borax. Some ant species prefer more or less sugar or may respond to protein (crushed dry dog food formula can work here).
- Ant baits containing the active ingredients fripronil or hydramethylnon or hydramethylnon + Pyriproxyfen are registered in the USA for ant and scale control in orchards and grapes. However, they currently are only registered for use in Australia for use in non-cropping situations.
- In Custard Apple, Bignall (2014) reports that if ants can be properly managed, populations of scales and mealybug can be reduced by 80%. Ants move pests around on the trees, but more importantly prevent natural parasites and predators from controlling pests. Removing ants allow the parasites and predators to do their job. Control ants in December and, if necessary, again later in the season by spraying the lower trunk and the soil within a 0.5 m radius with fipronil ant control spray.

Ground Sprays

Chlorpyrifos (Lorsban) and Fipronil (Regent) ground sprays are effective at controlling ants but are not currently registered for use in orchards. These products are also highly toxic towards beneficial insects and will likely reduce their populations substantially, even if they are only applied to the ground. The custard apple industry currently has a permit for the use of Fipronil as a ground/trunk spray.

Great care should be taken in applying any product if trying to conserve predators, parasites and pollinators.

Biological Predators and Management

The use of beneficial insects to control pest insects is increasing as a viable management tool and certainly one that organic growers have embraced. A range of beneficial insects can help manage scale and mealybug pests, including some that are commercially available. As consumers are increasingly valuing the idea of clean and green produce, biological control options have an important part to play in managing pests. Predator insects can also be part of an integrated pest management (IPM) approach. That is, using predator insects in conjunction with targeted chemical application. In this case predator friendly (soft chemicals) should be used. If you are trying to preserve naturally occurring predators or those released into the orchard, it is not recommended to apply synthetic pyrethroids (e.g., Bulldock® - products from group 3A), organophosphate (e.g. Dimethoate® - Group 1B) and carbamate (e.g. Carbaryl® - group 1A) insecticides. Other products also have high toxicity to predators and parasites including neonicotinoids (group 4A).

Further information on how "predator friendly" some of your insecticides may be, is available from the vegetable industry[5]. In addition, some biocontrol agent producers have information available online regarding the side effects of insecticides and fungicides on predators, e.g. Biobest and Koppert.

Some of the most common beneficial insects in lychee producing regions in Australia include various species of parasitic wasps (see below), lacewing larvae and adults, *Chilocorus* and *Cryptolaemus* ladybird beetles.

Predators

Parasitic wasps

E.g., *Leptomastix* spp., *Encarsia spp., Aphytis* spp., *Anicetus* spp.

Description

- Many wasps are parasites of scales or mealybugs. Most are extraordinarily small and will not be seen except under a microscope on a yellow sticky trap.
- Aphytis wasps are efficient parasitoids of scale in citrus and passionfruit. The adults deposit their eggs in the adult scale. The larva that hatches consume the scale from the inside and then emerge through the shell of the scale.
- Parasitised scales will remain on stems and leaves after they are dead, like scales that have been killed by pesticides. Dead parasitised scales have small exit holes on their back after the parasite emerges.

[5] https://www.soilwealth.com.au/resources/articles-and-publications/new-guides-pesticide-effects-on-beneficials-in-vegetable-crops/

Image 23 Coccid scale (probably *Saissetia* sp. or *Parasaissetia* sp.) parasitised by *Coccophagus* wasp larva.

Image 24 Coccid scale insect nymphs parasitised by *Encarsia* wasp. Note the dark centre of the individuals that are normally yellowish.

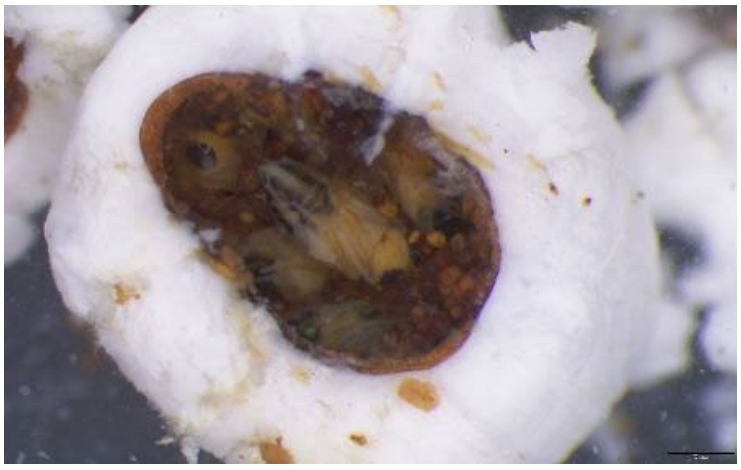


Image 25 Parasitised Indian wax scale (*Ceroplastes ceriferus*) with multiple parasitoid wasps visible through the exoskeleton.

Benefit

- Parasitic wasps lay their eggs in all developmental stages (eggs, larvae, nymphs, pupae, and adults) in a range of lychee pests.
- Wasp larvae feed and develop in the host, subsequently killing it.
- Adult wasps feed on the honeydew secretions of target hosts and nectar of flowers.

Lacewings

E.g., Green lacewing, *Mallada* spp., brown lacewing, *Micromus* spp.

Description

- Green lacewing
  - Green lacewing larvae are mobile and camouflage themselves by sticking the carcasses of their prey on their backs.
  - Adults are green-yellow in colour, 10—18 mm long, and have lacy see-through wings. Eggs are laid in groups on long stalks,
- Brown lacewing
  - Brown lacewing larvae are smooth with brown and white markings, and do not camouflage themselves.
  - Adults are pale brown with brown, speckled wings. Cream, oval eggs are attached singly to the underside of leaves.
- The addition of windbreaks containing flowering plants to increase the availability of pollen and nectar will assist in supporting multiple generation of lacewings and other beneficial predators.

Image 26 Green lace wing larvae that have recently hatched from eggs.

Benefit

- Effective predator.
- Feeds on many insects including mealybugs, scales, small caterpillar larvae and mites.
- Green lacewings are available commercially through Bugs for Bugs.

Ladybirds

E.g., *Cryptolaemus montrouzieri*, *Chilocorus circumdatus*

Description

- Adults of *Cryptolaemus* are 2—4 mm long and generally rounded in shape.
- *Cryptolaemus* is predominantly black, with a dark orange-red head.
- Larvae of *Cryptolaemus* grow to 13 mm, are white in colour with long waxy appendages. They appear superficially like mealybugs but are very mobile and, when turned over, legs and chewing mouthparts can be observed.
- *Chilocorus* is bright orange in colour
- *Chilocorus* larvae are yellow-brown with black setae (hairs).

Benefit

- Adults and larvae are voracious predators of scales, mealybugs, aphids, mites and eggs, and larvae of moths and butterflies. These predators are available through Bugs for Bugs - https://bugsforbugs.com.au/. If using them for the first time it is recommended to contact them to gain best advice on how to release for your orchard. Also ensure that broad spectrum pesticides have not be used as this can kill predator.

Your Lychee Field Guide and the links below offer further information and images of lacewings, ladybirds and parasitic wasps.

The key to good scale management is avoiding the use of broad-spectrum pesticides and creating the right environment in your orchard for beneficial insects to thrive. See the "*More Information and References*" section at the end of the toolkit for references and links to modifying your orchard to be predator friendly.

Oil and high potassium-salt soap sprays can be an effective tool as a soft option for helping reduce scale insect populations. Controlling ants is another way of assisting control.

Methods to preserve and encourage beneficial populations

Beneficials (predators, parasites and pollinators) have several requirements to survive and flourish. These include a food supply, correct environmental conditions and places to hide and rest. When there are sufficient pests in the crop, beneficials can flourish and grow to large numbers. However, when pests decrease in number it can be valuable to have alternative food sources nearby. Flowering plants present either in the growing area and in non-growing areas can provide places to rest and sources of pollen and nectar.

Image 27 *Cryptolaemus* larva feeding on mealybugs. These larvae can be confused with mealybugs.

