NSW GOVERNMENT | Department of Primary Industries

Macadamia plant protection guide 2020–21

NSW DPI MANAGEMENT GUIDE

Jeremy Bright

www.dpi.nsw.gov.au

PROTECT YOUR NUTS

BORDEAUX WG

Protectant Fungicide/Bactericide
200g/kg COPPER (Cu) present as
Tri-basic copper sulphate

- Control of Husk Spot, Anthracnose, Pink limb blight and Phytophthora stem canker
- Dry-Flowable granule for ease of mixing and minimal dust
- Superior weathering and sticking properties
- Available in 15kg bags

NASAA INPUT FOR ORGANIC PRODUCTION Cert. No. A6358M

HYDROCOP WG

Protectant Fungicide/Bactericide
500g/kg COPPER (Cu) present as
CUPRIC HYDROXIDE

- Control of Husk Spot, Anthracnose, Pink limb blight and Phytophthora stem canker (Qld only)
- High loaded copper hydroxide formulation for lower application rates
- Dry-Flowable granule for ease of mixing and minimal dust
- Superior coverage and adhesion due to small particle size
- Available in 10kg bags

NASAA INPUT FOR ORGANIC PRODUCTION Cert. No. A6358M

TRIBASIC LIQUID

Protectant Fungicide/Bactericide
190g/L COPPER (Cu) present as
Tri-basic copper sulphate

- Control of Husk spot, Anthracnose, Pink limb blight and Phytophthora stem canker
- An SC (Suspension concentrate) liquid formulation of Tribasic Copper Sulphate
- Superior mixing.
- Available in 20L, 200L and 800L packs

CROP DOC 600

Systemic Fungicide
600g/L of Phosphorous (Phosphonic) Acid present as Mono and Di Potassium Phosphite

- Control of Phytophthora root rot and Trunk (stem) canker (Permit PER84766)
- Formulated to be near pH neutral for increased compatibility
- Available in 20L, 200L and 1000L packs

KINGFISHER

Systemic Fungicide
250g/L Difenoconazole

- Control of Husk spot
- Available in 5L packs

PEREGRINE

Contact and residual Insecticide
240g/L Methoxyfenozide

- Control of Macadamia flower caterpillar and Macadamia nutborer
- Suspension Concentrate
- IPM compatible
- Controls both eggs and early instar larvae.
- Available in 5L and 10L packs

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*Always read product labels and permits before use.

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Macadamia plant protection guide 2020–21

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (June 2020). However, because of advances in knowledge, users are reminded of the need to ensure that the information upon which they rely is up-to-date and to check the currency of the information with the appropriate officer of NSW Department of Industry, or the user's independent adviser.

Recognising that some of the information in this document is provided by third parties, the State of New South Wales, the author and the publisher take no responsibility for the accuracy, currency, reliability or correctness of any information included in the document provided by third parties.

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

Always read the label

Agricultural chemical product users must always read the label and any permit before using the product and strictly comply with the directions on the label and the conditions of any permit. Users are not absolved from any compliance with the directions on the label nor the conditions of the permit by reason of any statement made in or omitted from in this publication.

Permits

Some of the chemical use patterns quoted in this publication are approved under permits issued by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and in force at the time the publication was prepared. Persons wishing to use a chemical in a manner approved under permit should obtain a copy of the relevant permit and approved use pattern from the supplier of the product at point-of-sale, must read all the details, conditions and limitations relevant to that permit, and must comply with the details, conditions and limitations prior to and during use.

Image acknowledgements

Cover photo: Battle of the nymphs; an assassin bug feeding on a fruit spotting bug.

Unless otherwise stated, the images in this guide have been sourced from the NSW Department of Primary Industries.

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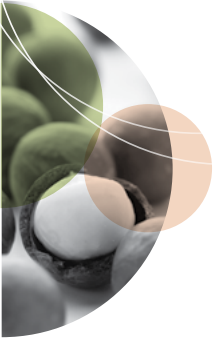

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AUSTRALIAN MACADAMIA SOCIETY

AusMac2021

Sunshine Coast Convention Centre QLD

EARLY BIRD TICKETS ON SALE NOW!

This event will now take place in early 2021 New dates to be announced soon!




Don't miss the premier event on the Australian macadamia industry calendar!

Over 2 ½ days, internationally acclaimed growers, researchers and industry experts will share their ideas and experiences to provide you with the latest results and technical information about key macadamia research, best practice, on-farm innovation and management.

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- Water use management
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- Using cover crop and inter row technology to improve soils and biodiversity
- How can growers improve pollination for better yields?
- Grower case studies: The secrets behind the success of our best growers
- Factors influencing total kernel recovery
- So, the climate is changing, but what does that mean for macadamias?
- Towards a better understanding of organic amendments and healthy soil
- How South Africa became the world's largest macadamia producer
- The technology changing our orchards
- The do's and don'ts of best practice orchard establishment
- Market update

Social events

- Golf day
- Welcome cocktail reception
- Women in Macadamias luncheon
- Happy hour
- Celebrity chef breakfast
- Gala dinner

Visit the AMS website www.australianmacadamias.org/industry and click on the AusMac2021 link for the full program, social events and to book your tickets & accommodation.




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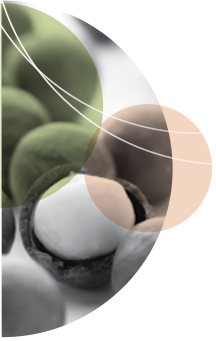

About this guide

This 6th edition of the NSW *Macadamia plant protection guide* aims to provide commercial macadamia growers with up-to-date information on all aspects of protecting your orchard from pests and diseases.

Feature article

Many longer-term macadamia growers consider the 2019 season to be the hardest they have experienced. During flowering, rainfall was significantly lower than average and there was only minimal soil moisture available to the plants. This was coupled with prolonged high temperatures and strong, hot dry winds that extended through the kernel sizing and oil accumulation phases. This year's feature article will review the effects of these conditions on macadamia and provide some insight into grower observations and survival strategies that worked. It will also describe how we can prepare our orchards for the next drought, as well as make them more 'climate ready'.

Pesticides

We do not list every pesticide that is registered for a specific use, but rather guide growers in their choice of chemicals. It is our policy to use common chemical names or active ingredients, not trade names, when referring to pesticides, crop regulation compounds and nutrient sprays. Some users find this inconvenient because the chemical name is often in small print on product labels compared with the prominence given to the trade name. Unfortunately, this practice is necessary because there can be many product names for the same active ingredient and it would be impossible to list them all at each mention in the guide.

Under the pesticides registration system administered by the Australian Pesticides and Veterinary Medicines Authority (APVMA), individual products are registered for use in or on specific crops for specific weeds, pests or diseases. Also, there can be variations in use recommendations between states for the same crop; even differences in application times or treatment intervals. Using common chemical names in recommendations is intended to simplify the advice. It means that at least one product containing that active ingredient is registered for the purpose given. The onus is on the pesticide user to ensure that their product use is consistent with the label or permit issued by the APVMA.

Pesticide use is under constant scrutiny through residue surveys and reviews. It is vital that these valuable tools for nut production are not misused.

Distribution

The guide is available free to macadamia growers and is distributed to all macadamia processors within Australia. Copies can be collected from NSW DPI offices at Wollongbar and Coffs Harbour, the Australian Macadamia Society, Local Land Services and selected rural retail stores across NSW. The guide can be downloaded from the NSW DPI website (http://www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts/growing-guides/macadamia-protection-guide).

Acknowledgements

Special thanks to Associate Professor Femi Akinsanmi for reviewing the diseases section and to Jenene Kidston, Technical Specialist Farm Chemicals NSW DPI, for reviewing the pesticide recommendations.

Feedback please

NSW DPI wants to ensure the information we are providing is what you need to make your business grow. Please contact us with your suggestions on how we can make future editions even more useful.

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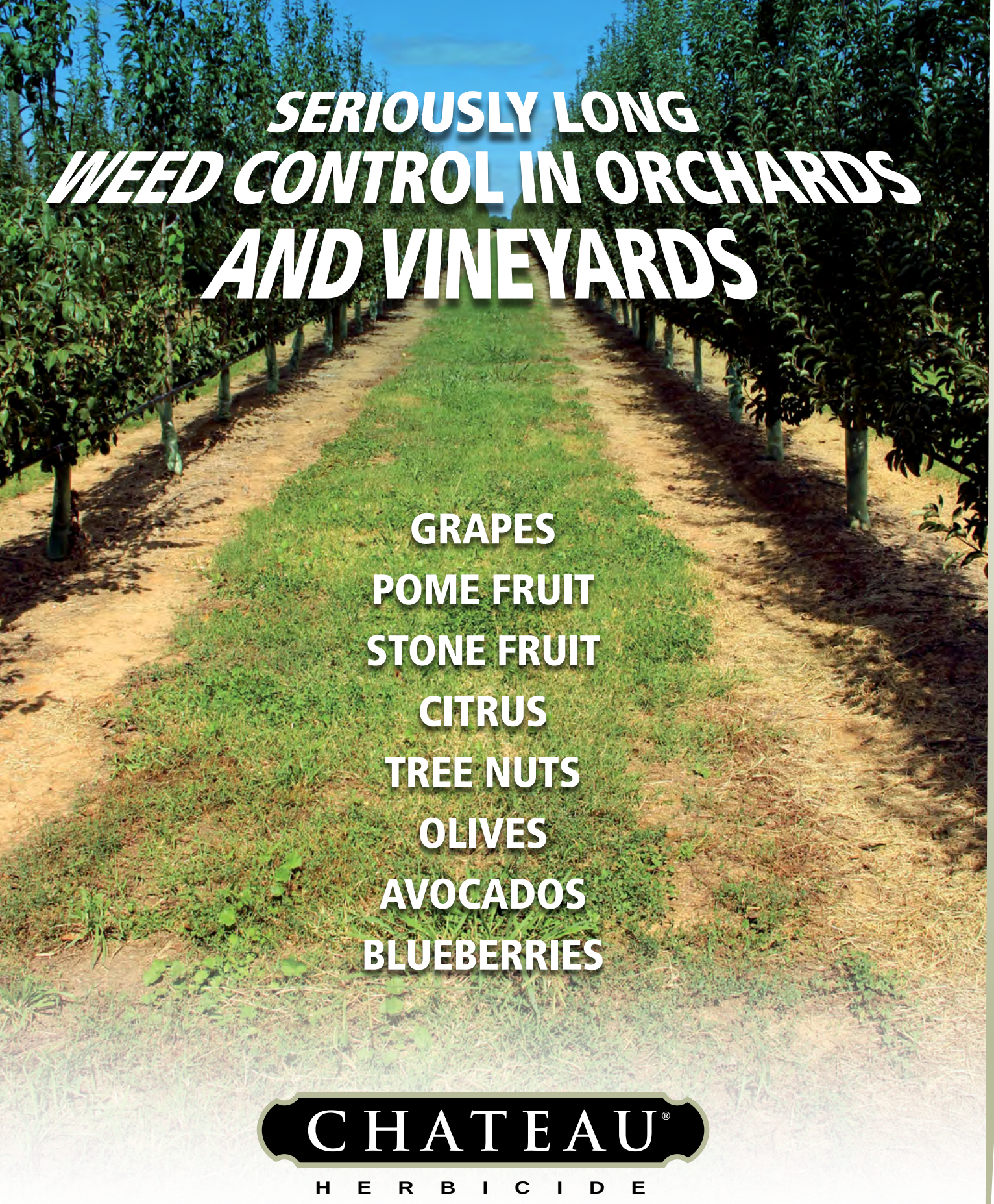

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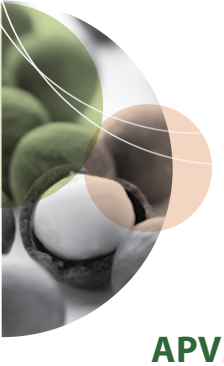


What's new?

APVMA review continues

The APVMA is reviewing several chemicals. The priority list has been further extended and includes the following that are relevant to the macadamia industry:

- acephate
- carbamate
- methomyl
- triazole
- trichlorfon.

Further information, including the reasons why the selected chemicals have been chosen for priority one review, are available on the APVMA website (https://apvma.gov.au/node/10876).

If the macadamia industry is to remain viable, it is imperative that we continually search for different management options. With our most effective chemistry continually under review, we must look for other options such as introducing new predatory pests, identifying chemistry that is as effective as the old chemistry (and not under review), adopting better systems for monitoring and managing trees to be less desirable to pests. Essentially, we need to continue developing a sustainable integrated pest and disease management (IPDM) system for the industry.

End of the line for Supracide

We have recently seen the withdrawal of the chemical methidathion, commonly referred to as Supracide. This cancellation will affect macadamia spray management on such pests as:

- fruit spotting bug
- macadamia felted coccid
- macadamia leaf miner
- macadamia mussel scale and white scale
- macadamia nut borer
- macadamia twig girdler

Growers may continue to use the cancelled product according to its label instructions until **4 February 2021**.

Orchard pests and diseases management priorities

This section of the guide has gone through a complete transformation. We have decided to do away with the calendar-style format in favour of having a section for each of the pests. Under the pest name will be a general description, risk period, pest identification, damage caused and management, including cultural, biological and chemical control. This will also contain images of the pests and links to further information.

Fall armyworm

Fall armyworm (*Spodoptera frugiperda*) is a new plant pest present in Queensland but not yet detected in New South Wales. This insect pest is a serious threat to Australia's grain, rice, cotton, horticultural and sugar industries.

Fall armyworm was detected in northern Queensland in February 2020 and is now considered established in that state.

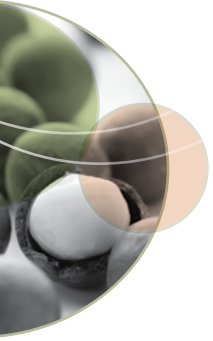
For more information, refer to the Department of Agriculture's fall armyworm page (https://www.agriculture.gov.au/pests-diseases-weeds/plant/exotic-armyworm).

If fall armyworm is detected in macadamia, there are four current permits for it: PER89241, PER89278, PER89293 and PER89353. All permits can be found on the APVMA website (https://portal.apvma.gov.au/permits) and any referred to in this guide are included from Page 137.

IPM project update year 3

The macadamia IPM project is now 3 years old. Some of the partners within this project have provided updates for the Plant Protection Guide showing how their section of the project is progressing. IPM will not have a final destination. The industry will continue along the path as we understand further the significance of cultural, biological and chemical practices.

"IPM is not an outcome; IPM is a journey"



Macadamia development stages

This section will help growers identify the macadamia growth stages that are referred to in this guide. The growth stage is determined by when the majority of the plant is in a specific stage of development. These are:

- pre-flowering: including bud development through to fully extended, green raceme (Figure 1 and Figure 2)
- early flowering: a mix of pre-flower and some open florets (Figure 3 and Figure 4)
- peak flowering: majority of the tree has fully opened flowers (Figure 5 and Figure 6)
- nut set: pollinated nut is up to and including match head size (Figure 7 and Figure 8)
- pea size nut and spring flush: nut is at pea size stage (Figure 9)
- shell hardening and oil accumulation: nut size increases to harvest (Figure 10).

Pre-flowering

Figure 1. Pre-flowering.

Figure 2. Pre-flowering.

Early flowering

Figure 3. Early flowering.

Figure 4. Early flowering.

Peak flowering

Figure 5. Peak flowering.

Figure 6. Peak flowering.

Nut set

Figure 7. Nut set.

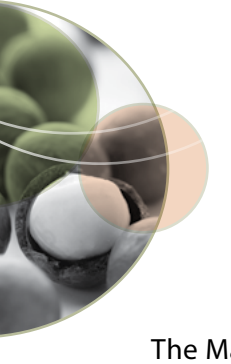
Figure 8. Nut set (match head size).

Pea size nut and spring flush

Figure 9. Pea size nut and spring flush.

Shell hardening

Figure 10. Shell hardening.



IPM project: year 3 updates

The Macadamia Integrated Pest Management (IPM) Program, using Hort Innovation funds from the Macadamia Levy, was launched in January 2017. The program involves a team of researchers and crop consultants with a diverse range of skills (Figure 11), focusing their efforts on developing sustainable pest management practices for the macadamia industry. Combinations of biological, cultural and chemical controls are being tested on commercial farms and research stations as part of the program. This section of the guide features updates from some of the program components.