Alternative food sources

The plant species used as alternative food sources can be important and will need to be altered depending on the geographic area of your business, the main pests at your business. Some commonly used species that are often used are those plants with small flowers that are present for extended periods, e.g., buck wheat, alyssum, Asteraceae flowers, with compact heads are excellent places for small beneficials to rest, hide and consume nectar and pollen if required. When using alternative food plants in non-cropping areas it is recommended to:

- Evaluate the use of different plant species that are suited to your climatic region and season that produce pollen or nectar. To assess their efficacy, monitor the species of insects and mites present over time. Preferentially choose plant species that have more beneficials and fewer pests.
- Grow plants in such a way that they can be easily removed or managed if they become infested with pests or diseases.
- Make a plan for your orchard for the types of plants that are effective in each season.
- Monitor the plants on a regular basis as part of normal scouting. Some plants may be effective sentinel plants for initial pest populations and increase beneficial populations.

Effect of pesticides on beneficials

Many pesticides are highly toxic to most beneficial species. In fact, sometimes even slight residues can cause high death rates on beneficial populations weeks (or even months) after application. In addition, some products can cause non-lethal side effects to beneficials, i.e., the beneficial remains alive but is impacted in other ways. This may include one or more of the following:

- It may not live as long.
- It may not lay as many eggs.
- It may not kill as many prey.
- It may not be as energetic or move around as often perhaps influencing its ability to survive harsh environmental conditions, escape predation etc.

Each beneficial has slightly different tolerances and susceptibilities to different pesticides. Even IPM compatible products may cause non-lethal deleterious effects in certain cases. The above negative impacts will be greater with more frequent pesticide applications. In addition, the negative impacts will be greater with increased concentration of the applied product.

Note that fungicides and other products applied to foliage can also negatively impact beneficial populations. A great deal of research is available online on the side effects of pesticides on biological control agents. Toxicity information is available through your local suppliers, mobile apps and online, e.g. those produced by Koppert and Biobest.

Actions to avoid negative pesticide side effects

As stated above, pesticides can negatively impact beneficial species. The following recommendations will minimise the amount of damage imposed on beneficial insect populations:

- Put in place as many cultural management actions as possible to prevent pest populations
- Monitor your crops regularly (preferably at least weekly) for pests, diseases and beneficial insects
- Only apply pesticides when pests are present and in numbers that will cause damage
- Spot spray pesticides in hot spot areas
- Avoid application of broad spectrum and highly residual products. In particular, older compounds tend to have greater negative effects including many compounds from the following groups. Note that there are exceptions, e.g., the active pirimicarb is a relatively safe aphidicide even though it is a carbamate compound.

- Carbamates (1A)
- Organophosphates (1B)
- Fiproles (2B)
- Pyrethroids (3A)
- Neonicotinoids (4A)

The negative effects of pesticides tend to be greater within protected cropping structures (e.g., polytunnels and glasshouses). Therefore, if highly residual and broad-spectrum products must be used, avoid using them within protected cropping structures. This is relevant for businesses that grow lychee nursery stock under protected cropping structures.

When product labels give a range of application rates against certain pests, e.g., 2-4mL/L, use the minimum rate to achieve a successful application. Higher rates of application produce greater negative side-effects. Therefore, use your experience or small trials to determine the lowest application rate possible to successfully kill pests that are present.

Calendar spraying versus use of scouting

Calendar spraying has long been rejected as a way of managing insect pests in orchards. The regular use of broad-spectrum insecticides is well documented to lead to insect resistance and the build-up of mites and scale.

Observation of non-orchard lychee trees usually reveals lots of activity including loopers, flower eating caterpillars, flush eating beetles and leaf miner but generally an absence of scale and mealybugs. This suggests that the natural predators can manage these pests. This management style may not be possible in commercial orchards.

Pest scouting is a well proven technique to management orchard spraying dependent on pest pressure and threshold damage limit. Ideally, scouting should be carried out by professional scouts who know their insect pests and predators and can recommend treatment options when required.

Best practice chemical control

Scale insects are difficult to manage using pesticides alone. Scales are most susceptible to chemical control when moulting and at the crawler stage. There are four permitted insecticides which can be used for scale and mealybug management in lychee; Summer/Pest Oils, Sulphur, Applaud® (active ingredient [a.i]. buprofezin) and Trivor® (a.i acetamiprid + pyriproxyfen). The active ingredients buprofezin (in Applaud®) and pyriproxyfen (in Trivor®) are both insect growth regulators which are most effective against juvenile stages.

Ideally, chemical scale control should be determined based on scouting data supplied by trained entomological consultants. Scale crawlers are susceptible to oil and soap-based products. Scale and mealybug (scales) are difficult to manage once protected by their hard and/or waxy covering.

Pest oils are most effective at the crawler stage. Rates will depend on the oil product used. Oils can burn so avoid applications during flowering and on mature fruit. Applications during the vegetative stage are ideal. Oils should be applied to healthy trees that are not stressed. Do not apply oils if the soil is dry and trees are suffering moisture stress; do not apply oils during hot weather (temperatures exceed 35˚C) or the shade temperature is expected to exceed 30˚C. Avoid application during slow drying conditions and avoid application for 4 weeks following the application of sulphur.

An organic alternative to oils is soap-based active ingredients. Natrasoap 285g/L potassium salts of fatty acid has a broad registration as a pesticide for the control of aphids, thrips, mealybug, two spotted mite, spider mite and whitefly in vegetables, fruit trees, pot plants and ornamentals. Complete coverage of the target insect is required, and the applications should be made in the morning or evening when temperatures are lower.

Both oil and high potassium soap-based sprays are effective at suffocating the crawlers.

Trivor® (a.i acetamiprid + pyriproxyfen) is a mixture of a hormonal growth regulator pyriproxyfen and the broad-spectrum contact insecticide acetamiprid widely used as a replacement for organophosphates and other older insecticides to control sucking type insects. Acetamiprid is a chemical in the neonicotinoid group of insecticides. The permit for instructions for mealybug and scale control indicate that application should be timed with the onset of crawler release and not on mature adult insects. Thorough and uniform coverage is required and no more than two applications should be applied per season and the application rate should not exceed 800 mL/ha per application. Growers report mixed results with Trivor®, this could be partly due to timing of the sprays or concentration used. Favourable results have been reported at rates in excess of 40 mL/100 L. This may be a matter of keeping in mind the discussion above on dilute versus concentrated sprays.

Sulphur sprays utilised for erinose mite control may also be effective on scale crawlers. The mode of action is BURN.

The last permitted product is Applaud® (Buprofezin 440 g/L). Applaud® is in the Thiadiazine chemical group and acts as an insect growth regulator (IGR) which acts by inhibiting chitin synthesis, interrupts moulting, suppresses oviposition & reduces egg viability. Vapor activity allows buprofezin to reach the undersides of leaves and new growth. Buprofezin has a low toxicity to beneficials and bees and hence is considered safe to use at or near flowering.

It is reported to have a high level of activity against most homopteran insect pests which includes whiteflies, mealybugs, soft scales, armoured scales, leafhoppers and planthoppers.

Bignall (2014) suggests that there are a few issues associated with the use of Applaud® that requires careful consideration. Because it kills juvenile insects when they moult, it is best applied when crawlers and young juvenile stages of the target pest are abundant, before too many adults are present as these will not be killed. The effects may take up to two weeks to become apparent, unlike knockdown insecticides, which kill pests very quickly. Applaud® may not be effective if it is applied when there are mixtures of crawlers and adults.

Insecticide resistance management

Insecticide resistance occurs from repeated use of products from the same mode of action (MoA) group. This causes a change in the sensitivity of a pest population resulting in a failure to achieve the expected level of control (at recommended label rates). Resistance can be passed on to offspring. Effectively this causes susceptible individuals to die, leaving behind resistant ones. Resistant individuals reproduce and result in a population with a relatively high proportion of resistant individuals.

Since the discovery of resistance in 1947, a pattern has developed often described as the ‘pesticide treadmill’. Products are released and applied consistently, leading to insecticide resistance and more frequent applications of the product. This in turn leads to greater levels of resistance until the product fails altogether. A new product is used, and the pattern starts again. Unfortunately, resistance to one pesticide MoA group can sometimes lead to resistance to pesticides of a different MoA.