Figure 11. The IPM project team.

New South Wales Department of Primary Industries

Dr Ruth Huwer

The key question: what happens if we remove broad-spectrum insecticides for macadamia pest management wherever possible?

The first step in answering this question is being conducted in a macadamia orchard at the Centre for Tropical Horticulture (CTH), Alstonville with the following treatments:

- 25% of the site is being managed using standard practices with broad spectrum insecticides at label rates
- 75% of the site is being managed using IPM principles and focusing on monitoring and decision making using the most appropriate current tools, including selective chemistry at label rates and acknowledging that trichlorfon (a broad-spectrum) may be necessary for controlling fruit spotting bugs (FSB). This part of the site will have flowering plants included and after discussions with Abigail Makim from BioResources and Tony Hodges from Williams Seeds, the selected mixture is:
  - Bahia (*Asteraceae*) 20%
  - *Dichondra (Convolvulaceae)* 20%
  - Mustard (*Brassica*) 20%
  - 7 Lucerne (legume) 10%
  - Red clover (legume) 10%
  - White clover (legume) 10%
  - Chicory (*Asteracea*) 5%
  - Plantain (*Plantaginaceae*) 5%

The orchard was seeded on 20 March 2020, after clean up and mulching (Figure 12).

Regular monitoring with the cherry picker between July 2019 and March 2020 was conducted as follows:

- weekly checks were made for FSB populations in hedges, macadamia nut borer (MNB) in pheromone traps and macadamia lace bug (MLB) in racemes
- fortnightly observations were made throughout the orchard and canopy for any pests or beneficials and fallen nuts were checked for FSB damage and macadamia seed weevil (MSW) eggs, larvae and pupae
- trap checks and lure changes were performed monthly for scolytid traps using two different lures (a 3:1 methanol:ethanol mixture or Ambro® lure (not available in Australia, only USA)) and yellow sticky traps for pests and beneficials.

Figure 12. The macadamia block ready for inter-row seeding.

Another step in the IPDM trials involves an unsprayed block that was originally used for assessing different plant densities for fruit spotting bug damage and the incidence of multiple flowering. However, due to macadamia lace bug and macadamia seed weevil damage, the annual crop yield has been less than a kilo of nuts per tree since 2015. This block now gives us the opportunity to assess the effects of increased biodiversity on nut yield and quality.

Six areas next to the macadamia orchard were planted with different native shrubs including *Grevillea* spp., *Banksia* spp., *Leptospermum* spp., *Westringia* spp. and *Lomandra* spp. (Figure 13 and Figure 14).

The inter-row was seeded with flowering plants (Figure 15 and Figure 16) with the following mixture as determined by Abigail Makim from BioResources and Tony Hodges from Williams Seeds:

- Callide (Rhodes grass) 40%
- Mustard (*Brassica*) 25%
- 7 lucerne (legume) 10%
- Red clover (legume) 10%
- White clover (legume) 10%
- Chicory (*Asteracea*) 5%

Seeding was completed on 10 February 2020.

Results will be made available in next year's *Macadamia plant protection guide*.

The past season in all macadamia growing regions was influenced by prolonged heat and drought. This generally resulted in reduced nut size and increased populations of some pests. For example, scolytid beetles took advantage of the drought-stressed trees as did *Leptocoris* spp. that generally prefers the drier weather.

Figure 13. One of six groups of native shrubs planted next to the macadamia orchard.

Figure 14. Close up of the *Grevillea* spp. planted next to macadamia orchard.

Figure 15. Inter-row planting.

Figure 16. Close up of the inter-row planting.

Hort Innovation
Strategic levy investment
MACADAMIA FUND

This project has been funded by Hort Innovation using the macadamia research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Queensland Department of Agriculture and Fisheries

Diana Leemon, Ian Newton, Shane Mulo and Grant Bignell

The QDAF component of the IPM program has focused on the following activities:

- investigating entomopathogenic fungi as insect control agents
- assessing banana spotting bug (BSB) pheromone traps and developing guidelines for their use
- using benchmarking data to:
  - identify regional pests and diseases that are limiting production
  - quantify factory rejects caused by insect damage
  - undertake an economic analysis of emerging IPM strategies.

Entomopathogenic fungi are natural disease organisms that have been used for controlling insect pests for over 100 years, though their use was superseded by chemical pesticides during the twentieth century. Several fungal biocontrol products based on entomopathogenic fungi are now registered worldwide. These products primarily consist of formulated fungal spores that are applied using methods similar to those used with chemical insecticides. The entomopathogen development component of this project aims to isolate, culture and characterise entomopathogenic fungi from macadamia seed weevils (Figure 17 and Figure 18) and soil in macadamia orchards, so that selected isolates can be formulated for field testing against insect pests. Preliminary investigations into the endophytic potential of the fungi will also be conducted. To date spore powder from four different *Beauveria* isolates has been supplied to NSW DPI. These isolates will be incorporated into trials to determine their efficacy for control of macadamia seed weevil.

Beauveria bassiana is a pathogen occurring naturally in macadamia seed weevil populations in the border regions of New South Wales and Queensland. Genetically related strains of this fungus were isolated from both the soil and infected seed weevils from different locations in the border regions. Developing a fungal biopesticide based on *Beauveria bassiana* for controlling macadamia seed weevil as part of an overall integrated pest management program is thus well supported.

Future research needs to focus on the best approach for formulating and applying the fungus to achieve optimal control of the weevil. Killing the larval stage will be a challenge as they are protected within the developing nut from any direct application of a fungal biopesticide. However, preliminary investigations of the endophytic ability of *Beauveria* within the developing nut warrants further study. If *Beauveria* can be applied to young nuts in a way that it can establish in them before female seed weevils lay their eggs, it might be possible to kill the developing larvae. The residual spores on the outside of the nuts could additionally contribute towards adult mortality after feeding.

Other fungal entomopathogen control strategies could focus on killing the emerging adults in the litter under trees by applying a granular or spray formulation at different times throughout the year.

Velifer® is a commercial formulation of *Beauveria bassiana* marketed by BASF that is currently registered in Australia for the biological control of

Figure 17. Macadamia seed weevil (*Kuschelorhyncus macadamiae*).

Figure 18. A macadamia seed weevil succumbed to *Beauveria bassiana* mycosis.

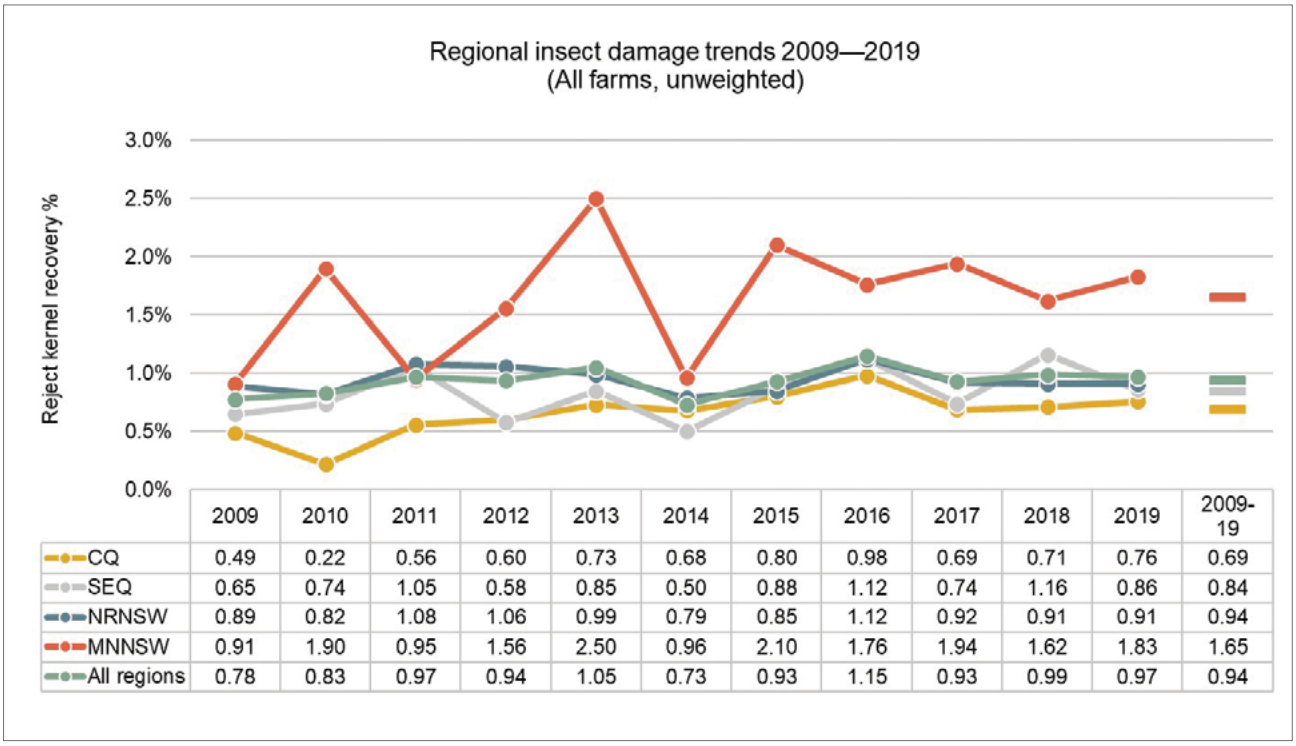
several pests of horticultural crops. We found the *B. bassiana* strain in Velifer® to be similar to the strains of *B. bassiana* naturally infecting macadamia seed weevils in Alstonville. If the concurrent research at the University of Southern Queensland shows the Velifer® strain of *Beavueria* can kill macadamia seed weevils, then consideration should be given to focussing future research on Velifer®. Extending the registration of an existing product for a new pest is likely to be quicker and more economical than trying to register a new strain of fungus as a biological control.

Testing with BSB pheromone traps has been continuing, with trap users reporting mixed results. Variable performance of the traps has previously been attributed to technical difficulties with the longevity and reliability of the chemical lures used. QDAF staff have been working with the trap producer to try to solve these technical issues and are planning further R&D to improve the trap design. Lure chemicals continue to be imported from the USA but the lures themselves are now loaded in Australia to increase the longevity of the pheromone; this seems to have largely solved the problem.

From small-scale field trials the new lures appear to be effective for the first 3 to 4 weeks after installation but may lose some efficacy after this time. QDAF staff are reviewing the trap producer's methods and are working with them to further improve processes and lure supply. They also plan to test a new tape (which may last longer in the field) and new trap designs. Ian Newton (QDAF) has consulted with and made recommendations to Andrew Hayes (USC) about ongoing bioassays aimed at developing a pheromone lure for FSB (*Amblypelta nitida*).

The macadamia benchmarking project has been tracking farm productivity and quality over the last 11 years. Factory insect damage reject levels have been recorded for each region since 2009 (Figure 19). Central Queensland (CQ), South East Queensland (SEQ) and Mid North New South Wales (MNNSW) suffered higher-than-average factory insect damage reject levels in 2019. The Northern Rivers of New South Wales (NRNSW) achieved below average levels in 2019.

Figure 20 shows the major factors limiting production for benchmarking participants in all regions in 2019. The top three factors ranked by participants were hot or dry weather, pests and wet weather. Over a third of farms in the CQ region reported pests as a limiting factor. The proportion of farms reporting pests as a limiting factor were similar in SEQ, MNNSW and NRNSW (14 to 17%). Fruit spotting bug was the most reported limiting pest in all regions. Phytophthora was the most commonly reported disease for SEQ and MNNSW. Husk spot was reported as the main limiting disease in CQ while flower diseases was the leading response for NRNSW.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2009-19
CQ	0.49	0.22	0.56	0.60	0.73	0.68	0.80	0.98	0.69	0.71	0.76	0.69
SEQ	0.65	0.74	1.05	0.58	0.85	0.50	0.88	1.12	0.74	1.16	0.86	0.84
NRNSW	0.89	0.82	1.08	1.06	0.99	0.79	0.85	1.12	0.92	0.91	0.91	0.94
MNNSW	0.91	1.90	0.95	1.56	2.50	0.96	2.10	1.76	1.94	1.62	1.83	1.65
All regions	0.78	0.83	0.97	0.94	1.05	0.73	0.93	1.15	0.93	0.99	0.97	0.94

Figure 19. Regional factory insect damage reject trends 2009–2019.

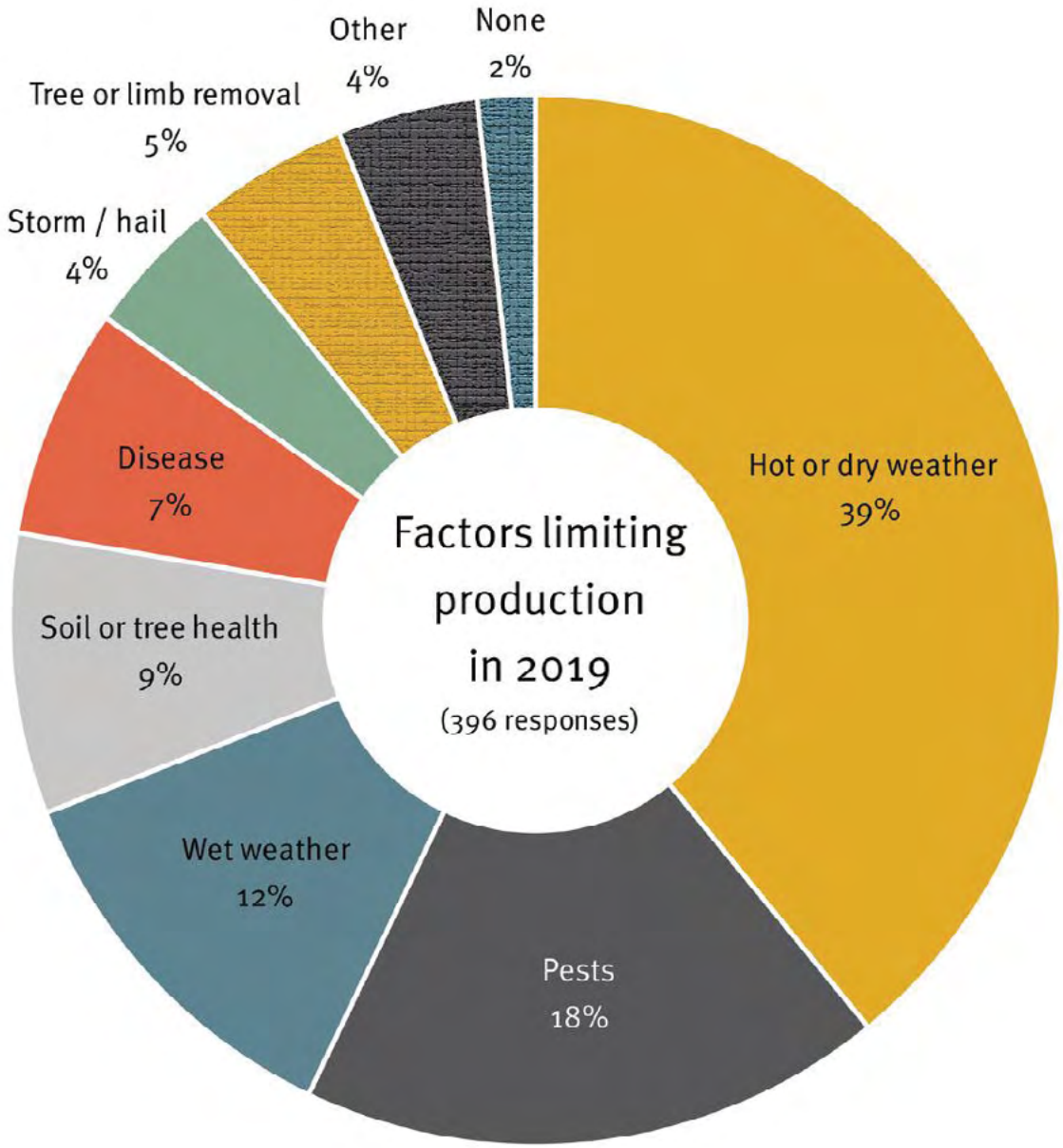


Figure 20. Major factors limiting macadamia production in 2019.

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BioResources

Dr Christopher Carr, Dr Abigail Makim and Mr Richard Llewellyn, BioResources Pty Ltd

Background

The aim of this project is to determine whether reduced mowing in the macadamia inter-row could improve the plant diversity and create an environment more favourable for supporting an insectary. This could then increase the number of beneficial arthropods in the orchard. More broadly, we may see more complex food webs and better orchard self-regulation of economic pests. Furthermore, this enhanced nutritional food web will benefit birds and micro-bats, which also have roles in pollination and pest suppression. It is estimated that beneficial insects provide 5–10 times the pest control in agricultural ecosystems compared to chemical applications (Pimentel et al. 1992), as these processes are occurring all the time. By encouraging more diverse ecosystems within the orchard, the likelihood and/or intensity of pest outbreaks decreases.

We worked with growers to consider practical reduced mowing options that are compatible with the seasonal demands of orchard management. We then sought to provide information on any relationship between reduced mowing and the potential for any increased rat, invasive weed and/or arthropod pest presence. Finally, we monitored the association between changes in inter-row vegetation management and changes in orchard beneficial/pest arthropod ecology.

Outcomes

Reduced mowing trials were conducted on 11 working farms in all major growing regions for 2.25 years. Early results suggest that reduced mowing is achievable on many macadamia farms.

We found that an inter-row insectary can be incorporated into existing orchard inter-row management, and with basic monitoring and management, will not lead to other problems with rats, weeds or arthropod pest reservoirs.

The treatments tested for reduced mowing included mohawk (Figure 21), alternate row mowing (Figure 22), and tree-to-tree no mow. We also considered seeding and cover cropping for insectaries in these reduced mow areas (Figure 23).

Outcomes from the project provide recommendations and guidelines for selecting and managing each of these options for growers to suit specific farm, season and site conditions. These recommendations and guidelines are available from Hort Innovation.

Case study

The following case study provides a snapshot of some of the project's results. The annual average results for inter-row insectary indicators for one farm in northern New South Wales trialling the mohawk system are presented in Figure 24. Plant species diversity, floral resources (nectar and pollen) for food for beneficial arthropods, reduced habitat disturbance and increased habitat complexity were evaluated. For this farm, the mohawk inter-row treatment significantly improved the value of the inter-row in terms of an insectary when compared to the control (industry standard, complete close mow). Specifically, for each assessment year:

- the count of plant species in the mohawk was almost double that of the control
- the percentage of biomass as floral resources was much higher in the mohawk compared with the control (zero)
- when habitat was evaluated by height (cm), it was 5 times greater for the mohawk than the control.

By classifying all arthropods sampled as prey and then separating nectarivores (potential pollinators), predators and parasitoids, we get four broad categories. This allows us to compare treatments in proportions. Using combined tree and inter-row abundance counts revealed a greater proportion of prey (57%), predators and parasitoids (63%) and nectivores (pollinators) (55%) in the mohawk compared with the complete close mow block (Figure 25).

There was no increase in any macadamia pests in the mohawk and there was greater species richness in terms of arthropod families represented both in the inter-row and trees.

There was a three-fold increase in thrips, which can be a secondary pest in macadamias, in the complete close mow block compared to the mohawk block over the season sampling period in the macadamia trees. While thrips were not reported as an issue on this trial site, it is likely that increased predators and parasitoids in the mohawk could have reduced their overall numbers. The economic benefit of increased beneficial arthropods for pest suppression and pollination could be measured in future studies.

Figure 21. A reduced mow mohawk in 10 m rows, northern New South Wales, May 2017.

Figure 22. An alternate row mowing system (mown on the left, unmown on the right), Bundaberg, April 2019.

Figure 23. A mohawk with seeding, mid north coast of NSW, October 2018.

It is worth noting that this case study is based on only 2.25 years of data and if these practices continue it is likely arthropod diversity will continue to increase. Further increases are likely with the incorporation of seeding and/or cover cropping in the inter-row. This is reported on in greater detail in the final report, which can be found at the Hort Innovation website.

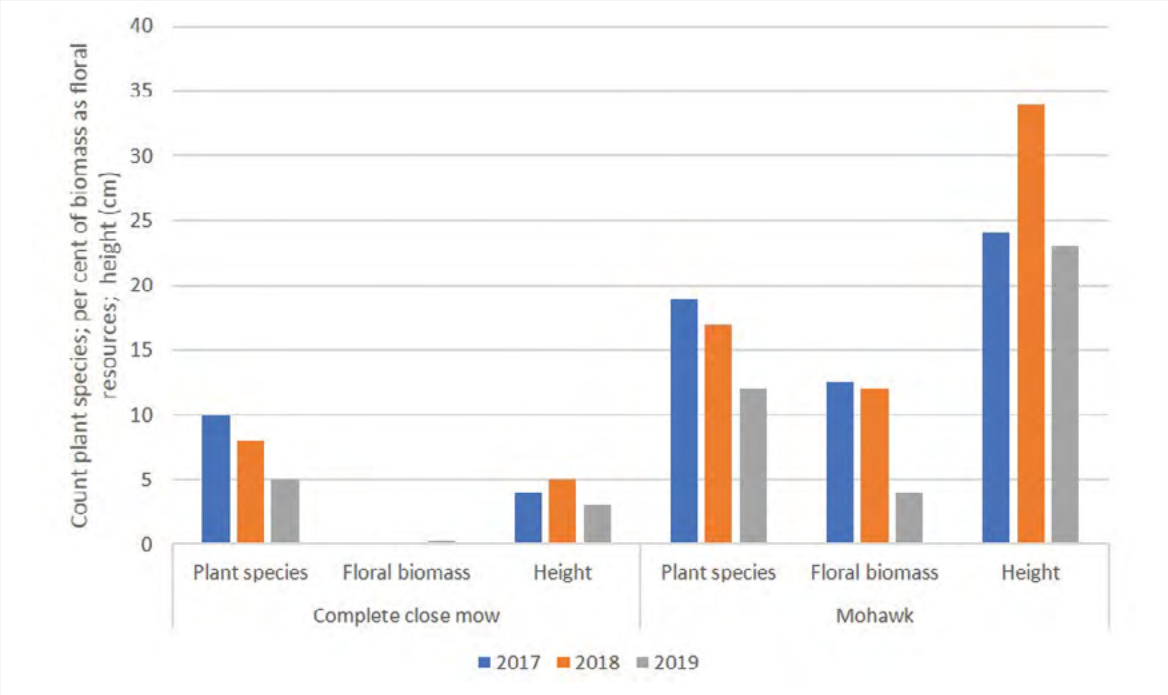

Figure 24. The annual average of insectary measures by treatment: count of plant species, the percentage of biomass as floral resources, and the height of vegetation (cm).

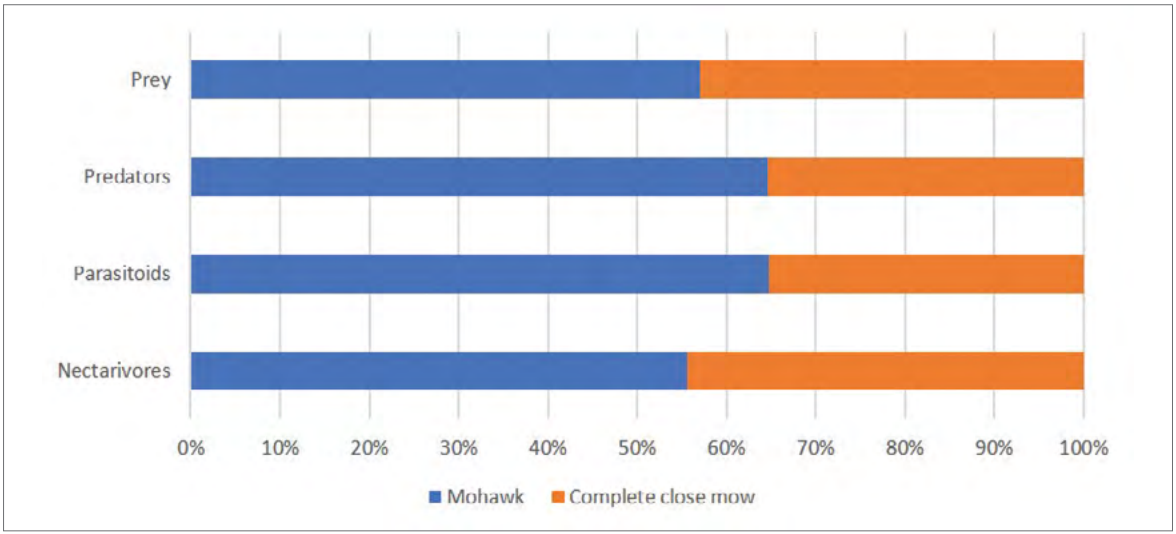

Figure 25. A comparison of the four categories of arthropods from tree and inter-row counts.

Hot Innovation links

Insectiaries literature review https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/insectiaries-literature-review/

Integrated pest management program for the Australian macadamia industry (various projects from MC16004 to MC16008) https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/mc16004-to-mc16008/

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Hort Innovation Strategic levy investment | MACADAMIA FUND

This project has been funded by Hort Innovation using the macadamia research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

University of Queensland, Centre for Horticultural Science – macadamia integrated disease management (IDM)

Associate Professor Femi Akinsanmi, Olumide Jeff-Ego, K Prasannath and Vheena Mohankumar




In macadamia, diseases caused by *Phytophthora*, fungi and bacteria pose the most threat to farm productivity. The potential spread and economic impact of these diseases to macadamia are rated as high. In the past decade, we have seen increased reports of detection and devastation caused by several pathogens in macadamia worldwide. It is therefore necessary to continue to improve surveillance strategies and preparedness, including evaluation of varietal susceptibility.

The IDM project operates through strong partnerships with macadamia growers, industry consultants, other national and international macadamia research programs and the industry peak body, the Australian Macadamia Society.

The overall objective of the IDM project is to safeguard the industry from pathogen threats, increase orchard productivity, improve nut quality and for continued access to international markets.

By improving our understanding of the pathogen biology and the environmental factors that contribute to disease emergence and severity, the IDM project provides diagnostic capability, resources and disease management options to support the industry.

Strategic and applied research, training and extension activities are ongoing for endemic priority diseases including Phytophthora diseases, flower blight complex, Botryosphaeria branch dieback, husk spot and Phomopsis husk rot.

Phytophthora diseases

Phytophthora diseases in macadamia cause significant economic losses. The potential economic risk to the global macadamia industry has stimulated extensive collaborations to identify the major causal *Phytophthora* species and deploy resistant germplasm.

A recent survey of Phytophthora diseases in Australian macadamia orchards has revealed a new major pathogen, *Phytophthora multivora*, as one of the causal agents of stem canker in macadamia (Figure 26 and Figure 27). Although several other species were obtained from the soil around macadamia roots and irrigation channels, the aggressiveness of these *Phytophthora* species is considered to be low in macadamia (Jeff-Ego et al. 2020). The exotic *Phytophthora ramorum* and *Phytophthora tropicalis* (the causal agent of macadamia quick decline in Hawaii and China) were not isolated in Australia.

Figure 26. Stem canker symptoms on macadamia caused by *Phytophthora multivora*.

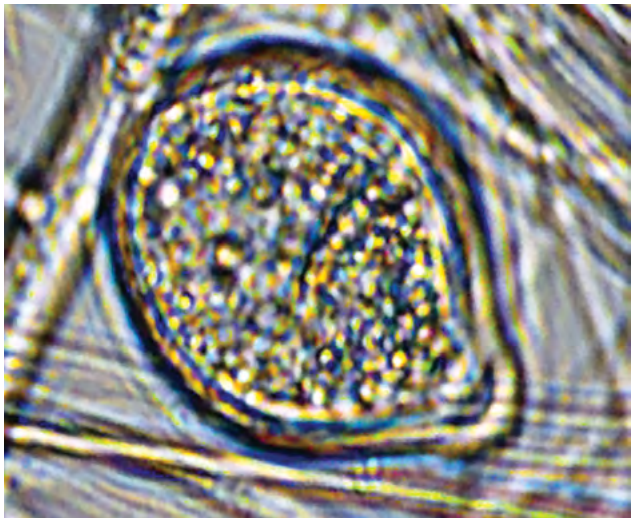

Figure 27. Sporangia of *Phytophthora multivora*.

A new *in vivo* macadamia whole-leaf-dip assay has been developed, with high-throughput potential to screen several *Phytophthora* species and determine varietal susceptibility.

Botryosphaeria branch dieback

A major concern to the macadamia industry is the increasing death of trees (Figure 28) associated with Botryosphaeria branch dieback. Several fungal species within *Botryosphaeriaceae* have been obtained from different tissues of macadamia (Jeff-Ego and Akinsanmi, 2018; Liddle et al. 2018). However, there is limited information on the pathogen biology and disease cycle, including the interrelated environmental stressors required for disease expression in macadamia. Understanding the biology and epidemiology of Botryosphaeria branch dieback in macadamia is the focus of current PhD research.

Monitoring of the fungal spores has so far revealed the influence of certain weather factors on the pattern of spore dispersal in macadamia orchards. The outcomes of this study will provide valuable tools and information to support disease management.

The current spray applications of phosphonates and soil health management strategies are still adequate to control *Phytophthora* infections and improve tree heath. The risk of residue above the minimum residue limit (MRL) in macadamia kernel is low when phosphorus acid products are applied at the recommended rates.

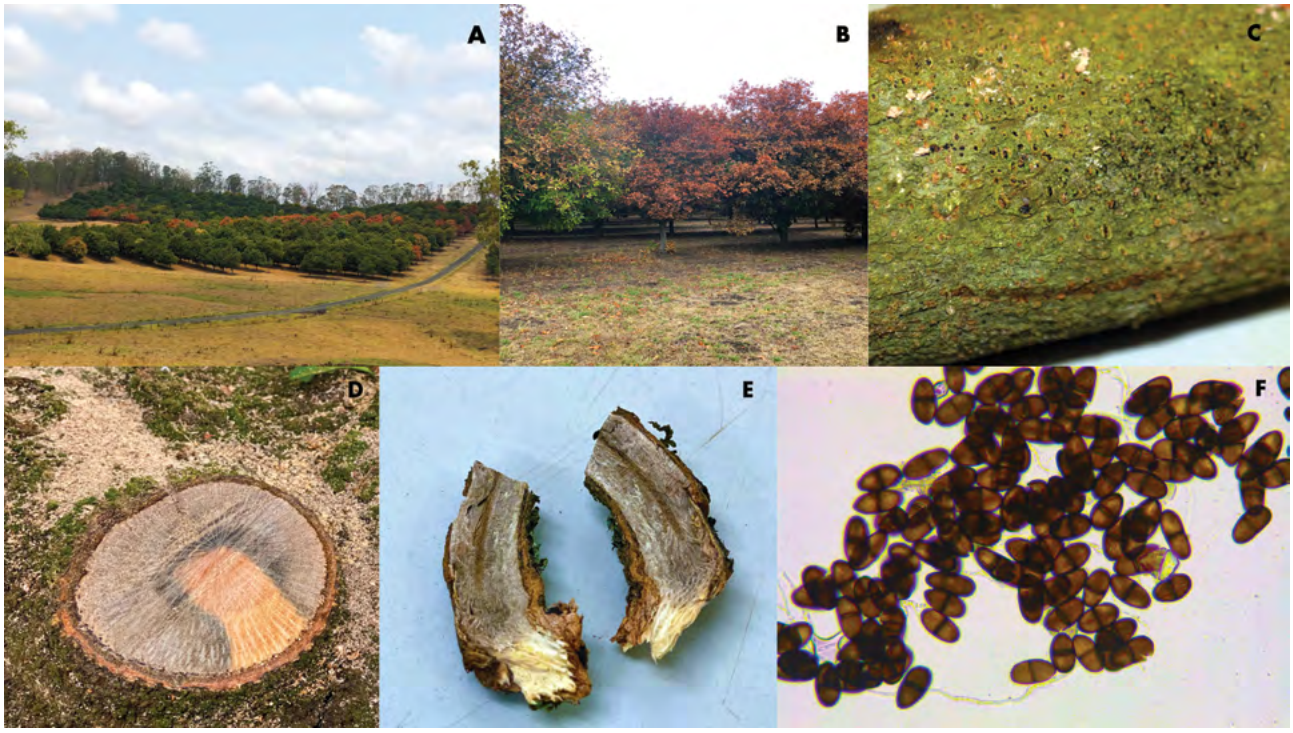

Figure 28. Botryosphaeria branch dieback symptoms on macadamia and fungal structures.
A-B: affected macadamia trees with characteristic brown, burnt-looking leaves that remain attached on the tree
C: fungal structure of Botryosphaeriaceae on macadamia branch
D-E: cross-sections of diseased trees with discoloured wood
F: conidia of one of the causal pathogens (*Lasiodiplodia* species).