The most effective method to reduce the likelihood of inducing insecticide resistance is to reduce the need to apply pesticides, by implementing as many cultural practices as possible. General practices include:

- Manage pest populations early by monitoring crop health regularly
- Check nursery stock for pests before planting
- Manage weeds proactively
- Grow resistant varieties, where possible
- Release biological control agents whenever possible
- Apply pesticides when a pest population will likely result in damage, but otherwise avoid applications

Pesticides are the main method to reduce pest populations quickly and avoid economic loss from high pest populations. If a pesticide must be applied, it is important to have a basic understanding of the pest lifecycle. The generation time is particularly important as is knowledge of vulnerable/tolerant life stages. The following recommendations will reduce pesticide resistance:

- Apply pesticides to the most vulnerable stage. In general, early-stage immature insects are the most vulnerable to insecticides (just after hatching). For scales, crawlers are most susceptible. Do not assume that all stages of an insect can be effectively managed with an insecticide, even if the species is on the label without specifying a particular stage.
- Some labels have a pesticide resistance management strategy included. Always follow these instructions.
- Apply the full recommended rate. Using a low dose can increase pesticide resistance; individuals with low level resistance survive and may give rise to greater resistance in the future.
- Ensure good coverage to increase the chance of contacting the pest and achieve best efficacy.
- Maintain pesticide application equipment regularly, e.g., calibration of equipment, cleaning equipment, replacing nozzles as required.
- Apply pesticides using best management practice guidelines.
- Avoid applying broad spectrum pesticides that kill predators and parasites whenever possible.
- Do not continue to apply chemicals from a MoA group that has possibly failed due to pesticide resistance.
- Alternate/rotate between chemistries, as per section below.

Rotation/Alternation of Insecticides

Regular use of one pesticide chemistry (MoA) will increase the risk of resistance. Using products from multiple MoAs can reduce this risk substantially and can be achieved in several different ways. It is critical to reduce exposure of consecutive pest generations to the same insecticide MoA. For this reason, rotation scheduling can vary depending on the pest lifecycle.

For pests with a *short generation time*, it can be beneficial to employ a 'window' approach, in which the same product is applied on 2-3 consecutive occasions within the timespan of one pest generation. Depending on the pest and environmental conditions this could be over a week or month. Then for the next generation, apply an insecticide from a different MoA and continue this approach until pesticides are no longer required. However, exceptions occur. Some strategies recommend rotating to a different MoA after each application, i.e. to never apply sequential applications from any one MoA.

For pests with a relatively *long generation time*, e.g., months, it is critical to understand the lifecycle of the pest to apply insecticides during the vulnerable stage (which is often before damage is obvious). It is recommended to apply pesticides from different MoA's sequentially, if required.

Insect scouting

Insect scouting is an important part of integrated pest management. Where available, the services of a professional trained scout should be considered by producers who have 2,000 trees plus. As a tropical/sub-tropical fruit orchardist it is likely that you grow several different species besides lychee for example mango, avocado or macadamia etc. To competently scout all crops is nearly a full-time job, hence our suggestion is to use the services of a professional pest scout.

Where access to trained personnel is not possible or you prefer to carry out the activity yourself, you will need some basic equipment and skills.

Suggested Equipment:

- Hand lens (x10 or better magnification)
- Click counter
- Smart phone camera with clip-on lens magnifier

- Lychee Field Guide to assist with identification of pest insects, beneficials and/or exotic pests
- Beat sheet (cardboard or dark plastic sheet to act as a backdrop for insects shaken from leaves, flowers or fruit)
- Block/Pest record data sheet. This is the tried and tested old fashion way. But it works! A number of options are also available online and you can use your smartphone to enter data.
- Sample bags (paper and plastic) and specimen jars for insect specimens that you cannot identify
- Flagging tape to identify hotspots

Technique

Sampling a large orchard block to get a realistic feel for insect pressure in the block can be a time-consuming exercise. Within a block of trees, random sampling is an often-suggested technique. Random sampling gives each tree an equal chance of being selected and ensures that a representative sample of the entire block is taken. However, this is difficult to do. One suggested method is walk/drive through your orchard using the ABC logo as a movement map and sample every “x” trees based on a 2 to 5% sampling rate (L. Wittenberg pers com. 2022). For a 1,000-tree block, that is 20 and 50 trees respectively or a stop at every 50 or 20 trees. For mango the suggested sampling rate is 10% or 10 trees per 100 (Chin et al. 2010).

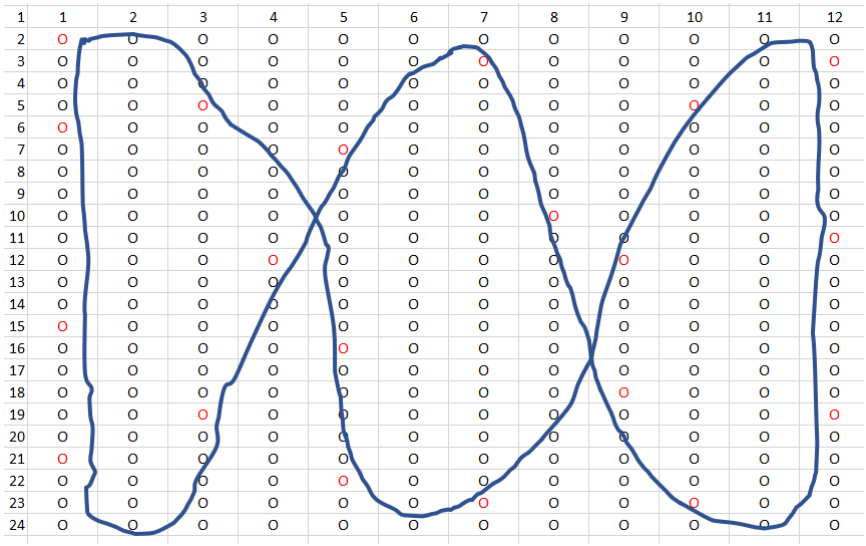


Image 28 Suggested sampling pattern (red dots) for random tree scouting in a 288-tree orchard

Sampling more trees leads to a better representation of what is happening in the block, the downside is the additional time required. A few monitoring suggestions from the mango industry (Chin et al. 2010) for lychee growers to consider.

- Divide the orchard into blocks of 100 trees.
- Monitoring is especially important prior to flowering and during the flowering and fruiting periods. Monitor 10 trees per 100 trees (10 per Ha) at weekly intervals or every 2-3 days during flowering as caterpillars can cause extensive damage in a short time. For orchards with more than 500 trees, set aside at least 1-2 hours per week for monitoring.
- Individual trees selected for monitoring are chosen at random, ensuring that a reasonable coverage has been made of the fruit trees on the edges and within the orchard.
- Suggested sampling technique for each randomly selected tree:
  - most insects are found on the flush, flowers and fruit rather than old shoots
  - focus the general sampling area on the new shoots, flower panicles or fruit unless you are inspecting the tree for borers or termites
  - sample the four compass points per tree North, South, West and East

  - it is easier to sample at head height, however, be aware of pests that are also on foliage lower and higher than head height

- Record information as shown on a monitoring sheet or notebook.
- The insect action level is the pest population density at which control is recommended. Refer to insect action levels in your Lychee Field Guide.

The problem is that insects are not necessarily random when they move into an orchard. Your experience with the pest and your block will be an important input into your scouting technique. The “Lychee Field Guide” contains advice on action levels for insect pests. For Mealybugs and Scale the Chemical control action advice is “check 20 trees spaced throughout the block. Control when 5% or more of 5 sample leaves, stem or fruit are infested with 5 or more scale”.

The important aspect of scouting is to record your findings and flag areas that are considered hotspots. Keeping records over successive years enables you to understand when specific pests usually become problematic, where particular hotspots occur (there are usually parts of the orchard more prone to certain pests than others), and what management methods have been effective (or not) in the past.

Introduced nursery stock can introduce scale and mealybug to your property. Growers should organise inspection of new nursery stock thoroughly, particularly if purchased off-farm, and treat new stock to achieve scale and mealybug control prior to transfer and field planting. This is particularly important if nursery stock is acquired from nurseries remote from your growing region. See Table 5 for details of allowable insecticides for the treatment of new planting material.

In Field Chemical control strategies used by other major (mango) and minor (persimmon and custard apple) industries

Chemical control strategies for scale and mealybug utilised by other, similar fruit industries can act as a guide as to what the lychee industry could add to their arsenal, via the application for permits and or chemical registration.