Flower blight complex

The flower blight complex in macadamia in Australia includes dry flower (Pestalotiopsis blight), grey mould (Botrytis blight) and green mould (Cladosporium blight). Preliminary information from a PhD study has shown key differences in the biology and favourable climatic conditions for growth and development in the flower blight pathogens.

Temperatures between 18 and 22 °C are optimum for Botrytis blight, whereas the peak spore production and infection of the other pathogens occurred at about 25 °C (Figure 29). The dry flower causal agents (*Pestalotiopsis macadamiae* and *Neopestalotiopsis macadamiae*) function well within a wider temperature range of 22–30 °C and *Cladosporium* blight pathogen (*Cladosporium cladosporioides*) performs best at a narrow temperature range of 22–25 °C. Another key difference in the biology of the pathogens is the difference in the favourable flower stages for infection and disease development.

This information may be critical for field diagnostics and management options, including disease risk assessment protocol.

Phomopsis husk rot

Severe cases of Phomopsis husk rot (PHR) are often intermittent and the resulting economic impact may be significant. Recent reports have shown the diversity of the causal pathogens and four new species that cause PHR in macadamia have been described including *Diaporthe australiana*, *Diaporthe drenthii*, *Diaporthe macadamiae* and *Diaporthe searlei* (Wrona et al. 2020). It is estimated that effective control of PHR resulted in over $8,000 increase in NIS/ha (at $4/kg NIS, 10% MC) compared with the untreated control. Consistent effective control is hindered by limited knowledge about PHR aetiology and epidemiology. Further research is currently underway to address this gap in knowledge.

Leaf spots in macadamia

Spots are often observed on macadamia leaves. In most cases, these are caused by damage to the leaf tissue through chemical burns or injury. Extensive spots on all the leaves of young macadamia trees is a concern, due to the potential loss in the photosynthetic ability of the leaves, resulting in death and poor establishment of the affected trees.

Two new types of fungal leaf spots (Figure 30) were commonly detected in commercial macadamia orchards (Prasannath et al. 2020):

- **Pestalotiopsis leaf spot** – symptoms are circular dark brown spots with yellow halos caused by *Neopestalotiopsis clavispora*.
- **Colletotrichum leaf spot** – symptoms are irregular dark brown spots caused by *Colletotrichum siamense*.

These spots may coalesce to form a 'patch' blight. Further studies are underway to determine the importance of these pathogens and as sources of inoculum for other diseases in macadamia.

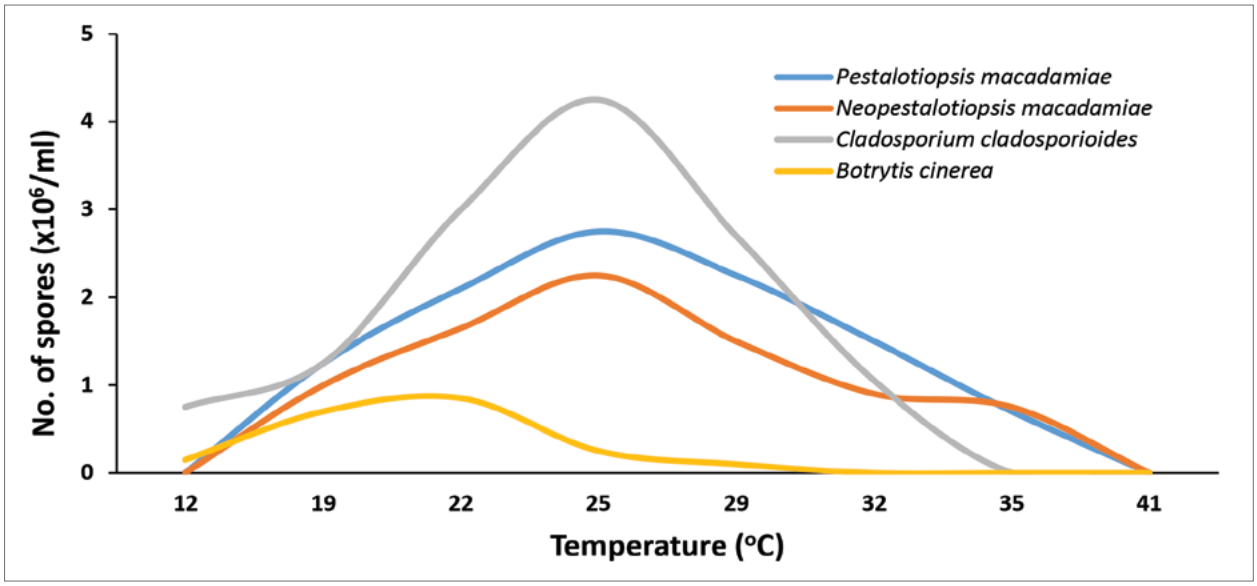

Figure 29. The average number of spores produced by flower blight pathogens at different temperatures.

Figure 30. Symptoms of leaf spots in macadamia. Top row: Pestalotiopsis leaf spot, symptoms are circular dark brown spots with yellow halos caused by *Neopestalotiopsis clavispora*. Bottom row: Colletotrichum leaf spot, symptoms are irregular dark brown spots caused by *Colletotrichum siamense*.

Acknowledgements

The research was funded by Hort Innovation using the macadamia research and development levy and funds from the Australian Government, project no. MC16018. We thank the industry crop consultants for their support and the diseased samples they submitted for diagnostics. We acknowledge and thank Dr Chris Searle of MacAvo Consultancy for the field photographs of the leaf spots symptoms and his contributions.

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Lessons learnt from the drought

Jeremy Bright, NSW DPI Development Officer – Macadamia

How to make your farm more resilient for the next drought and to make it more 'climate-ready'.

This year we are looking at some strategies for growers to implement to make their farm more resilient to extended dry periods and droughts. Most of this information has come directly from growers who have experienced these conditions. Interestingly, one of the main outcomes is that it is not the drought stress that kills the trees, but rather, the more serious secondary pest and disease infestations in the following years.

Background

Ironically, while writing this feature article we have just received over 200 mm of rainfall (February 2020), flood warnings are current for our rivers and there appears to be further heavy rain on the way. However, it was only three months ago that most of NSW was declared in drought. The north coast, which is normally lush, green and beautiful was brown, dry and smoky. With very limited rainfall in the previous 10 months, dams were getting low and fires were burning almost everywhere. On Tuesday 12 November 2019, a State of Emergency was declared and the fire prediction map showed that Mid North Coast macadamia growers were in the direct path of a major bushfire. Fortunately, the weather changed and the fire did not spread as predicted, however growers around the Bora Ridge area were affected (Figure 31), and my thoughts go out to them.

Figure 31. Bushfire damage to a macadamia farm.

Given this scenario and working through it on a daily basis, we all felt quite helpless because most of the everyday macadamia activities, such as spreading mulch and applying nutrition, rely on having moisture in the soil, which was not there. It was not a case of business as usual.

The prolonged drought and intense fire season have provided us with a good opportunity to work out strategies to enhance the resilience of our macadamia trees to give them a better chance of surviving a drought. These strategies can be applied, not just whilst enduring drought, but even before the dry conditions set in.

Retaining soil moisture

Grass

Depending on the time of year it is better to keep the grass longer by mowing less frequently for better moisture retention. For instance, during spring and summer (September–January) leaving the grass long can be beneficial by reducing evaporation. However, after January when the orchard floor is being prepared for harvest, it is better to reduce the grass height to help with harvest operations, yet still maintain adequate soil moisture.

Many growers have taken on this message and implemented alternate row mowing. Initially there was concern that the longer grass would be a corridor for rats. As a remedy, growers would mow a row and leave a row, i.e. alternate row mowing (Figure 32). This would prevent a 'rat highway' from establishing.

Figure 32. A tree-to-tree alternate row mow system. Photo: Paul O'Connor.

Mulch

Mulch is excellent for retaining soil moisture, being most effective when applied to moist soil and up to 10 cm deep. Regularly re-applying (e.g. every 2–3 years) provides the best results. The amount of mulch required per hectare at different depths is listed in Table 1.

Table 1. Mulch areas under the canopy and the amount required per hectare.

Mulch area	Amount of mulch per hectare
4 × 4 m^2	1.60 m^3 at 10 cm depth = 499.2 m^3/ha
	0.80 m^3 at 5 cm depth = 249 m^3/ha
3 × 3 m^2	0.90 m^3 at 10 cm depth = 280 m^3/ha
	0.45 m^3 at 5 cm depth =140 m^3/ha
1.5 × 1.5 m^2	0.22 m^3 at 10 cm depth = 68 m^3/ha
	0.11 m^3 at 5 cm depth = 35m^3/ha

As well as moisture retention, mulch builds soil organic matter and cation exchange capacity (CEC). Organic matter causes soils to clump and form aggregates, which improves soil structure, while the CEC influences how the soil retains essential nutrients and provides a buffer against soil acidification.

The microbial activity within the organic matter breaks it down to improve soil structure and oxygen levels, as well as improving the CEC. For best results, organic matter should be concentrated within 1.5 m from the tree trunk.

A 1% increase in soil organic carbon (SOC) equates to about a 2% increase in water holding capacity. Therefore, soil with a water holding capacity of 200 mm will hold an additional 4 mm of water, although this assumes the increase in SOC is consistent for the profile (Edwards 2019).

Preliminary trials using moisture probes have been conducted in ferrosol soils on the Alstonville plateau. Results show that a 24 m² profile at 600 mm deep with 3% OC would hold 360 L of water, whereas with 6% OC canopy full point at 600 mm will hold 460 L of water.

An increase in SOC is especially important during dry spells such as the dry springs which have been occurring recently. While these are not classed as drought, they effectively call on moisture resources for the plant to provide energy for cell structure development, i.e. nut sizing. This additional water holding capacity will allow the plant more resilience in these extended dry times. In peak nut production periods, the evapotranspiration could be 6–8 mm per day (Bureau of Meteorology), which equates to 160-180 L/tree/day on an 8 x 4 m spacing.

Additional benefits from mulch include minimising run-off and erosion because the soil is protected rather than being left bare. Therefore, applying mulch or compost should be a routine practice (Figure 33).

Applying mulch to a dry profile will prevent any eventual rainfall from penetrating the soil profile of existing root zones. If you are fortunate enough to have an irrigation system, then this could be used to break down the mulch and assist in further retaining moisture.

Figure 33. Applying mulch on a macadamia orchard.

The inter-row

Macadamia tree roots extend into the inter-row so it is important to build up the organic matter in this area. An easy way to do this is to leave any organic material out in the inter-row instead of broom-sweeping it back in under the tree trunk, then regularly bring in more mulch or compost to place under the tree. If this mulching is done early enough, the fine roots will grow up into the previously spread mulch and hold it firmly in place. Several growers have commented that this system works well for them and does not compromise harvest efficiency. However, other growers have found that for orchard floor clean up just before harvest, it might be necessary to sweep any material that could compromise harvest efficiency in under the tree. It might seem like a bit of a balancing act between keeping sufficient mulch in the right areas but at the same time not hindering harvest. Therefore, organic matter should be concentrated within 1.5 m from the tree trunks.

Managing Phytophthora

According to Associate Professor Femi Akinsanmi, from the Centre for Horticultural Science at the University of Queensland, one of the core principles that should be entrenched in standard orchard practice is that of 'good soil health equals good tree health'. Associate Professor Akinsanmi has written many great articles for us over the years and has mentioned several times that growers and industry should be concentrating their efforts on building organic matter within the soil. This provides the trees with more resistance and resilience to phytophthora, and ultimately builds orchard resilience for the next dry period or drought.

"good soil health equals good tree health"

Excessive herbicide use near the organic matter zone (1.5 m from the trunk) will create a 'barren zone' that will decrease microbial activity. This will disrupt the conditions you are trying to establish to create a system with phytophthora resistance.

To determine the strength of your soil and thus tree root structure, you can conduct a simple 'snap test'. This involves pushing a shovel into the soil and if the soil does not 'snap' with the shovel entering it (the 'snap' being the breaking of fresh roots), this could indicate insufficient root structure in the soil. These are the roots that need to get the moisture and nutrition from the soil, and if they are not structurally sound, then it is highly likely that the trees will probably go into decline relatively quickly when put under severe moisture stress. This snap test (Figure 34) can also be used to determine whether the root structure is sufficiently robust to resist pathogens such as phytophthora.

Figure 34. Associate Professor Femi Akinsanmi explaining the snap test.

Pruning

Trees should not be pruned when they are stressed. This includes during dry periods as the trees will be water-stressed. The exception to this is if you need to prune out dead or diseased limbs to prevent further disease spread (Figure 35). Commonly these limbs will harbour bark beetles (Scolytidae beetles) and possibly *Botrysphaeria*, so you should ensure dead and dying branches are cleaned out regularly.

Pruning for rejuvenation should not be done when there is limited moisture availability because poor sap flow through the tree will not be able to support new flush. It is better to have an effective long-term pruning program that builds resilience and provides a good structure to help the trees withstand drought conditions.

Figure 35. Dead wood can be taken out in dry times. Photo: Eddy Dunn.

Nutrition

During drought, and especially when there is no irrigation, it is often not practical to apply fertiliser to the ground. Unfortunately, the nutrition program will need to be stalled during this time.

Growers with irrigation should consider reducing their nutrient application so they can still supply adequate nutrition to support nut production, but not enough to encourage new flush as this will potentially create a competitive pull for resources from the flower and developing nut.

Another problem that can arise from prolonged fertiliser application without irrigation or rainfall is that the level of salts in the soil can build-up because they are not flushed through the soil. These excessive salts can contribute to root burn and potential disease.

New plantings

When planting out new trees in 'normal' conditions, ensure that the soil is of reasonable depth and has sufficient organic matter to give the trees the best possible chance.

Planting out new young trees should be delayed where drought is probable. On many occasions during drought we have seen some very quick tree decline. Further investigation revealed that most of the trees were planted on very shallow soil with underlying rock shelves (Figure 36). This meant that the plants were struggling to find adequate moisture to support themselves. Once the soil moisture was depleted, the trees shut down, making them susceptible to bark beetles, which attacked the trees and quickly put them into decline.

Avoid pruning that will invigorate new growth during drought as there will be insufficient moisture to support the new flush.

Summary

This drought has revealed the macadamia industry to be remarkably resilient. I have tried to gather the important lessons from growers, consultants, researchers and my own experiences. Hopefully we can build on these lessons and incorporate them into documentation outlining 'good practice' for how the industry can prepare their orchards to be more resilient to drought, or perhaps even become 'climate-ready'.

Figure 36. Trees originally planted on a shallow rock shelf.

Do not prune water-stressed trees unless you need to prune out dead or diseased limbs to prevent further disease spread.

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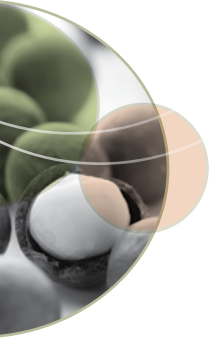

2020 hindsight – plagues, fire, wind and water: so what's next?

Wider pest windows, more generations in a season and more exotics

Craig Maddox, Technical Officer – Entomology, NSW DPI

The macadamia tree originated in the coastal rainforest districts of eastern Australia about 20–50 million years ago. First macadamia orchard attempts were made around 1895–1900 on cleared areas of the Alstonville plateau. Successful cropping started when DDT was used at flowering (Brimblecombe 1948) to control *Amblypelta nitida* (fruit spotting bug, FSB). The larger mechanised macadamia farming we see today began with CSR Limited developments in 1963 (Ainsbury 1983).

Macadamia flowers fail to set for many reasons, the *Macadamia Information Kit* (O'Hare and Rigden 2004) gave seven, not including macadamia lace bugs. The motto of the old growers was "*you have to protect the flowers*"; not much has changed today if you want a consistent yield. Three questions for the next 'would be organic' macadamia grower to consider very carefully before investing include:

1. how were macadamias pollinated before European bees arrived in 1840?
2. why did crops continually fail before 1948 with all that biodiversity around?
3. why was the DDT spray timing at flowering for FSB so effective? We know FSB is a problem all year round.

While tree health provides a base level of production, the myriad of pests and pathogens that could potentially invade the tree explains why we still rely on effective pesticides. With appropriately timed intervention, we can alter the balance in favour of the tree to enable survival (and even production) outside the normal limits of the plants' distribution. The effects of drought stress on rainforest trees have never been more evident than in the last 18 months for NSW (Table 2).

FSB remains the key pest of macadamia as its presence determines the need to spray the crop throughout the season in most districts. Measuring population changes in monitoring hedges and alternate hosts for over 10 years (Figure 37) has helped to adjust spray timing to coincide with new adult arrivals. Reducing FSB numbers entering orchards from neighbouring vegetation remains a priority research area.

Drought limits FSB activity but when wet weather arrives, they quickly exploit the crop (Figure 37 and Figure 38). During spring and summer when only 40% of the usual rainfall occurred, FSB numbers in the *Macadamia ternifolia* monitoring trees were only 30% of the usual levels (Figure 37). Within two months of rain, FSB numbers in the *Murraya paniculata* hedges returned to normal levels (Figure 38). FSB is well adapted to the climatic vagaries of Australia and very few parasitoids can match its dispersal capacity. It is always ready to exploit its' many hosts and it can feed through macadamia shell year-round (Figure 39).

Table 2. Rain (mm) per calendar year at the Centre for Tropical Horticulture (CTH) in Alstonville, NSW. This needs to be compared with the 40-year averages of 1,800 mm per annum and the August–December average of 534 mm.

Rain (mm) at Alstonville, NSW					
	2015	2016	2017	2018	2019
Annual	1939	1489	1970	1397	787
August–December	632	448	663	466	213

The new pest species *Leptocoris* spp. (Figure 40) filled the bug niche for macadamia during the dry periods at CTH Alstonville, just as they did in Gympie and Bundaberg. This pest also feeds through the shell but its activity windows are later in the season and they are easier to monitor than FSB.

Scolytid beetles are one of the more vexing pest management problems worldwide. Since foliar organochlorine applications were banned, forestry on virtually every continent has struggled to control these pests. Furthermore, their activity period has expanded in more temperate regions, where a 2–5 °C increase in annual temperatures has meant an extra two generations of beetles, resulting in wide areas of tree death. Controlled

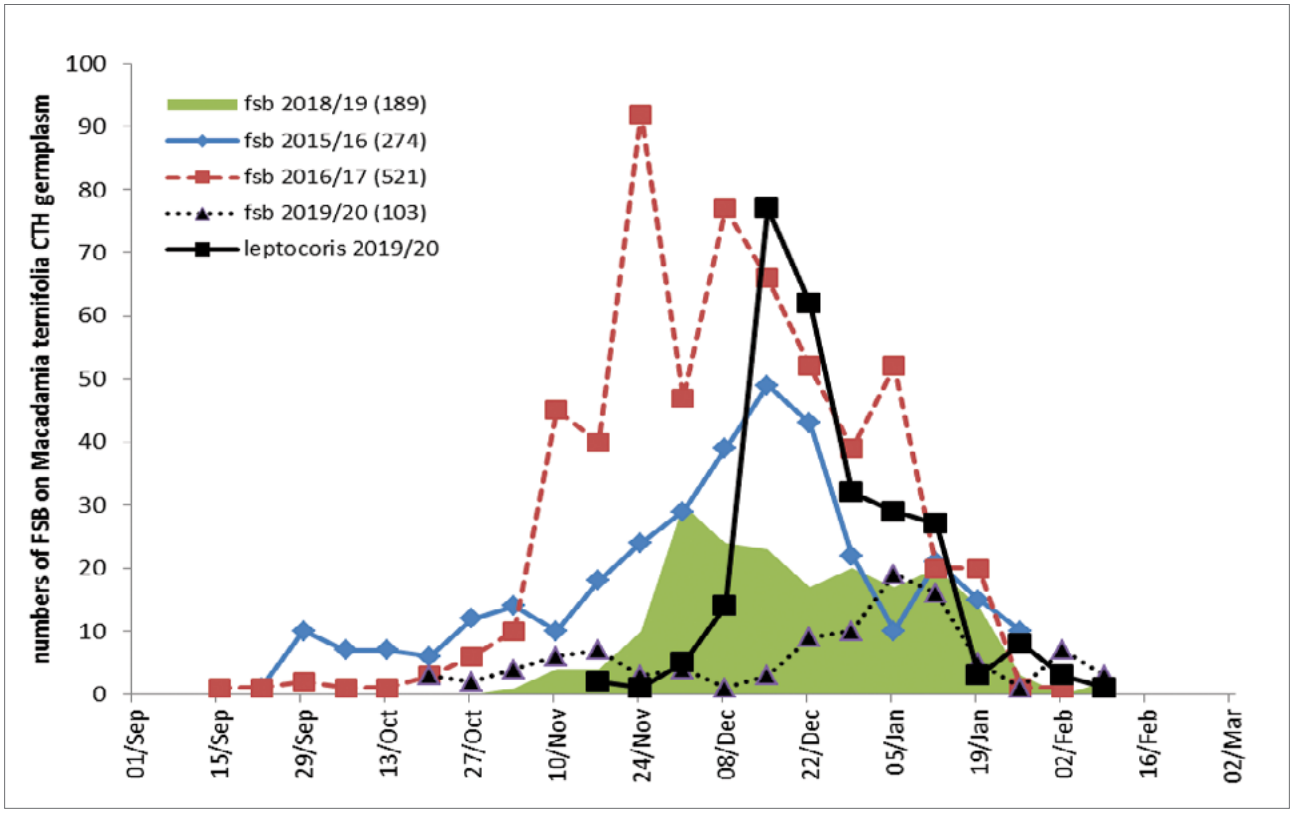

Figure 37. How the dry weather has influenced *Amblypelta nitida* levels on the germplasm *Macadamia ternifolia* at CTH Alstonville. The numbers of FSB seen for the season are in brackets and the arrival of a new pest, *Leptocoris* spp. this last season (solid black line). Macadamia lace bug prevented germplasm block nut set in 2017–18; no FSB population was observed in that season.

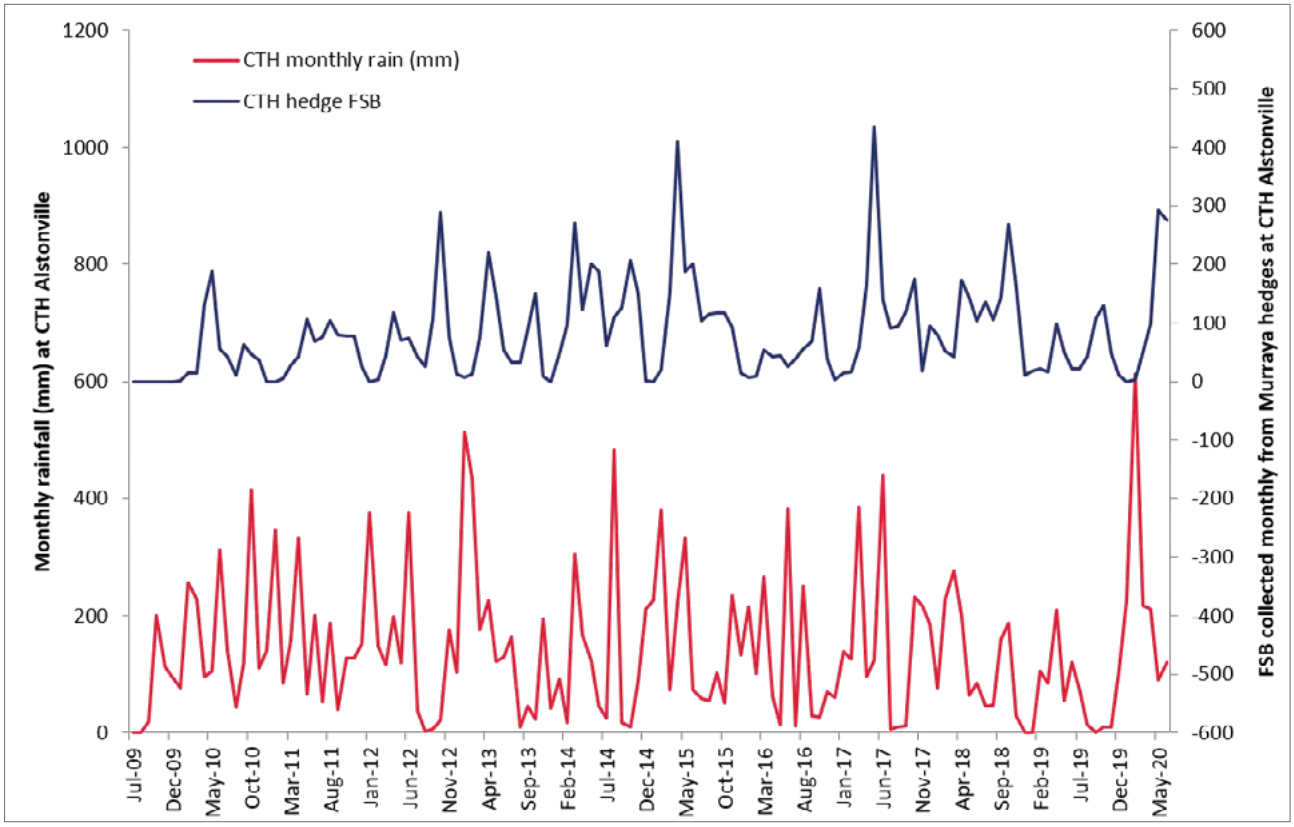

Figure 38. The levels of *Amblypelta nitida* caught in the CTH Alstonville *Murraya paniculata* hedges (black line) compared with the monthly rainfall (mm) (orange line). There were lower populations in drier seasons and there is usually no fruit in January–February, so not many bugs then. The hedges are proving to be reliable population indicators and enable us to predict flights in the field by using the weekly age structure.

burning of the infected forests in Canada and the USA failed because more trees were lost to the resulting 'uncontrolled wildfires'.

Figure 39. *Amblypelta nitida* feeding on *Macadamia ternifolia* nuts at CTH Alstonville.

Figure 40. *Leptocoris* spp. on *Macadamia ternifolia* monitoring plants at CTH Alstonville January 2020.

In Australia, drought normally ends with fire, which purges the vegetation of the beetles, then the populations slowly build up again until the next dry spell. The obvious problem for a macadamia orchard is that there is no fire and the trees have an ever increasing borer load. The cultural option for many tree crops worldwide is to prune and burn the infected wood. Doing this in winter will reduce the carry-over levels of cerambycid and scolytids within the trees.

Macadamia has a 'spray season' that normally targets other pests (shaded areas Table 3 and Table 4) and some of the current pesticides do control the adult beetles. However, beetle activity now extends beyond the coverage period. *Cryphalus subcompactus* (bark beetle; Figure 41) is flying from February until June in most orchards. This beetle is responsible for the ringbarking in most of the smaller branch dieback in macadamia. *Cnestus solidus* (Figure 42) is 20 to 100 times more prevalent through dry summers, and *Xylosandrus crassiusculus* numbers have been increasing since its detection in 2016 (Figure 42).

The main catch on the flight cards and in the methanol ethanol lures was *Cryphalus subcompactus* and *Hypothenemus seriatus* (Figure 41). In the Ambro® lures, well over 50% was *Cnestus solidus* in 2019–20, *Xylosandrus crassiusculus* was high in autumn in both years and *Xyleborus* spp. were caught in low numbers all year round *(*Figure 41).

Figure 41. *Xyleborus* spp. above, *Cryphalus subcompactus* (bark beetle) and *Hypothenemus* spp. below (all 1–2 mm). This is the usual catch in the methanol:ethanol lures.

The ambrosia scolytid beetle most likely to be associated with Dothiorella, Fusarium or Botryosphaeria fungal dieback, is *Euwallacea prebrevis* (tentative identification Helen Hahrung USQ QDAF and Ainsley Seago NSW DPI), which has been regularly found in south-east Queensland since 2009. Much work has been done on its relatives overseas to answer questions such as; does it just take out branches that are already senescing and therefore can be pruned out? We know it invades large healthy lower limbs during March–May, but does it bring the fungus with it or is the disease already there (Figure 43 to Figure 45)?

Table 3. How the dry conditions during 2018 and 2019 influenced scolytid beetle activity levels in macadamia orchards in the Northern Rivers area of NSW, CTH Alstonville (1800 mm annual rain, Rous 1500 mm, Caniaba 1300 mm; total rainfall for CTH Alstonville in 2019 was 787 mm). The shaded area represents the season normally covered by spraying for other pests (e.g. lace bug, FSB and seed weevil). The latent breeding population in autumn is the carry-over source between seasons and this has killed trees on a large scale, especially when sap flow reductions occur as water becomes scarce.

	Yellow flight traps for total scolytid catch						
	10 traps on site				8 traps		3 traps
	Rous				CTH		Caniaba
Month	2013–14	2014–15	2015–16	2019–20	2018–19	2019–20	2019–20
July	2	1	0	–	1	0	–
August	1	3	3	–	0	4	–
September	7	1	2	–	0	7	–
October	5	6	1	–	5	12	–
November	4	8	1	–	5	6	–
December	7	3	1	–	2	8	–
January	1	9	0	–	2	10	–
February	3	7	16	–	13	1	–
March	2	5	3	6	19	6	–
April	10	–	9	–	5	4	–
May	8	–	9	31	6	0	58
June	4	8	–	1	1	1	–

	3:1 methanol:ethanol traps			Ambro® lure traps			
	1 trap		2 traps	4 traps	8 traps	8 traps	2 traps
	CTH		Caniaba	CTH			Caniaba
Month	2018–19	2019–20	2019–20	2017–18	2018–19	2019–20	2019–20
July	1	7	–	0	11	5	–
August	8	51	–	5	5	33	–
September	6	12	–	3	4	308	–
October	20	29	–	0	9	120	–
November	11	98	–	2	26	136	–
December	1	65	–	5	33	47	–
January	0	32	–	0	10	165	–
February	1	5	42	8	116	41	15
March	38	23	102	14	76	43	19
April	31	10	–	35	8	34	–
May	188	25	583	36	30	20	25
June	37	1	–	–	8	17	–

Figure 42. The usual catch from Ambro® lures is a mixture of scolytids (top three) and a lot more *Cnestus solidus* (bottom), the larger trunk boring scolytid beetle.

Figure 43. *Euwallacea perbrevis* on live macadamia branches showing tunnel entrances and fresh boring.

Figure 44. The fungal wedge spreading inside where the beetles have been concentrating their feeding.

Figure 45. Branch dieback with the *Euwallacea perbrevis* tunnels evident when the wood is split.

For the cerambycids, the yellow flight traps (or intercept traps) remain the best indicator other than light trapping (Table 4). We have had consistent captures of the smaller beetles in spring and only the occasional individual in autumn, while there were twice as many caught in 2019 compared to 2018.

The most common cerambycids caught on the flight traps in macadamia orchards in NSW were *Syllitus* spp. (Figure 46) and *Mesolita* spp. (Figure 47).

Various cerambycids attack many parts of the macadamia plant. Tree deaths in recent seasons at Dunoon and Caniaba have been associated with *Tricheops ephippiger* mass feeding under the main trunk (Figure 48). We are only really able to catch the smaller ones on flight cards, light trapping will provide a much better indication of what is attacking the trees through a season. Given the outbreak of introduced scarab beetles that also need lights, the timing of more work here could not be better.