Mango

Registered: Imtrade Patriach® RMR™ Insecticide (a.i. pyriproxyfen + piperonyl butoxide); Chlorpyrifos 500 (ai. Chlorpyrifos); Spirotetramat 240 SC (a.i. spirotetramat); Pyriproxyfen 100 EC (a.i. Pyriproxyfen); ACP Pickup 440 (a.i. buprofezin); DC Maxx C24 (a.i. paraffinic oil); Summer Spray Oil (a.i. petroleum oil); Trivor® (a.i. acetamiprid + pyriproxyfen); Conquer (a.i. imidacloprid); Carbaryl 500 (a.i. carbaryl).

Custard Apples

Permits: Transform® (a.i. Sulfoxaflor); Samurai® (a.i. clothianidin) and Fipronil for use as an ant bait/spray.

Persimmons

Permits: Petroleum oil, chlorpyrofos, Mainman (a.i. flonicamid)

Post-Harvest Management using a High-Pressure Wash

The microscopic fauna that is present on all fruit includes mites, scale, and relatives and potentially insect eggs, larvae and crawler stages. Most mites found and identified during the study are either predators or benign and potentially useful feeders of detritus and fungal hyphae. Regardless of the level of their benevolence, mites are easily dealt with using the high-pressure wash technology reported here.

Based on project work conducted as part of LY18000 we know that high pressure washing fruit as part of the post-harvest packing line will remove up to 90% of mites and 60% of scale and mealybugs. Monitoring of export shipments to the USA particularly from sheds incorporating a high-pressure wash in their packing lines confirm the success of the technique.

Limiting insects and mites on fruit requires pre- and post-harvest management inputs. The following recommendations are made.

- Undertake pre-harvest pest management to control surface pests including mites and scale relatives. The surface insect and mite load on fruit is an important factor to consider as part of producing fruit suitable for export to quarantine markets. Australian lychee growers produce fruit to a high standard under HACCP programs and in country movement is managed under the Interstate Certification Assurance program to ensure that pest free fruit are produced and marketed.
- Select clean fruit with a low pest load for treatment and subsequent export.
- Wash fruit, high volume spray to waste, at the start of the packing line to remove dust, surface pests and plant residues on fruit.
- Install a high-pressure wash (HPW) system with the following elements to consider.
  - **Maximise the time fruit are exposed to high pressure spray.** Ideally fruit are exposed for a sufficient time to ensure that the entire fruit surface is exposed directly to high pressure water. Based on the limited systems evaluated, 10 to 12 second exposure results in a working solution. Slower moving rollers on wide conveyor systems (1.0 m plus) are better suited to longer exposure times while maintaining sufficient throughput.
  - **The recommended operating pressure of the HPW system.** Work conducted during the 2018/19 season and in the 2019/20 season showed that 650 kPa is operationally useful. Operating pressures up to 1200 kPa are possible without damaging fruit but they are unlikely to improve the efficacy of the treatment.
  - **Number and type of nozzles.** Effective spray coverage is essential to maximise the benefits of a HPW system. The best HPW manifold system has 36 nozzles (18 pairs of nozzles) operating over a roller conveyor bed area (1.0 m wide and 0.9 m long). Flat fan nozzles with a flow rate of 3.5 to 4.0 L/min appear to work well.
  - **Spray to waste or recirculate.** Ideally the HPW system will operate on a spray to waste basis to avoid the build-up of pathogens over time (Olesen, Wiltshire and McConchie, 2003). The ability to incorporate a spray to waste system is beyond the water supply assets of many lychee grower/pack sheds. If recirculating water through the HPW special care will need to be taken with filtration and regular changes of water and potentially the addition of chlorine or alternative disinfectants. The incorporation of a pre-wash and post wash manifolds which spray to waste may assist in reducing pathogen loads.

Example High Pressure Spray Unit details

Unit A

- Internal/External dimensions: External 1500mm x 1000mm. Internal spray area 1250mm x 1000mm
- Number of rows of sprays and distance apart: 8 rows (PVC) 170mm apart. Nozzles are 190mm apart and distance from nozzle bottom to PVC rollers is 160mm.
- Number of sprayers in each row: 5 nozzles per row
- Type/brand of spray nozzle: XR Teejet 110 degrees 04VP Red Colour
- Operating pressure: Between 85 to 115 PSI
- Pump details: Davey VM10-8H3 Multistage 3KW 3 Phase Pump
- Filter details: 50mm Rivulus Semi Auto Self-cleaning screen filter, 120 mesh (130 micron)

Your feelings on the usefulness or otherwise of the unit:

"Never want to be without it again. Plan was to use it only for USA exports but ended up washing all my fruit. It does a wonderful job on the residue that Flatids leave on the fruit. The high-pressure sprayer cleans fruit and speeds up the grading process."

What would you change if you were building again?

"The washer is at an angle like an elevator. If I build it again, I would lift the bottom end a bit higher off the ground. It is only 200mm from the ground and it is pretty tight when you want to clean the trays every afternoon after packing."

HPW PVC roller conveyor

HPW assembly added

Image 29 Unit A: High Presser Washer PVC roller conveyor (left) assembly added (right)

	
Pump and filter	Fruit entering the HPW
	
Fruit in the HPW	View at the top and exit point from the HPW. Fruit exit under an air blast to remove excess water before the grading conveyor.

Image 30 Unit A: High Presser Washer fruit process

Unit B

- Internal/External dimensions: External 2300mm x 1100mm. Internal spray area 1800mm x 900mm
- Number of rows of sprays and distance apart: 8 rows (PVC) 180mm apart. Nozzles are 180mm apart and distance from nozzle bottom to PVC rollers is 190mm.
- Number of sprayers in each row: 4 nozzles per row
- Type/brand of spray nozzle: XR Teejet 110 degrees brown colour
- Operating pressure: 110 PSI
- Pump details: Davey VM-10-2/3 Multistage
- Filter details: 50mm Rivulus Semi Auto Self-cleaning screen filter, 120 mesh (130 micron)

Your feelings on the usefulness of otherwise of the unit:

"A necessary tool for export fruit. Running the system at 50-70 psi does a very good job at cleaning fruit for the domestic market."

What would you change if you were building again?

"Probably wouldn't change anything as I am pretty happy with the system."

Comment: The HP sprayer is water hungry.

"When recycling water through the high pressure sprayer, you need to have a good pre-wash and filter system in place to deal with the incredible load of leaf, stalk, flower and dust that comes with the fruit out of the orchard."

Fruit elevator and primary wash

Fruit leaving the elevator – down and to the right into the HPW

View of fruit transfer from elevator to HPW

HPW primary filter when recirculating water

Image 31 Unit B: Primary fruit wash process pre-High Presser Washer

	
System view – HPW prior to hydrocooler	32 nozzle unit (8 rows x 4 nozzles per row)
	
Fruit exiting the HPW into the hydrocooler	Fruit exit the hydrocooler, under an airblast to remove excess water and onto the grading conveyor.

Image 32 Unit B: High Presser Washer fruit process

More Information and References

References

Bignall, G. (2014). Accelerating the Development of the Australian Custard Apple Industry. Final report. HAL Project Report CU11000

Chin D. et al. (2010). Field Guide to Pests, Beneficials, Diseases and Disorders of Mangoes. NT Government.

Diczbalis, Y (2020). Mite and insect disinfestation of lychee fruit using high pressure water sprays. Horticulture Innovation, Project (LY1800) Final Report.

Dodds, K and Fearnley, J. (2020). Orchard plant protection guide for deciduous fruits in NSW 2020-21.

Held, D. (2019). Controlling Scale Insects and Mealybugs. Extension Alabama A&M & Auburn Universities.

Senior, L. (2012)– Scoping Study: managing options for mealybug in persimmons. Hort Innovation – PR11000. *Provides useful background information to scale and mealybug management.*

Spray application, Insect and Predator management information sources

The good bug book (second edition) is a valuable reference for the beneficial organisms commercially available for biological control in Australia. It includes illustrations as well as tables of information on their susceptibility to pesticides and is published by Integrated Pest Management Pty Ltd for the Australasian Biological Control Association Inc. It can be purchased from the website: https://bugsforbugs.com.au/product/ good-bug-book-cd/

Spray Sense leaflet series - Spray Sense is a series of leaflets which focus on providing up-to-date information on a range of pesticide issues. Everyone who is involved in the manufacture, sale, distribution, use and provision of advice is encouraged to use this information to apply pesticides more effectively. https://www.dpi.nsw.gov.au/agriculture/chemicals/spray-sense-leaflet-series .