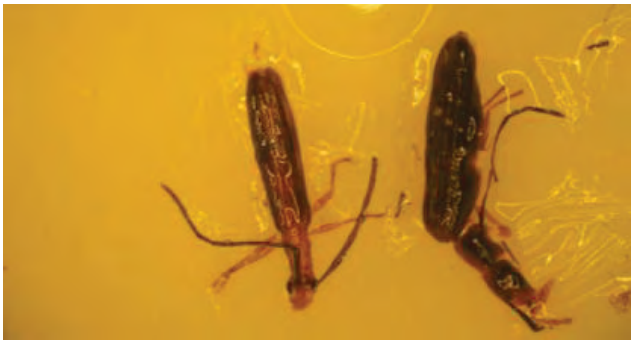

Figure 46. The most common cerambycid in the flight traps in macadamia orchards in NSW is *Syllitus* spp.

Figure 47. The cerambycid associated with smaller branches and racemes is *Mesolita* spp.

Figure 48. *Tricheops ephippiger,* cerambycid emerging from the dead tree trunks at Dunoon.

The exotics keep coming, even for macadamia where we already have most of the main problems, it does not mean they do not pose a threat. The best way to restrict that threat is to keep access to the things that work.

Table 4. Detection of cerambycid beetle activity in macadamia orchards in the Northern Rivers area of NSW, at Rous Farm, CTH Alstonville and Caniaba using the flight cards (best option at present for the smaller species), methanol ethanol traps and Ambro® lure traps (relatively ineffective). Shaded is the period of the season normally covered by spraying for other pests (e.g. lace bug, FSB and seed weevil). The latent breeding population in autumn is the potential carry-over source if the weather is particularly dry. Survivourship of larvae increases and longer life cycles of 2–4 years for larger species means they can re-emerge several years later as a potential threat.

	Yellow flight traps for cerambycid catch						
	10 traps on site				8 traps		3 traps
	Rous				CTH		Caniaba
Month	2013–14	2014–15	2015–16	2019–20	2018–19	2019–20	2019–20
July	0	0	1	–	0	0	–
August	0	0	0	–	0	0	–
September	0	2	1	–	1	1	–
October	2	8	8	–	3	7	–
November	1	10	1	–	0	0	–
December	2	0	1	–	0	0	–
January	0	4	0	–	0	1	–
February	1	0	0	0	0	0	–
March	0	0	0	0	1	0	–
April	2	1	0	–	0	1	–
May	0	0	0	0	0	0	0
June	0	3	0	–	0	–	–

	3:1 methanol:ethanol traps			Ambro® lure traps		
	1 trap		2 traps	8 traps	8 traps	2 traps
	CTH		Caniaba	CTH		Caniaba
Month	2018–19	2019–20	2019–20	2018–19	2019–20	2019–20
July	0	0	–	0	0	–
August	0	0	–	0	0	–
September	0	2	–	0	2	–
October	0	0	–	0	0	–
November	0	0	–	0	0	–
December	0	0	–	0	0	–
January	0	0	–	0	0	–
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	–	1	0	–
May	0	1	0	0	0	1
June	–	–	–	–	–	–

The Australian Macadamia industry used to have permits to use chemistry that penetrated the timber, reducing the larval populations and suppressing the fungal and bacterial pathogens associated with the more damaging scolytid beetles. Perhaps this is why this industry here has not seen the heavy tree losses where scolytid beetle and Botryspheriacae diseases have expanded globally? The withdrawal of those options means we are now facing more subtle threats to the longer-term viability of trees that will be worse in more drying times. The NSW DPI entomology team will continue this work, hopefully finding a suitable soft option soon.

References

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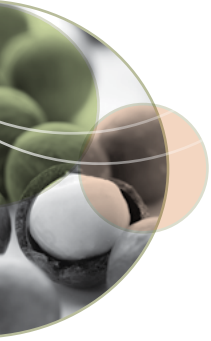
Brimblecombe AR. 1948. Fruit spotting bug as a pest of the macadamia or Queensland nut. *Queensland Agricultural Journal*, 67: 206–211.

O'Hare P and Rigden P. 2004. Growing macadamia: common questions. Chapter 3 in: Macadamia Information Kit. Agrilink, your growing guide to better farming guide. Department of Primary Industries, Queensland Horticulture Institute. Brisbane, Queensland, http://era.daf.qld.gov.au/id/eprint/1964/3/mac-growing_guide_Part3.pdf



Controlling pests and diseases in macadamia

While cultural controls will help to reduce pest and disease pressures in the orchard and should be used alongside chemical control programs, neither pesticide nor alternative management systems alone will give consistently satisfactory results; integrated management is required. Therefore, this section offers macadamia growers suggestions for integrated approaches to managing pests and diseases, incorporating responsible pesticide use.

Weather influences the incursion of several pests and diseases. Growers should be aware of conditions that increase the risk of outbreaks. For example, wet weather can trigger diseases such as husk spot, Botrytis and other fungal problems. High temperatures within and around the orchard can increase the speed at which insect pests develop through their life cycle.

Maintaining an open canopy, or selecting varieties that accommodate an open canopy, supports pest and disease control. Darker canopies have higher pest pressure. By opening up an orchard through canopy management, there can be substantial reductions in pests.

Reducing canopy height and maintaining it at or below the row width helps with pest control. Higher canopies are harder to achieve thorough coverage with crop protective sprays. Sticktights (old nut husks that do not fall) are an infection source across seasons and are more difficult to manage in taller trees. Removing dead and decaying branches is recommended. Sick trees should also be removed as they can encourage pests such as bark beetle and trunk borer.

Working with neighbours in an area-wide management (AWM) approach is another good strategy growers can pursue. This method recognises orchards as one large unit rather than individual farms. When pest incursions are detected anywhere within the area, they are controlled strategically. This reduces the chances of the pest populations developing within the area. A good example of this is macadamia nut borer parasitism; by monitoring moth flights across the region, the industry is able to coordinate the release of wasps to control the pest.

Trees are more vulnerable to damage from pests and diseases when they are stressed. Tree health can be supported by maintaining good soil health, which includes erosion control, adequate soil pH, maintaining high levels of organic matter to cover exposed roots, and ensuring adequate nutrients are available to the tree.

Very rarely will vertebrate pests be controlled through any one method, except perhaps exclusion fencing for pigs and deer. In most cases vertebrate pest solutions require a good understanding of the pest and its habitat, feeding (Figure 49) and breeding patterns.

This section provides an overview of the main pests and diseases of macadamia in NSW and Queensland and gives options for control based on research and grower experiences.

Figure 49. Pigs are getting very comfortable browsing in macadamia orchards.

Insect pests

Banana fruit caterpillar

The banana fruit caterpillar, *Tiracola plagiata*, has been a pest in banana plantations for over 100 years. In 1919, the Queensland Agricultural Journal noted the pest being located throughout the Queensland coast. The mature banana fruit caterpillar (BFC) was even featured on the Norfolk Island stamp (Figure 50). In macadamia it appears to be a serious pest in Emerald, Rockhampton, Baffle Creek, Bundaberg and on occasions, Gympie. The pest has a very large host range and also appears to be in greater numbers where inkweed (*Phytolacca octandra*) is present.

Figure 50. The 1976 Norfold Island stamp, featuring the banana fruit caterpillar adult.

Risk period

Table 5. The peak risk period for the banana fruit caterpillar is from early flowering to the end of spring flush.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Adults are medium to large moths (Figure 51) measuring 50–60 mm across the wings. The darker forewings are dull grey-brown with a dark brown V-shaped area on the fore margins. The hind wings are usually light brown to grey. The drab grey-brown larvae (Figure 52) have two pairs of black marks on the top of the body and grow to about 60 mm (Figure 53). The life cycle takes approximately six weeks.

The caterpillars will hide under leaf litter through the day and have excellent camouflage for this; if disturbed they will 'play dead'. They emerge at night to climb up the trunk and feed on the developing nutlets.

Management

Banana fruit caterpillar feeds during nut set, so monitoring should start at flowering. Look for chew marks on developing nuts up to 2 cm in diameter (Figure 54). Monitor the leaf litter under the tree weekly early in the season as adult moths will come in distinct flights. Usually there has to be a thick layer of leaf litter for the caterpillars to hide in.

At night the caterpillars can be found on the lower limbs of the tree or hanging via long silk threads that will glisten in torch or tractor lights (Figure 55).

It only takes a few caterpillars around the base of the tree to cause considerable damage to production. Threshold levels of 15 caterpillars per tree in a high set year and 5 per tree in a low set year have been suggested, but you should talk to your pest scout as this figure may change from year to year.

Figure 51. Banana fruit caterpillar adult.

Figure 52. Banana fruit caterpillar larvae.

Figure 53. A banana fruit caterpillar. Photo: Chris Searle.

Figure 54. Banana fruit caterpillar damage to macadamia. Photo: Chris Searle.

Figure 55. Banana caterpillars 'abseiling' from the tree to the ground on a silken thread, glistening in the light. Photo: Chris Searle.

Cultural and physical

The BFC is vulnerable within the mulched leaves at the base of the tree. Growers have had success through sweeping out leaf litter and mulching it up with a mower or slasher. Bundaberg grower Geoff Chivers reports that this system works very well in his orchard. Regular weekly monitoring will determine when to repeat this practice as re-emergence occurs. In future, it is hoped pheromone lure and trapping systems can be developed for this pest, making the timing for sweeping more precise.

Biological

There are many potential options for biological control of BFC, but further investigation is required because they would involve mass rearing and in-field releases of the beneficials before the infestation period. Other options that warrant further investigation include trap cropping, pheromone trapping, fungal, trunk and butt sprays as well as physical barriers.

Chemical

The chemical control option for BFC is listed in Table 6. Sprays for other pests within a season could help with control.

Further reading

Australian Pesticides and Veterinary Medicines Authority permit search, http://permits.apvma.gov.au/PER12796.PDF

CABI. 2019. Invasive species compendium, *Tiracola plagiata*, https://www.cabi.org/isc/datasheet/54016#tonaturalEnemies

Coffs Harbour Butterfly House. 2019. *Tiracola plagiata*, http://lepidoptera.butterflyhouse.com.au/hade/plagiata.html

Queensland Department of Agriculture and Fisheries. 2017. Banana fruit caterpillar, https://www.daf.qld.gov.au/business-priorities/agriculture/plants/fruit-vegetable/insect-pests/banana-fruit-caterpillar

Searle C and Boote M. 2016. Banana caterpillar (*Tiracola plagiata*) a pest that needs monitoring in Bundaberg and northern orchards. Suncoast Gold Newsletter.

Table 6. The chemical control option for banana fruit caterpillar in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Methomyl (Lannate® L) PER12796	S7	1A	0	High	Ground surface spray only. Blow out leaf litter before spraying.

Beetles (various) – an emerging pest

Scolytid beetles (Figure 56) have recently become more prevalent in the macadamia industry. This situation becomes far more complicated because scolytid beetles represent a family of beetles with many species that attack different parts of the macadamia plant. This section will describe the scolyitds we are beginning to understand. Since certain effective broad-spectrum pesticides are no longer available, these beetles have become a major concern worldwide, particularly in the forestry industry. NSW DPI is working towards obtaining accurate morphological taxonomies of these beetles to correctly identify them. In general, they all sit under Scolytinae, but as identification becomes more exact, the beetles will be allocated to their own categories.

Figure 56. *Cryphalus subcompactus*, scolytid adult.

Risk period

Table 7. Beetles can be present in macadamia orchards all year.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification and damage

Pest identification is more likely to be associated with **where** the damage is on the macadamia plant (e.g. phloem, xylem, hardwood, branches or trunks) and the **type** of damage caused rather than the actual taxonomy. The ecological niche of these beetles is breaking down lignin and they have different modes of action to do this.

Pin hole borers

Hypothenemus eruditus (predominantly NSW) and *H. seriatus* (predominantly Bundaberg) are beetles that infest the nuts in shell (Figure 57). The damage will be influenced by shell thickness, how long the fallen nuts have been left on the ground between harvests and orchard cleanliness. They are normally on the husk but in December and January, they can move into the shell and kernel. Areas of Queensland also have *H. birmanus*, which feeds on avocado trunks as well as macadamia. The Bundaberg region now has the Auger beetle (Figure 58), which will cause similar issues.

Ambrosia beetle

The ambrosia beetle (*Xyleborus* spp.; Figure 59) will burrow into the tree. They cause physical damage with the tunnels they create and pathogenic damage by introducing the ambrosia fungus into the xylem. They then cultivate their fungal garden as a food source for their offspring. This fungus contributes to plant dieback.

The elm bark beetle (*Hylurgopinus rufipes*), the vector for Dutch elm disease, is an example of this. In 2016–17, the NSW DPI Entomology team saw several single trees being destroyed by lightning strikes. Secondary to the lightning strike was the appearance of *Xylosandrus crassiusculus* (Figure 60) and *Cnestus solidis*, the latter drills into the hardwood, finishing off the plant and forms spaghetti-like sawdust masses (Figure 61). A clear sign of ambrosia boring damage is the sap exudation (Figure 62) and waste product collected at the base of the trunk (Figure 63).

Classic bark beetle

The classic bark beetle, *Cryphalus subcompactus*, feeds on the cambium layer and can potentially ring-bark branches (Figure 64), causing significant dieback (Figure 65 and Figure 66). In many cases, these trees are also suffering from other problems.

Longicorn beetle

Longicorn beetles (Cerambycidae; Figure 67) lay eggs into the bark crevasses. The larvae burrow into the hard wood going down into the trunk, leaving sawdust at the entry hole. When they emerge, they create a spiral cut similar to a plane used to smooth wood. Branches and limbs will most likely drop when the beetles emerge.

Carpophilus beetle

The carpophilus beetle (Figure 68) inhabits nuts in shell that other pests have recently exposed.

Carpophilus will feed on the kernel and, if they make it into silos and breed, will become a problem. Pheromone lures have worked well in controlling carpophilus beetle in other crops.

Figure 57. Pin hole beetle (*Hypothenemus seriatus)* damage, Bundaberg, Queensland.

Figure 58. Auger beetle (*Xylopsocus gibbicollis,* left) and *Euwallacea* spp. (right).

Figure 59. *Xyleborus* spp. damaging macadamia.

Figure 60. A 2 mm long scolytid, *Xylosandrus crassiusculus,* found in dead tree in Queensland.

Figure 61. The spaghetti-like sawdust masses caused by ambrosia beetles.

Figure 62. Sap holes in the trunk of an infected tree.

Figure 63. The sap collection at the base of a tree caused by ambrosia beetles.

Figure 64. Ring barking caused by *Cryphalus subcompactus.*

Figure 65. *Cryphalus subcompactus* exit holes in a dead branch at Bundaberg, Queensland.

Figure 66. A close up of the *Cryphalus subcompactus* exit holes.

Figure 67. A longicorn beetle (*Urocanthus* spp.) found on a young macadamia tree.

Figure 68. Adult carpophilus beetle (left) and larvae (right and above). Photo: Craig Maddox.

Management

The key to controlling most beetle pests is to maintain healthy trees with good sap flow and good orchard hygiene. If the tree has reasonable sap flow, the beetles cannot enter. When sap flow is reduced, for example during dry weather or disease, the beetle can tunnel into the plant.

Traps (Figure 69) are available to monitor the presence of most bark beetles and to indicate their flight times, but they will not control the pest. In general, beetle pests are somewhat controlled during the regular spray season. It is after March through to August, when no sprays are applied, that these pests can become prevalent in the orchard. If you find an affected tree, particularly if you see beetle exit holes, it is important to regularly check the trees nearby, because when beetles leave an infested tree, they usually move onto the trees nearby.

Figure 69. A trap that can be used to monitor bark beetle numbers.

Cultural and physical

Maintain good soil and tree health, as well as general orchard hygiene.

As the beetles are dry season pests, maintaining adequate irrigation where available will help prevent them from establishing in your orchard.

Postharvest sorting and hygiene will help to remove any nuts infested with carpophilus and

Hypothenemus spp., but it is easier to prevent the pests from establishing in the orchards and creating the holes through which carpophilus beetle enters, rather than dealing with them at postharvest.

A clear sign of bark beetle infestation is dieback. Any areas of dieback should be cut out of the tree and when cutting, check the cross-sectional cut. It should be clean and without any discoloured wedging (Figure 70) as this could indicate that the fungus that causes branch dieback (*Botryosphaeria ribis*) has also infested the branch (see 'Branch dieback' on page 86). Keep cutting the branch lower until you see a clean cross-section.