Bugs for Bugs Predator Insect Technical Information Notes

- *Chilocorus* beetle - https://bugsforbugs.com.au/wp-content/uploads/Tech-sheet-Chilocorus-150920.pdf
- Lacewing - https://bugsforbugs.com.au/wp-content/uploads/Tech-sheet-Lacewings-150920.pdf
- *Cryptolaemus* beetle - https://bugsforbugs.com.au/wp-content/uploads/Tech-sheet-Cryptolaemus-150920.pdf

Pest management in orchards - The future of IPM (treefruit.com.au)

Orchard environment and IPM information sources.

Orchard habitat management to enhance IPM systems - Microsoft Word - AP00033.doc (horticulture.com.au)

Recommendations for native vegetation selections in horticultural landscapes - Recommendations for native vegetation selection in horticultural landscapes - BioResEd

Improving soil health, pollination and pest regulation in lychee orchards with managed vegetative diversity - – what to do and how to do it - Lychees050722.pdf (bioresed.com.au)

Links to providers of beneficial insects and other IPM services and entomological equipment suppliers.

Australian Entomological Supplies https://www.entosupplies.com.au/

Queensland

- BioResources Pty Ltd - http://www.bioresources.com.au/ or Home - BioResEd
- Bugs for Bugs - http://www.bugsforbugs.com.au/

New South Wales

- BioWorks Pty Ltd - http://www.bioworksonline.com.au/
- Ecogrow (suppliers of beneficial nematodes) - http://www.ecogrow.com.au/

Victoria

- Organic Crop Protectants (OCP) Suppliers of insect traps and lures, organic spray oils and insecticides, fruit fly bait - https://ocp.com.au/product/insect-tech-range/

South Australia & Western Australia

- Biological Services - https://biologicalservices.com.au/

Note that some biological control agent producers also have products/beneficial insects suitable for Lychee growing regions, even though they are based in other states.

Links to Horticulture Scout contacts

Crop Consultant Queensland - https://cropconsultantsqld.org.au/
LW Crop Services, Leonie Wittenberg, leoniewittenberg@westnet.com.au

Lychee Scale and Mealybug checklist

☐I understand the pest problem and know what to look for

☐I monitor my orchard or engage a professional pest scout

☐I respond to action thresholds

Table 4 Lychee Pest and Disease Registered and Permitted Chemicals as of September 2022

Disclaimer: This information is not a replacement for APVMA Permits and Labels. Please reference these before use. Reference using the Australian Pesticide and Veterinary Medicines Authority (APVMA) website https://portal.apvma.gov.au/home Click Product Search or Permit Search and enter lychee or litchi

Pesticide Common Name	Pesticide Type & Chemical Group	Active Ingredient/s	Pests	Registered or Permit (PERxxxxx)	Application Rate	Method of Application	Application recommendations/ Comments	WHP (days)	USA Registered
Insecticides/Miticides									
Applaud®	Insecticide Group 16	440 g/L Buprofezin	Scale (Coccidae, Diaspididae & Eriococcidae), Mealybugs (Pseudococcidae) and Hardis	PER 86401	30-60 ml/100L	Foliar	2 sprays 14 to 21 days apart when nymph and crawlers present. Avoid petroleum oil within a month of sulphur application	14	Yes
Apparent Sulfur®	Fungicide/Miticide Insecticide Group M2 Fungicide	800 g/kg Sulphur	Eriophyid Mite and white louse scale (Unaspis citri)	PER 91169	400 g/ 100 L	Foliar	Apply before growth flush and after 14-21 days until all new growth damage free	No WHP	Yes
Batavia summer insecticide® plus other registered products*	Insecticide	815-861 g/L petroleum oil	Green Shield Scale (Pulvinaria psidii), Soft Green Scale (Coccus viridis) and Soft Scale (Coccidae)	PER91166	1.2 L/100 L	Foliar	Apply from before panicle emergence to when fruit is 15 mm in diameter. High volume. No more than 4 sprays per season with a minimum of 21 days apart. Avoid overlaps of Sulphur and oils within 1 month of each other	1	Yes
Intrepid®	Insecticide Groups 4A/7c	106 g/L acetamiprid + 124 g/L pyriproxyfen	FSB, Fruit Fly, Mealybugs and Scale, Hardis	PER89945	40 ml/100 L or 800 mL/ha	Foliar	Apply at crawler stage spring or early summer. Max 2 applications 14 + days apart. Do not apply during flowering	28	No

☐I know what chemicals I can use

☐I have added a HPW unit into my pack line to disinfest fruit

☐I talk to my fellow lychee growers to discuss pest problems

Lychee Orchard Spraying

Overview

This guide is designed to assist lychee growers to set up their sprayers based on a combination of spray efficacy and drift management principles. It provides a brief overview of the adjustment, use and basic calibration of lychee orchard air displacement sprayers.

These sprayers are known by various descriptions including Misters, Mistblowers, Fan Sprayers and Air Blast Sprayers.

While the principles of operation may vary, the aim of effective spraying is to apply the required dose of pesticide to the target.

Thanks to HARDI, SILVAN and CROPLANDS for the photos and associated contributions.

Contents

Hort Innovation
Strategic levy investment

LYCHEE FUND

Australian Lychee Growers Assoc. ALGA

Queensland Government

The Department of Agriculture and Fisheries funds extension services in the reef catchment through the Queensland Government Reef Water Quality Program.

How do orchard sprayers work?

In all instances you are trying to displace air within the canopy with air containing pesticide droplets.

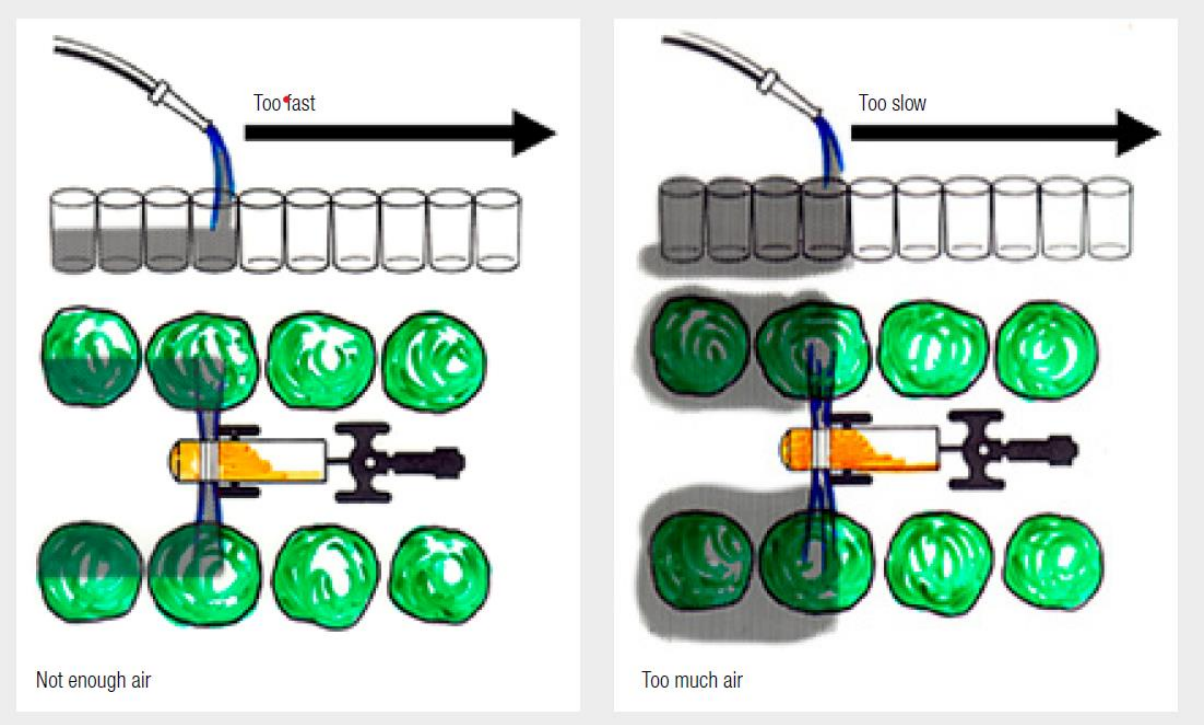
There are two (2) fluid systems at play when these machines are operating.

1. **Air produced by the fan. (Air Displacement)**
2. **Liquid producing droplets from a pump and nozzles.**

Both liquids are important and the combination of both is the basis of a successful spray job.