Figure 70. A discoloured cross-section potentially indicating that *Botryosphaeriaceae* has also infested the branch.

All infested material should be burnt as soon as possible. Do not make a burn pile that will sit in the corner of the orchard for months as this will provide a perfect breeding environment for the beetles. If you cannot burn, such as during a fire ban, the next best option is to finely chip all dead and decaying timber. These can then be incorporated into a composting pile where the temperature ranges between 50 and 65 °C before turning (see NSW DPI Primefact 'How to compost on farm'). These temperatures will kill the bark beetle within the chip. If burning or composting is not performed, beetles will breed in infested trees and attack other less healthy plants.

Another non-burn chipping option is to solarise the chip. This involves laying plastic over the chip pile and placing it in direct sunlight. Temperatures will reach over 70 °C, which is enough to kill the beetle.

Do not leave burn piles anywhere in the orchard.

Biological

The NSW DPI entomology team have noticed some bark beetles have been infested by *Metarhyzium* or *Beauvaria*. Research is continuing to see if this could become an effective control method.

Chemical

There are no products with label registration or permits for any of the Scolytids. As these beetles are active throughout the growing period, it is fortunate that sprays for other pests within a season should help with control in most seasons.

Further reading

Maddox C, Mitchell A and Dawes M. 2009. Identification of Australian Scolytid beetles in macadamia tissue and the use of DNA barcodes for the rapid identification of exotic pest incursions. *Australian Macadamia Society Bulletin*, March 2009.

Mitchell A and Maddox C. 2010. Bark beetles (Coleoptera: Curculionidae: Scolytinae) of importance to the Australian macadamia industry; an integrative taxonomic approach to species diagnosis. *Australian Journal of Entomology*, 49 (2): 104–113.

Black citrus aphid

The black citrus aphid (*Toxoptera citricida*) infests young shoots and flowers on new growth. In mature orchards it is considered a minor pest, but in nurseries or newly planted trees in the field, it can be serious.

Risk period

Table 8. The peak risk period for the black citrus aphid is from pre-flowering to peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Identification and damage

Black citrus aphids are soft-bodied and up to 2 mm long. They will often be accompanied by ants that will tend the honeydew secretions from the damaged flower buds (Figure 71). Black sooty mould often accompanies this. Infestations are most common in the cooler months of winter and early spring.

Management

Monitoring should start around winter and spring so the aphids can be identified early, i.e. before flowering. Also look for ants which will accompany the citrus aphid.

Biological control

There are several natural enemies of the black citrus aphid, including parasites, predators and pathogens. The most common are ladybird beetles (adults and larvae), syrphid fly (hoverfly) larvae, lacewing larvae, and tiny parasitic wasps that lay their eggs in the adult aphids. These populations should be encouraged through growing refuge corridors. The Hort Innovation IPM project is looking into this.

Chemical

There is no registered chemical available for use on black citrus aphid in macadamia. Sprays for other pests within a season should help with control.

Figure 71. Black aphids and ants on flower. Photo: Chris Fuller.

Further reading

Jackson G. 2017. *Citrus aphid fact sheet*, https://www.pestnet.org/fact_sheets/citrus_aphids_249.htm

Queensland Department of Agriculture and Fisheries. 2003. *Macadamia problem solver and bug identifier*, http://era.daf.qld.gov.au/id/eprint/1964/12/mac-problemsolver_Part4.pdf

Flower looper

The flower looper (*Gymnoscelis subrufata*) damages flower racemes but is considered to be a minor pest for macadamia.

Risk period

Table 9. The peak risk period for the flower looper is from pre-flowering to peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Identification and damage

Flower looper larvae are up to 15 mm long and light green with brown spots running along the body (Figure 72). The larvae feed on flower buds, mainly at the bulbous ends.

Management

Monitoring from pre-flowering to flowering will help identify the flower looper's presence as well as any other flower pests.

An IPM approach should help control this pest.

Chemical

There is currently no chemical registered for the macadamia industry to control flower looper. Controlling other flowering pests, such as lace bug and macadamia flower caterpillar, will usually control this pest.

Figure 73. An adult flower looper on a raceme. Photo: Craig Maddox.

Figure 72. A flower looper. Photo: Chris Fuller.

Fruit spotting bugs

The fruit spotting bug (*Amblypelta nitida*) and the banana spotting bug (*A. lutescens lutescens*) are considered to be the most important pests of macadamia. Both feed on macadamia fruit and flowers and have multiple host plant species. *Amblypelta nitida* is present in Northern NSW and South East Queensland, while *A. lutescens* can be found from the Queensland border through to Cape York.

Risk period

Table 10. The peak risk period for fruit spotting bugs is from peak flowering to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Both spotting bugs have seven life stages including an egg stage, five nymph stages and an adult stage. Eggs are oval, about 1.7 mm long and pale green with a slight opalescence. They are laid singularly on fruit, leaves and branches. Wing buds appear at the third nymph stage, growing until the fifth stage. The first instar nymphs of both species look similar, but the later stages can be distinguished by colour patterns. Fruit spotting bug (FSB) nymphs have reddish–black legs and antennae and an orange–brown abdomen (Figure 74). Banana spotting bug (BSB) nymphs are a pinkish red and white and have a distinctive light red stippling surrounding the pair of large black spots on the abdomen (Figure 75). The adult stages of both species are winged and relatively narrow. Both species are approximately 15 mm long and differ primarily in colour. The FSB is generally a slightly darker green with a black background sheen, while the BSB is generally slightly more rectangular with a yellowish–brown background. The BSB has distinctive white halos around the abdominal spots.

Damage

The first indication of fruit spotting bug damage is a heavy nut fall of young green, roughly pea-sized nutlets. On most varieties a sunken dark spot is visible. Brown lesions become apparent on the inside of the husk and on the developing soft shell and kernel. When the shell starts to harden, damage shows as a pin-point mark, craters or crinkled spots on the shell. These become darker and sunken as the nuts develop.

Kernel damage appears as a translucent brown water-soaked spot. In many cases, this may be covered by mould when inspected after harvest. It only takes a few insects per tree to cause a lot of damage, particularly when the nuts are small.

Natural thinning is a normal process of macadamia. However, about two months after initial set (usually from October to December), if there is a noticeably higher nut drop, it could be attributed to fruit spotting bugs. As the nuts develop further, they are less likely to drop after being stung.

Figure 74. *Ambypelta nitida* nymph.

Figure 75. *Amblypelta lutescens lutescens* nymph.

Management

Fallen nutlet counts from October to November are the key monitoring tool crop scouts use to inform spray recommendations; the spray threshold is 3% of nuts falling.

As the nuts mature later in the season (December onwards), they are less likely to fall once stung, but they will be unmarketable. Nuts of all sizes and maturity levels can be damaged, although less frequently after shell hardening in January. Damage is visible as dark, slightly sunken spots on the husk, collapsed testa while it is soft, and misshapen, brown and shrivelled translucent kernels. Further damage can be caused by secondary disease from organisms spread by FSB.

Monitoring

Regular FSB and BSB monitoring is essential but is not always easy because:

- they are very mobile, tending to move around in the top half of the trees
- they are shy and do not congregate in large numbers
- a small number can cause significant damage
- they lay eggs singularly

Key steps for effective monitoring include:

- identifying FSB and BSB entry points and natural harbours
- monitoring bordering vegetation
- identifying hotspots in the crop (FSB often return to a damaged tree)
- check at least 10 trees in hotspots and 20 trees in other areas
- understand the timing and methods for monitoring, for example, when searching for fresh FSB and BSB damage:
  - start when small pea-size nuts start dropping in October
  - after the initial nutlet shedding, dissect 10 fresh green fallen nuts per tree and check for sting lesions in the husk and shell (Figure 76)
  - identify other insect damage e.g. macadamia nut borer and macadamia seed weevil (Figure 77)
  - repeat fortnightly until nut drop stops in December
  - late damage is difficult to detect as the nuts remain in trees.

Fallen nuts need to be checked for fresh damage from early in the season until mid-December. This ceases to be an accurate indicator of recent activity the further into the season you measure. Activity after the shell hardens from January onwards, particularly on the thinner shelled varieties (e.g. A4, 849), is hard to detect from the ground and if unchecked, can be very costly.

When monitoring nut drop in spring, it is important to recognise and distinguish the common causes of nut drop, including macadamia seed weevil, macadamia nut borer and fruit spotting bug feeding (Figure 77).

Using a trap crop

Trap crop hedges are being used commercially for FSB and BSB monitoring. A trap crop is a species planted in a hedge next to the macadamia crop that also attracts FSB and BSB. One of the best trap crop species is *Murraya paniculata*, or mock orange. Other proven species include *Macadamia ternifolia* and longan. These species are now being trialled for their effectiveness in predicting FSB and BSB movements as part of the Hort Innovation levy funded IPM project (MC16004).

Trap crop monitoring aims to predict when adult bugs start moving into an orchard. Ideally, a grower can then time their spraying accordingly, thus limiting production losses with minimal sprays at targeted times.

Figure 76. Checking for sting lesions in husk and shell.

Figure 77. Common causes of nut drop include macadamia seed weevil (top left), macadamia nut borer (top right) and fruit spotting bug feeding (bottom).

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During spring, a FSB hotspot will appear in the trap crop before the macadamia crop. The FSB stay in the hedge once feeding starts and monitoring should detect a build-up of large 5th instar nymphs. These are almost adult size, with black antennae, black 'knees' and only wing buds rather than fully expanded wings.

Adult FSB will be ready to fly 10–14 days after 30% of the bugs reach the 5th instar nymph stage. This is the optimal time to spray for the first FSB wave of the season. The hedge should be continually monitored for further generations to emerge.

Cultural controls

To reduce the risk and damage from fruit spotting bugs:

- select appropriate varieties (avoiding thin-shelled macadamia varieties)
- reduce tree height to improve spray coverage
- reduce canopy density by selective limb removal or new growing systems
- reduce tree density (tree removal)
- reduce out-of-season flowering
- use cover crops in the inter-row
- improve bordering alternate host vegetation management.

Biological controls

Use cover crops in the inter-row to provide habitat for natural enemies of FSB, such as:

- egg parasitoids
  - *Anastatus* spp. near pentatomidivorus (Eupelmidae)
  - *Ooencyrtus caurus* (Encyrtidae)
  - *Gryon* spp. (Scelionidae)
  - *Centrodora darwini* (Aphelinidae)
- nymph and adult parasitoids include the tachinid fly, *Trichopoda giacomellii*
- predators:
  - spiders
  - ants e.g. green tree ant *Oecophylla smaragdina* and big head ants *Pheidole* spp.
  - predatory bugs e.g. assassin bug *Pristhesancus papuensis* and lacewings, e.g. brown lacewing *Micromus tasmaniae*.

Chemical control

Timing is critical for fruit spotting bugs. Spraying a week early will not be effective. Therefore monitoring is key to the control. Trap crops of *Murraya paniculata* are good FSB indicators and can help determine pressure levels. Monitor orchard boundaries, particularly if backing onto host species. Use previous incidences to help predict incursion. The chemical control options for fruit spotting bugs are listed in Table 11.

Table 11. The chemical control options for fruit spotting bugs in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acephate (Lancer® 970)	S6	1B	0	High	Do not spray when bees are foraging.
Acetamiprid + pyriproxyfen (Trivor®)	S6	4A + 7C	14	High	Do not spray when bees are foraging. Toxic to bees.
Azinphos-methyl (Gusathion® 200 SC)	S7	1B	7	High	Contact and stomach action, moderate persistence. Dangerous to bees and will kill bees foraging in the crop. Residues toxic to bees may remain for several days after application.
Beta-cyfluthrin (Bulldock® 25 EC)	S6	3A	7	High	Do not use more than two sprays per season to avoid resistance.
Methidathion (Suprathion® 400 EC)	S7	1B	21	High	Avoid using other 1B chemistry to prevent resistance occurring. **Can only be used until 4 February 2021.**
Sulfoxaflor (Transform™ Isoclast®)	S5	4C	0	Medium	Do not spray when bees are foraging.
Trichlorfon (Lepidex 500) PER13689	S6	1B	2	High	Toxic to bees.

Green vegetable bug

Green vegetable bug (*Nezara viridula*) adults and nymphs will feed on macadamia nuts at all stages. When disturbed, the green vegetable bug (GVB) releases a strong aroma to deter predators.

Risk period

Table 12. The peak risk period for green vegetable bugs is from peak flowering to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The adult green vegetable bug is 15 mm long, green and shield-shaped (Figure 78). The nymphal stage looks similar to the adult, but with a range of green, yellow and black markings. Females lay clusters of 40 to 80 pale yellow eggs that become pink over time. They will hatch in about one week. The nymphs develop through five stages before becoming adults. The complete life cycle takes approximately 5–8 weeks and there are about 3–4 generations a year. The GVB will overwinter on other host crops, under bark or in sheds. In warmer coastal areas, GVB will feed and breed all year round.

Damage

There might not be any signs of GVB damage on the shell, but when the kernel is extracted, the signs will be similar to those caused by FSB (Page 41). Most damage occurs from early shell-hardening onwards. Lack of external damage requires pest scouts to physically crack open the nuts to assess them.

Management

GVB does not normally develop on macadamia; most infections are caused by the adults migrating into the orchard from another host crop. GVB will also attack legumes (such as beans and soybeans) so growing areas where sugar cane is rotated with bean crops should have thorough monitoring, particularly after a bean crop has been harvested.

Cultural and physical

Remove weeds that could be breeding sources for GVB. A diverse inter-row planting can still be used but host species should not be included and close monitoring will be essential, both within the inter-row and the adjoining macadamia crop. Options for managing pests within the inter-row plantings are still being refined through 'The IPM program for the macadamia industry' (MC16008).

Biological

GVB eggs are frequently parasitised by a wasp, *Trissolus basalis* and GVB nymphs are attacked by ants, spiders and other predatory bugs. The fifth instar and adult can be parasitised by the tachinid fly, *Trichopoda giacomellii*.

Chemical

Timing is critical. Monitor orchard boundaries, particularly if backing onto GVB host species for the full season. Use previous years' incidence to help predict incursion. The chemical control option for GVB is listed in Table 13. Sprays for other pests within a season should help with control.

Figure 78. Adult green vegetable bug.

Table 13. The chemical control option for green vegetable bug in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Trichlorfon (Lepidex) PER13689	S6	1B	2	High	Toxic to bees.

Leptocoris

Leptocoris species (commonly called soapberry bugs, family Rhopalidiae), are widely distributed throughout NSW and Queensland. They will leave their native host and attack cultivated plants such as macadamia.

Risk period

Table 14. The peak risk period for *Leptocoris* species bugs is from nut set to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The adult *Leptocoris* spp. has a narrow body, is reddish–brown, winged and about 12 mm long (Figure 79). Underneath the body is dull red with a dark green area in the middle of the abdomen. Legs and antennae are black. *Leptocoris* spp. nymphs have a bright red abdomen with a brown–black head (Figure 80). There are most likely two species of *Leptocoris*; *L. rufomarginatus*, found in Northern NSW and *L. tagalicus*, found in the Amamoor region, Gympie. Both species will feed on macadamia.

Ideally the native host plants such as the foam bark tree (*Jagera pseudorhus)* and golden rain tree (*Koelreuteria elegans)* will carry *Leptocoris* spp. while macadamia are susceptible. If however, the native host has no crop, *Leptocoris* spp. will seek out macadamia. An incursion will generally be a large aggregation of *Leptocoris* spp. into the macadamia crop.

Damage

The damage from *Leptocoris* spp. will appear similar to Fruit spotting bugs (FSB) and Green vegetable bug (GVB) damage but it will be shallower in the kernel (Figure 81). The damage from all of these pests will render the kernel unsaleable.

NSW DPI research suggests that, through dry weather such as experienced in 2019–2020, fruit spotting bug pressure was low and *Leptocoris* spp. pressure was high. Once rainfall returned, FSB pressure increased and *Leptocoris* spp. pressure decreased.