1. Air displacement

Consider the following diagram.



Think of air displacement as a hose filling glasses of water. If you go too fast you don't fill the glass enough (Not enough air displacement). If you go too slow (you overfill the glass) and will blow chemical through the canopy which is a loss of pesticide as well as being environmentally unsound (too much air displacement).

The correct air displacement is a function of air volume produced by the fan and forward speed of the sprayer. There are two main types of fans used in orchard spraying.

Axial flow fans are high volume fans used in air blast sprayers. These units typically produce air volumes around 30000 to 80000 cubic metres of air per hour at low air speeds of 20 to 40 metres per second. These machines usually have adjustable blades up to 45 degrees. The higher the blade angle the more power is consumed. By design, these fans usually push more air on one side over the other. Features such as straightening vanes help prevent this effect.

Above. A HARDI® axial flow “Jupiter” air blast sprayer

Centrifugal fans produce high air speed, 30 to 100 metres per second lower volumes of air around 5000 to 20000 cubic metres per hour. These fans are associated with air shear or pneumatic “misters” and hydro pneumatic sprayers where a more directed localised air flow is desirable.

Above. SILVAN® centrifugal fan “Turbomisers”. 3-point linkage unit on the right showing fan.

Croplands Quantum®

Micronair® Au 8120 attached to air blast sprayer.

Alternatives to the traditional orchard sprayers include Croplands Quantum® sprayers which give a more directed air flow and Micronair® rotary CDA atomisers which replace the hydraulic nozzle array resulting in lower water volumes per hectare.

All machines can perform very well in lychee orchards. There are some easy activities which can be done to evaluate your sprayer and optimise its efficiency. You will need an assistant.

Test the air flow.

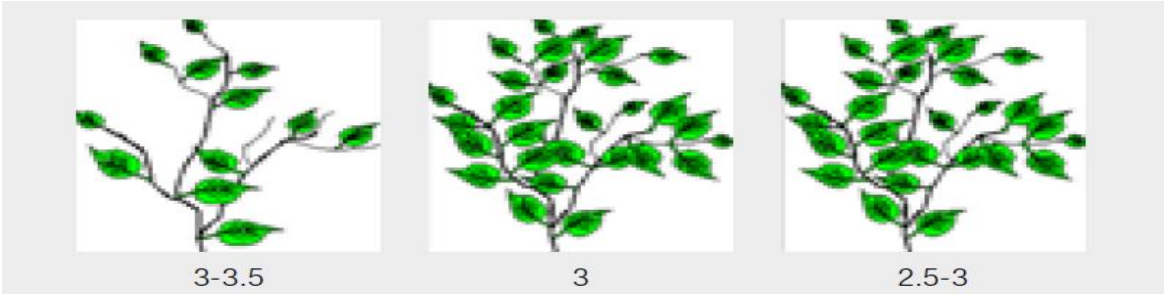
(a) The easiest method is to use flagging tape and somebody who is young and athletic. Simply attach 300 mm to 800 mm pieces tape with staples throughout the tree on the inside as well as on the outside of the canopy.
(b) If the fan blades are adjustable start at around 45 degrees. Run the sprayer at 540 PTO speed. If the tractor is having difficulty, then reduce the fan angle to about 35 degrees and/ or change the fan speed to low if the sprayer has a gearbox.
(c) Try various forward speeds starting at 3Kph up to about 7Kph. Don't forget to record your data and sprayer settings.
(d) You are looking for some movement of the flagging tape in the most protected parts of the tree. E.g., High in the canopy, opposite side of the sprayer behind the trunk and just inside the of the canopy. Ensure that there is not too much air. If you are having violent movement at the top of the canopy, then you are displacing too much air and pushing chemical through the tree canopy and out into the interrow area.
(e) Try different ground speeds and fan angles and record your settings. Take time to do this properly as it is critical to good spray technique.
(f) Check for "Shingling". This is where the leaves will overlap to form an impenetrable wall. The flagging tape placed inside the canopy should show this. If the shingling is severe then some sort of laminar flow disruption device may need to be attached to the sprayer. This can be common on some towers and side conveyers. A few angled vanes attached to the air outlet side of the tower usually fixes the problem. You may want to adjust volutes or air direction devices in towers or side conveyers as well.
(g) Below are some formulas provided by HARDI A/S Denmark on calculating air volumes. Use a leaf factor of 2.5 for Lychee.

$$\frac{\textbf{1000} \times \textbf{Speed (km/h)} \times \textbf{Spray width (m)} \times \textbf{Tree height (m)} = \textbf{Air volume (m}^3\textbf{/h)}}{\textbf{3 (Leaf area factor*)}}$$

* For light foliage use factor 3.0 to 3.5. For dense foliage use factor 2.5 to 3.0

If the air volume is known, the following formula is a guide for maximum speed:

$$\frac{\textbf{Fan output (m}^3\textbf{/h)} \times \textbf{3 (Leaf area factor*)} = \textbf{Speed (km/h)}}{\textbf{1000} \times \textbf{Spray width (m)} \times \textbf{Tree height (m)}}$$



Foliage factor. Use 2.5 for Lychee.

(h) When you are happy with the air displacement then move on to the pumps, pressure, and nozzles.

2. Producing droplets

Pumps and pressures

Various high pressure diaphragm and piston pumps are used in air blast sprayers where hydraulic pressure is used to create the droplets. Pressures around 10 bar are common, although some nozzles will produce an adequate droplet spectrum a low a 3 bar pressure. Ensure you have an accurate pressure gauge.

Regarding air shear pneumatic and CDA sprayers, low pressures of 1 to 3 bar is generally the rule. Pumps are of the low pressure type and flow rates will vary depending on the machine. Always read the manufacturer's instructions.

In all cases ensure that the pump intakes are clear, and filters are not blocked and of the mesh size recommended. Fill the spray tank with clean water with maximum bypass circulation operating. This is particularly important when using solid formulations such as wettable powders and water dispersible granules.

Nozzles and nozzle placement

As a rule of thumb smaller droplets mean better coverage and higher pressures produce smaller droplets. Although this statement is still valid there are situations where droplets under 100 microns can cause excessive drift under low humidity and high temperatures. In recent years, nozzle manufacturers have concentrated in narrowing the droplet spectrum, so droplet size is less affected by pressure. In fact, pressure can be associated with spray volume and less with droplet size on some of the newer nozzles.

Hollow cone and to a lesser extent flat fan nozzles are those usually fitted to sprayers that use hydraulic pressure to produce droplets. Below is the nozzle flow chart for the popular Albuz® ceramic hollow cone. These nozzles produce fine to very fine droplets ideal for contact insecticides and protectant fungicides where coverage is important.

bar	l/mn									
	WHITE	LILAC	BROWN	YELLOW	ORANGE	RED	GREY	GREEN	BLACK	BLUE
5	0.27	0.36	0.48	0.73	0.99	1.38	1.50	1.78	2.00	2.45
6	0.29	0.39	0.52	0.80	1.08	1.51	1.63	1.94	2.18	2.67
7	0.32	0.42	0.56	0.86	1.17	1.62	1.76	2.09	2.35	2.87
8	0.34	0.45	0.60	0.92	1.24	1.73	1.87	2.22	2.50	3.06
9	0.36	0.48	0.64	0.97	1.32	1.83	1.98	2.35	2.64	3.24
10	0.38	0.50	0.67	1.03	1.39	1.92	2.08	2.47	2.78	3.40
11	0.39	0.52	0.70	1.07	1.45	2.01	2.17	2.58	2.90	3.56
12	0.41	0.55	0.73	1.12	1.51	2.09	2.26	2.69	3.03	3.71
13	0.43	0.57	0.76	1.17	1.57	2.17	2.35	2.79	3.14	3.85
14	0.44	0.59	0.79	1.21	1.63	2.25	2.43	2.89	3.26	3.99
15	0.46	0.61	0.81	1.25	1.69	2.33	2.51	2.99	3.36	4.12
16	0.47	0.63	0.84	1.29	1.74	2.40	2.59	3.08	3.47	4.25
17	0.48	0.64	0.86	1.33	1.79	2.47	2.67	3.17	3.57	4.37
18	0.50	0.66	0.89	1.37	1.84	2.54	2.74	3.25	3.67	4.49
19	0.51	0.68	0.91	1.40	1.89	2.60	2.81	3.34	3.76	4.61
20	0.52	0.70	0.93	1.44	1.94	2.67	2.88	3.42	3.85	4.72

Albuz® hollow cone nozzle flow chart

Albuz® hollow cone and Teejet® TX hollow cone nozzles are a very good choice when applying protectant fungicides and contact insecticides

		l/min																			
		2 bar	3 bar	4 bar	5 bar	6 bar	7 bar	8 bar	9 bar	10 bar	11 bar	12 bar	13 bar	14 bar	15 bar	16 bar	17 bar	18 bar	19 bar	20 bar
TX-VS1	100	0.055	0.065	0.074	0.081	0.087	0.093	0.098	0.103	0.108	0.112	0.116	0.120	0.124	0.127	0.131	0.134	0.137	0.140	0.143
		VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VS2	100	0.110	0.131	0.148	0.164	0.177	0.189	0.201	0.211	0.221	0.231	0.240	0.248	0.256	0.264	0.272	0.279	0.286	0.293	0.299
		VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK3	100	0.164	0.196	0.223	0.245	0.266	0.284	0.301	0.317	0.332	0.346	0.359	0.372	0.384	0.396	0.407	0.418	0.429	0.439	0.449
		F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK4	50	0.218	0.262	0.299	0.331	0.360	0.386	0.410	0.433	0.454	0.474	0.493	0.512	0.529	0.546	0.562	0.578	0.594	0.608	0.623
		F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK6	50	0.327	0.393	0.448	0.496	0.539	0.579	0.615	0.649	0.681	0.711	0.740	0.767	0.794	0.819	0.844	0.867	0.890	0.912	0.934
		F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK8	50	0.433	0.525	0.603	0.671	0.732	0.788	0.840	0.888	0.934	0.978	1.02	1.06	1.10	1.13	1.17	1.20	1.24	1.27	1.30
		F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK10	50	0.541	0.657	0.753	0.838	0.915	0.985	1.05	1.11	1.17	1.22	1.27	1.32	1.37	1.42	1.46	1.50	1.55	1.59	1.63
		F	F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK12	50	0.649	0.788	0.904	1.01	1.10	1.18	1.26	1.33	1.40	1.47	1.53	1.59	1.65	1.70	1.75	1.81	1.86	1.90	1.95
		F	F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK18	50	0.968	1.18	1.37	1.53	1.67	1.80	1.93	2.04	2.15	2.25	2.35	2.45	2.54	2.63	2.72	2.80	2.88	2.96	3.03
		F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TX-VK26	50	1.40	1.71	1.97	2.20	2.41	2.60	2.78	2.95	3.11	3.26	3.40	3.54	3.67	3.80	3.92	4.04	4.16	4.27	4.38
		F	F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF

Teejet TX nozzle flow chart

Below is the flow chart for Teejet TP nozzles. These are high pressure rated 80 degree flat fans similar to XR Teejet. Droplets are generally larger than hollow cones at any given pressure and may be useful in taller trees where the higher sedimentation rate could produce better coverage and less drift. Some Avocado growers report good results with these nozzles although they can be difficult to source.

		l/min																		
		2 bar	3 bar	4 bar	5 bar	6 bar	7 bar	8 bar	9 bar	10 bar	11 bar	12 bar	13 bar	14 bar	15 bar	16 bar	17 bar	18 bar	19 bar	20 bar
TP8001VK	100	0.32	0.39	0.45	0.50	0.55	0.60	0.64	0.68	0.71	0.75	0.78	0.81	0.84	0.87	0.90	0.93	0.96	0.98	1.01
TP80015VK	100	0.48	0.59	0.68	0.76	0.83	0.90	0.96	1.02	1.08	1.13	1.18	1.23	1.27	1.32	1.36	1.40	1.45	1.48	1.52
TP8002VK	50	0.65	0.79	0.91	1.02	1.12	1.21	1.29	1.37	1.44	1.51	1.58	1.64	1.71	1.77	1.82	1.88	1.94	1.99	2.04
XR8003VK	50	0.96	1.18	1.36	1.52	1.67	1.80	1.93	2.04	2.15	2.26	2.36	2.46	2.55	2.64	2.73	2.81	2.89	2.97	3.05
XR8004VK	50	1.29	1.58	1.82	2.04	2.23	2.41	2.58	2.74	2.88	3.03	3.16	3.29	3.41	3.53	3.65	3.76	3.87	3.98	4.08
XR8005VK	50	1.61	1.97	2.27	2.54	2.79	3.01	3.22	3.41	3.60	3.77	3.94	4.10	4.26	4.41	4.55	4.69	4.83	4.96	5.09
XR8006VK	50	1.94	2.37	2.74	3.06	3.35	3.62	3.87	4.10	4.33	4.54	4.74	4.93	5.12	5.30	5.47	5.64	5.81	5.96	6.12
XR8008VK	50	2.58	3.16	3.65	4.08	4.47	4.83	5.16	5.47	5.77	6.05	6.32	6.58	6.83	7.07	7.30	7.52	7.74	7.95	8.16

Above Teejet TP nozzle flow chart

Some new sprayers still come equipped with the ceramic disc core nozzles. These nozzles can perform quite well when the correct disc and core are used. They produce medium to very fine droplets depending on pressure. Notice how the nozzle spray angle increases with pressure.

Hollow Cone Type Spray Tips

		mm	l/min												
			0.7 bar	1 bar	2 bar	3 bar	4 bar	5 bar	6 bar	10 bar	15 bar	20 bar	1 bar	10 bar	20 bar
D1	DC13	0.79	—	—	0.22	0.26	0.29	0.32	0.34	0.43	0.50	0.57	—	66°	68°
D1.5	DC13	0.91	—	—	0.25	0.29	0.33	0.36	0.39	0.48	0.56	0.63	—	70°	72°
D2	DC13	1.0	—	0.22	0.29	0.33	0.37	0.41	0.44	0.53	0.63	0.70	41°	74°	75°
D3	DC13	1.2	—	0.24	0.30	0.35	0.41	0.44	0.48	0.59	0.68	0.77	45°	77°	78°
D4	DC13	1.6	0.27	0.31	0.40	0.47	0.53	0.59	0.63	0.76	0.89	1.0	64°	84°	85°
D1	DC23	0.79	—	—	0.24	0.28	0.32	0.34	0.38	0.46	0.54	0.61	—	63°	65°
D1.5	DC23	0.91	—	—	0.28	0.34	0.39	0.42	0.46	0.58	0.69	0.78	—	66°	67°
D2	DC23	1.0	—	0.28	0.37	0.43	0.49	0.53	0.57	0.70	0.83	0.93	43°	72°	72°
D3	DC23	1.2	0.25	0.29	0.39	0.46	0.52	0.58	0.62	0.78	0.93	1.1	56°	77°	77°
D4	DC23	1.6	0.32	0.37	0.51	0.61	0.70	0.77	0.83	1.1	1.3	1.4	62°	88°	88°
D5	DC23	2.0	0.37	0.44	0.59	0.72	0.82	0.91	0.98	1.3	1.5	1.7	73°	96°	95°
D6	DC23	2.4	0.42	0.50	0.69	0.83	0.95	1.1	1.2	1.5	1.8	2.0	79°	100°	99°
D1	DC25	0.79	—	—	0.33	0.40	0.45	0.50	0.54	0.69	0.83	0.95	—	49°	51°
D1.5	DC25	0.91	—	—	0.45	0.53	0.61	0.67	0.73	0.91	1.1	1.2	—	54°	55°
D2	DC25	1.0	—	0.37	0.51	0.62	0.71	0.79	0.86	1.1	1.3	1.5	32°	61°	61°
D3	DC25	1.2	0.39	0.45	0.63	0.75	0.86	0.95	1.0	1.3	1.6	1.8	47°	69°	69°
D4	DC25	1.6	0.57	0.68	0.94	1.1	1.3	1.4	1.6	2.0	2.4	2.8	63°	82°	82°
D5	DC25	2.0	0.64	0.81	1.1	1.4	1.6	1.7	1.9	2.4	2.9	3.3	70°	85°	84°
D6	DC25	2.4	0.87	1.0	1.5	1.8	2.0	2.3	2.5	3.2	3.8	4.4	77°	89°	88°
D7	DC25	2.8	1.0	1.2	1.7	2.0	2.3	2.6	2.9	3.7	4.5	5.1	83°	92°	91°
D8	DC25	3.2	1.2	1.4	2.0	2.4	2.8	3.1	3.4	4.4	5.3	6.2	89°	96°	95°
D10	DC25	4.0	1.5	1.7	2.4	3.0	3.5	3.9	4.2	5.5	6.7	7.7	94°	102°	101°
D12	DC25	4.8	1.8	2.2	3.0	3.7	4.3	4.8	5.2	6.7	8.2	9.5	101°	111°	110°
D14	DC25	5.6	1.9	2.3	3.3	4.1	4.7	5.2	5.8	7.5	9.1	10.2	105°	113°	112°
D1	DC45	0.79	—	—	—	0.48	0.56	0.61	0.67	0.84	1.0	1.2	—	39°	40°
D1.5	DC45	0.91	—	—	0.53	0.64	0.74	0.81	0.90	1.1	1.4	1.7	—	48°	50°
D2	DC45	1.0	—	0.43	0.66	0.80	0.91	1.0	1.1	1.4	1.7	2.0	26°	58°	58°
D3	DC45	1.2	—	0.53	0.74	0.91	1.0	1.2	1.3	1.6	2.0	2.3	34°	62°	62°
D4	DC45	1.6	0.67	0.80	1.1	1.4	1.6	1.8	2.0	2.5	3.1	3.6	59°	73°	72°
D5	DC45	2.0	0.87	1.0	1.5	1.8	2.0	2.3	2.5	3.2	3.9	4.5	63°	76°	75°
D6	DC45	2.4	1.1	1.3	1.9	2.3	2.7	3.0	3.3	4.3	5.3	6.1	70°	80°	79°
D7	DC45	2.8	1.3	1.5	2.2	2.7	3.1	3.5	3.9	5.0	6.2	7.2	78°	86°	85°
D8	DC45	3.2	1.6	1.9	2.7	3.3	3.9	4.3	4.8	6.2	7.6	8.9	84°	89°	88°
D10	DC45	4.0	2.0	2.5	3.5	4.4	5.0	5.6	6.2	8.0	9.8	11.5	88°	92°	91°
D12	DC45	4.8	2.5	3.1	4.4	5.3	6.2	6.9	7.6	9.8	12.1	14.0	95°	101°	100°
D14	DC45	5.6	2.8	3.4	4.9	6.0	7.0	7.8	8.6	11.2	13.6	15.9	99°	104°	103°
D16	DC45	6.4	3.3	4.0	5.7	7.1	8.2	9.3	10.2	13.2	16.3	19.1	106°	111°	110°

Disc Core hollow cone spray nozzles

Nozzle placement

Usually, nozzles of higher flow are placed where the highest leaf density is found. Depending on tree shape this is somewhere equivalent to 2 o'clock on the left side and 10 o'clock on the right side viewed from the rear of the sprayer. Similar locations are used where side conveyors and towers are used. On air shear/ pneumatic sprayers this is the time to adjust flow rates to the spray heads.

Using the results of the air flow and displacement tests set up the nozzles accordingly with higher flows around the 10 and 2 o'clock regions. Flagging tape about 600mm long attached to the fan outlet will indicate the air movement. See below diagram nozzle array. (This is an example only)

Blue 2.15 litres per minute

Red 2.87 litres per minute

Red 2.87 litres per minute

Red 2.87 litres per minute

Blue 2.15 litres per minute

Yellow 1.4 litres per minute

Flow per side 14.31 litres at 10 bar

Flow both sides 28.62 litres per minute at 10 bar.

The final steps

(a) On a fine afternoon with no prospect of rain place around 100 to 200 litres of clean water in the tank. You will need an observer/ assistant.
(b) Set the sprayer to operate at the desired pressure.
(c) Place ultraviolet tracer in the tank according to the manufacturer's recommendations. This is usually around 1 litre in 50 litres to 1 litre in 200 litres. You can use water sensitive paper however it is a very small representative area of the whole canopy.
(d) Operate the sprayer using the settings you calculated previously. Try a couple of different ground speeds and have the observer checking for spray penetration and runoff. TREES SHOULD BE SPRAYED TO THE POINT OF RUNOFF for a conventional air blast hydraulic nozzle machine.
(e) Record the number of trees sprayed in one minute.
(f) Have the observer look from the rear of the sprayer. If the observer can see a cloud entering the suction side of the fan, then you are going too fast. If the spray is bursting through the canopy into the atmosphere and the leaves are dripping excess spray, then you are going too slow. Keep an eye on the flagging tape previously placed in the canopy.
(g) This could also be a time to adjust any volutes or air diversion devices used with side conveyers and towers.
(h) Use the Ultraviolet torch at night to assess the coverage, particularly in those more protected sites in the canopy. See table below. Always consult the label which may give specific recommendations on droplet size. The figures below are from various publications and personal experience. Keep in mind what and where the spray target is in the canopy.

Number of droplets per sq centimetre (Fine Droplets)	Minimum % coverage per sq centimetre for larger than "fine" droplets.	Spray type
20 to 30	45	Contact Insecticides
50 to 70	60	Protectant Fungicides
10 to 30	30	Systemic and trans laminar pesticides

Droplet size chart

Category	Symbol	Color Code	Approx. VMD Range (microns)
Extremely Fine	XF	Purple	<60
Very Fine	VF	Red	60-145
Fine	F	Orange	145-225
Medium	M	Yellow	226-325
Coarse	C	Blue	326-400
Very Coarse	VC	Green	401-500
Extremely Coarse	EC	White	501-650
Ultra Coarse	UC	Black	>650

How much liquid per tree?

This has been a point of discussion and or disagreement for years. Most orchard canopy spraying operations refer to “spray to runoff”. This doesn’t mean the chemical is dripping off the leaves and soaking into the soil. It means wetting the foliage to the point just before runoff happens. Conventional spraying water volumes range from 500 ml to 4 litres per tree depending on age and size of tree. Growers with CDA, Air shear, and sprayers with a more directed air flow can use less water volume. Good coverage with an air shear machine on smaller trees has been demonstrated with about 50% water volume of conventional air blast hydraulic nozzle application.

Calibrating the sprayer

From the data gathered above calibrating the sprayer on a trees per hectare basis should be easy. We will use the data from the sprayer above and assume the orchard planting is 4 metres between trees and 8 metres between rows. 10000 ÷ (8x4) = 312 trees per hectare

Parameter	Units	Comments
Total frow from all nozzles	28.62 litres @ 10 bar	
Number of trees sprayed per minute	20	Assuming spraying both sides
Speed	80 metres per minute	4.8 Kph
Trees per hectare	312	From above calculation 10000 ÷ (8x4) = 312

Calculations

Litres per tree = Total Flow ÷ Number of trees sprayed per minute

= 28.62 ÷ 20

= 1.43 litres per tree.

Spray volume applied per hectare = Number of trees per hectare x litres of spray per tree

= 312 x 1.43

= 446 litres per hectare.

The above calculations are for small trees and represents medium to high volumes of water per hectare. (Spray to Runoff) Use the dilution recommendation in this case. For example, if using abamectin for two spotted mites, then add 50 to 100 ml of the 18 grams/ litre product in 100 litres of water in the spray tank. Where adequate coverage can be achieved with low volumes then less water may be used, however adjustments will need to be made to the tank concentration. Low volume spraying of say 150 litres per hectare using the same orchard would require 3 times the product per tank, 150 to 300 ml per 100 litres. This would not be advisable for mite control where coverage is essential but may be adequate for systemic fungicides. Always check the product label.

There are various methods of determining coverage and calibration. This is just one that seems to work reasonably well. The tree row volume method is also useful for calibration, however there is no provision for assessing air volumes or coverage. Below is a link to the method

https://www.fgv.com.au/grower-services/latest-updates/grower-news/409-tree-row-volume-concept-calculations-and-application

Note: In recent years there has been a move to tighten spraying regulations. The main concern is drift management. In future we will need to revisit and test the various spray techniques to ensure the lychee industry remains at the forefront of environmental stewardship. This booklet is designed to assist growers to set up their sprayers based on a combination of spray efficacy and drift management. Further drift reduction work will be needed in future.

Happy Spraying

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Water sensitive paper(WSP)
Most spray equipment suppliers and farm chemical resellers will stock WSP.
Read instructions carefully.