In the 2019–20 season, weekly monitoring picked up flights into macadamia at the Centre for Tropical Horticulture, Alstonville in mid-December and they were coming into selected trees at twice the rate of FSB detection. It is not unusual for *Leptocoris* spp. to come in through drier seasons, as was observed in the Gympie area during the 2014–15 season.

Figure 79. *Leptocoris* spp. Photo: Ruth Huwer.

Figure 80. *Leptocoris* spp. nymph. Photo: Ruth Huwer.

Management

Monitoring is the key to controlling *Leptocoris* spp. Growers can identify potential pressures by monitoring any surrounding host plants such as the foam bark or golden rain tree. It is likely that in a dry year, *Leptocoris* spp. pressure will be high. Pest scouts who perform routine fruit spotting bug checks will also be able to identify *Leptocoris* spp. within the crop (Figure 82). Pest consultants will also have control strategies and as they are working within the region your farm is located, will be able to alert growers to population pressures. As *Leptocoris* spp. populations increase within the orchard, so will the damage to the crop.

Cultural and physical

Ensure that tree height is suited to the capacity of your orchard sprayer. An inability to cover all of the crop will leave opportunities for *Leptocoris* spp. to continue damaging nuts; coverage is key. Ensure adequate plant density and allow good air movement throughout the canopy. Use existing foam bark or golden rain trees as *Leptocoris* spp. monitoring tools. Where they are in high numbers on these trees, be aware of the stage of production of your macadamia crop and be prepared to control the infestation.

Biological

A fly parasite Tachinidae Phasiinae *Gymnoclytia* spp. (Figure 83) has been isolated in the field by NSW DPI entomology staff and identified by Ainsley Seago, NSW DPI. Egg parasitoids used for fruit spotting bug are not effective on the *Leptocoris* spp. eggs. Birds do not usually feed on *Leptocoris* spp.

Chemical

There is currently no product registered for controlling *Leptocoris* spp. in macadamia. Sprays for other pests within a season might help with control but NSW DPI entomology staff have identified that not all fruit spotting bug chemicals will control *Leptocoris* spp. There is a requirement for registration of a product that will control it. Talk to your crop consultant regarding control strategies.

Figure 81. Fruit spotting bug feeding damage on the left and *Leptocoris* spp. damage on the right. Photo: Craig Maddox.

Figure 82. *Leptocoris rufomarginatus* on a macadamia after shell hardening. Photo: Craig Maddox.

Figure 83. The parasitic fly (*Gymnoclytia* spp.) of *Leptocoris* spp. identified in the field by NSW DPI entomology team. Photo: Craig Maddox.

Macadamia felted coccid

Macadamia felted coccid (*Eriococcus ironsidei*) and other Pyralid moths have been an issue recently in both nurseries and in-field plantings. Macadamia felted coccid is a common nursery pest which can quickly destroy young seedlings and newly planted trees. In established trees, high macadamia felted coccid numbers on flowers will cause flower death. It is important for growers to implement good quarantine protocols, especially when receiving nursery material onto their farms. Disinfesting this material and cuttings will help reduce felted coccid incursion onto farms.

Risk period

Table 15. Macadamia felted coccid can be present in macadamia orchards all year.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Macadamia felted coccid (MFCoccid) appear similar to mealybugs. The name comes from the felt-like appearance of the adult female and pupal case of the males. Adult females will moult twice and then become immobile and look like scale. Adult males moult once before developing wings and spend their adult life looking for females to mate with. Once mated, the female will develop its felted sac covering where it deposits eggs (Figure 84). There can be up to 6 generations a year with the life cycle taking around 40 days.

Figure 84. Felted sacs where the female macadamia felted coccid will lay her eggs. Photo: Chris Fuller.

Signs of damage

MFCoccid can damage all above ground parts of the tree (Figure 85), including the macadamia husk (Figure 86). Young leaves will be distorted and stunted as the individuals insert their needle-like mouthparts into the plant tissue and remove sap (Figure 87). MFCoccid will also excrete droplets of sugary honeydew onto the lower branches. The damaged leaf will develop yellow spots, turn brown and eventually die. On bearing plants, nut yields can be reduced and nut drop might be delayed.

Figure 85. Macadamia nuts covered with macadamia felted coccid. Photo: Ryan Finnerty.

Figure 86. Macadamia felted coccid on a nut husk. Photo: Chris Fuller.

Figure 87. A macadamia leaf that has been damaged by macadamia felted coccid. Photo: Chris Fuller.

Management

Growers should enforce strict disinfestation of any new plant material coming onto their orchard to ensure limited opportunity for felted coccid to enter. The introduction of macadamia felted coccid to new areas will cause sudden flare ups where they are in numbers that are too high to control (peaks and troughs pest predator cycle). Spot spraying affected and surrounding trees is an option. MFCoccid travels best with movement of infested material such as budwood, cuttings and potted nursery trees. This path has seen MFCoccid move between farms, regions and even countries.

Cultural and physical

Inspecting incoming materials and disinfesting are the best prevention strategies available.

Biological

Natural MFCoccid enemies include:

- ladybird beetles and larvae *Midus pygmaeus*, *Rhizobius ventralis*, *Serangium maculigerum*
- predatory moth *Batrachedra arenosella*
- egg parasitoids *Aspidiophagus* spp., *Metaphycus* spp.

These can maintain adequate control but initially MFCoccid populations increase quite quickly and cause severe damage.

Chemical

Regular monitoring will provide early identification so treatment can be applied before MFCoccid numbers reach damaging levels. This is the key to effective integrated pest management. The chemical products available to control MFCoccid are listed in Table 16.

Further reading

Ironside DA. 1995. *Insect pests of macadamia in Queensland*. Queensland Department of Primary Industries, Brisbane.

O'Hare P, Quinlan K, Stephenson R and Vock N. 2004. *Macadamia grower's handbook*. Queensland Department of Primary Industries, Brisbane, http://era.daf.qld.gov.au/id/eprint/1964/6/mac-growing_guide_Part6.pdf

Table 16. Chemical control options for macadamia felted coccid in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Diazinon (Diazinon)	S6	1B	14	High	Toxic to bees. Qld and NSW only
Methidathion (Suprathion® 400 EC)	S7	1B	21	High	Be wary of repeated applications as this will create resistance. **Can only be used until 4 February 2021.**
Petroleum oil (Summer spray oil) PER11635	S5	Unspecified	0	Low	Do not apply petroleum oil when temperatures exceed 32 °C or when soil is dry and trees are suffering from moisture stress.

Macadamia flower caterpillar

Macadamia flower caterpillar (MFC) is a pest solely of the Proteaceae family and is a major pest of macadamia. Generally, early flowering varieties will avoid high MFC infestations, but as flowering duration extends, MFC numbers build up so later varieties are affected most. Unchecked MFC can cause 100% damage to orchards.

Risk period

Table 17. The peak risk period for macadamia flower caterpillar is from pre-flowering to peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The adult moth is most active during the main flowering period, i.e. July to October. Eggs are laid on flower buds and are white–yellow (Figure 88), making them easily confused with immature scale insects. There are five larval stages and they all feed on the flowers or buds. Larvae usually start out yellow but when fully developed, will become light green to grey and up to 12 mm long. Macadamia flower caterpillars (Figure 89) can severely reduce a nut crop if not controlled. Adult moths are grey, 6–7 mm long with a wingspan of 14–18 mm and generally most active at night.

Figure 88. Macadamia flower caterpillar egg on a flower bud. Photo: Chris Fuller.

Figure 89. Macadamia flower caterpillar.

Signs of damage

A drop of sap is often seen on the side of the flower where larvae have entered the flower bud. Other signs include browned-off flowers (Figure 90), destroyed buds as well as webbing (Figure 91) and frass covering the flowers and racemes. As with most pests active at flowering, early flowering cultivars are not as heavily affected. Later flowering cultivars and those with prolonged flowering are likely to suffer the most damage from macadamia flower caterpillar.

Figure 90. Browned-off flowers from macadamia flower caterpillar. Photo: Chris Fuller.

Figure 91. Flowers and racemes covered in webbing. Photo: Chris Fuller.

Monitoring

Regular monitoring from pre-flowering through to nut set (July to September) is critical to treat the problem before too much damage is caused. Inspect racemes for egg deposits and monitor thoroughly through the block, recognising 'hotspots'. Monitor 20 racemes with at least one raceme per tree. As eggs are 0.5 mm, it is best to pick the raceme off the tree and examine it using a 10× lens. Shaking flower racemes can help detect larvae.

Cultural and physical management

Infestation will be worse where there are warm dry springs. Alternative hosts such as rough and smooth shell macadamia, red bottlebrush, *Grevillea* species and woody pear (*Xylomelum pyriforme*) also need to be considered when monitoring and treated as hotspots or removed.

Biological control

Releasing biological control species within surrounding host plants such as *Grevillea* spp. could keep MFC in check and protect the controls when operations call for spraying. The following biological controls are commercially available:

- wasps (larvae parasite) *Agathis rufithorax*, *Brachymeria* spp. and *Phanerotoma* spp
- egg parasitoids *Trichogrammatoidea flava*
- parasitic bug *Termatophylum* spp.
- syrphid fly larva *Melanostoma agrolas*.

Chemical control

The chemical control options for macadamia flower caterpillar are listed in Table 18.

Table 18. Chemical control options for macadamia flower caterpillar in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acephate (Lancer® 970)	S6	1B	0	High	Do not spray when bees are foraging.
Bacillus thuringiensis (Bt) (Bacchus® WG)	PS exempt	11C	0	Low	Apply Bt at first sign of activity. Bt is best used in a routine program, it is not suitable for emergency treatment.
Methoxyfenozide (Prodigy®)	PS exempt	18	28	Low	Target eggs and newly hatched larvae.
Spinetoram (Success® Neo)	S5	5	7	Medium	Insecticide with contact action. Toxic to bees.
Tebufenozide (Mimic 700)	S5	16A	28	Low	Lethally creates unsuccessful moulting process.
Trichlorfon (Lepidex)	S6	1B	2	High	Good coverage is essential for control. Toxic to bees.

Macadamia kernel grub

The macadamia kernel grub (*Assara seminivale* and other pyralids) deposits its eggs on the nuts in the field before harvest. The grub has become more of an issue in recent years. The problem is compounded if infested nuts are sent to the processors and stored in silos where the grub will continue to infest other nuts.

Risk period

Table 19. The peak risk period for macadamia kernel grub is during shell hardening to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Macadamia kernel grub adults (Figure 92) have dark brown forewings with a black mark halfway along the costa and a black tip. The hindwings are fawn with dark veins. The wingspan is between 13 and 21 mm. Larvae are cream and grow to about 15 mm long. The kernel grub often pupates within the hard nut. The pupae are about 1 cm long.

The kernel grub is usually recognised by the larvae which gain access to the kernel either through damage caused by other pests such as the macadamia nut borer or fruit spotting bug, or through an open micropyle. The larvae then consume the entire kernel, replacing it with a webbed mass of insect faeces (Figure 93).

Damage

An entire kernel will be consumed and larvae will be surrounded by faeces. It is not uncommon to find several larvae in one nut.

Management

Be aware of varieties with open micropyles as this creates an easy entry point for the kernel grub. Ensure good control of pests that create damage to the hard shell of the nut.

Cultural and physical

Management and control of other pests such as fruit spotting bug and nut borer will prevent most kernel grub damage. Monitoring is the key to controlling this pest. Using egg traps for navel orangeworm can be helpful.

Biological

Unfortunately, the biological control for nut borer does not predate on kernel grub.

Chemical

There are no products registered to control this pest. Sprays for other pests within a season should help with control.

Further reading

Anon. nd. Kernel grub (*Assara seminivale*), http://www.bioresources.com.au/ResearchProgram/kernelgrub.html

Queensland Department of Agriculture and Fisheries. 2003. Macadamia problem solver and bug identifier, http://era.daf.qld.gov.au/id/eprint/1964/12/mac-problemsolver_Part4.pdf

Herbison-Evans D and Crossley S. 2015. Macadamia kernel grub. Coffs Harbour Butterfly House, http://lepidoptera.butterflyhouse.com.au/pyra/seminivale.html

Figure 92. Macadamia kernel grub adults. Photo: Craig Maddox.

Figure 93. Macadamia kernel grub larvae. Photo: Chris Fuller.

Macadamia lace bug

Macadamia lace bugs (*Ulonemia* spp.) are native to northern NSW and Atherton, Queensland. Macadamia species and other similar Proteaceae plants are their native host. There are at least four macadamia lace bug (MLB) species, with *Ulonemia decoris*, which is the most damaging, found in NSW. Once established, MLB populations can increase rapidly and become self-sustaining.

Risk period

Table 20. The peak risk period for macadamia lace bug is from pre-flowering to peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Macadamia lace bugs are small insects, approximately 3–4 mm long (Figure 94). This makes them difficult to see with the naked eye, therefore it is important to look for symptoms to identify their presence in your orchard. They are named for the intricate 'lace-type' pattern on their hemelytra and thorax. Adults lay eggs into the plant tissue and nymphs emerge within days to begin feeding. The nymphs go through five instar stages before becoming adults. The adults can fly well and have been reported to disperse to other populations up to 20 km away, making it easy for them to recolonise in areas from which they had previously been eradicated.

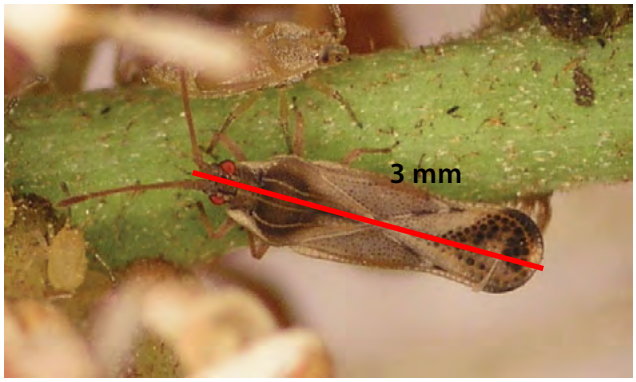

Figure 94. Adult macadamia lace bug (*Ulonemia decoris*, approximately 3 mm long) on a raceme. Nymphs are also present, left of the adult. Photo: Craig Maddox.

Damage

MLB pierces the plant tissue to feed on sap, damaging the leaves and flowers (Figure 95), starting at the tips where they appear blackened (Figure 95). Left unchecked, the whole flower blackens and dies (Figure 96). Shaking the head of infested flowers reveals MLB. Nut set is prevented when MLB is not treated, causing > 90% production losses in later varieties. These losses can happen quickly, so monitoring your crop early (e.g. at pre-flowering) and consistently is essential. Look for cast lace bug skins on dead florets and live nymphs on racemes (Figure 97).

Figure 95. Pre-flowering racemes with lace bug damage highlighted. Photo: Craig Maddox.

Figure 96. Florets damaged by macadamia lace bug. Photo: Craig Maddox.

Figure 97. Cast lace bug skins on dead florets. Photo: Craig Maddox.

Figure 98. Lacewing larva (right) versus lace bug nymph. Note the dead bodies on the lacewing's back. Photo: Chris Fuller.

Management

MLB numbers build up over successive seasons as they overwinter on the bark of trees. Start monitoring when the flower raceme is green and unopened, especially if MLB was a problem the previous year. Early action now will mean less damage later. MLB damage worsens when multiple flowerings extend throughout the season. MLB can trigger out-of-season flowering when the main flower set is destroyed. Ethephon (e.g. Ethrel®) has been used successfully to promote nut drop and return trees to synchronised flowering where out-of-season flowering has occurred. Implementing good orchard hygiene is important. Cleaning equipment and clothing when moving between farms is a good way to prevent MLB movement.

Cultural and physical

Generally, what was a 'hotspot' the previous year will probably be a hotspot this year. NSW DPI research found that MLB prefer overcrowded dark orchards, therefore pruning to open trees up for light and ensuring adequate, manageable tree height will assist with control. Only adult MLB can fly, so once canopies close over within and across the row, a highway is created for nymph MLB to spread across the orchard.

Biological

Macadamia lace bug has many naturally occurring enemies such as predatory bugs, lacewing larvae (Figure 98), ladybird larvae and spiders. While these beneficial species might not appear in sufficient numbers to control a rapid increase in lace bug populations at flowering, their preservation is an essential part of a long term sustainable integrated pest management approach in macadamias. NSW DPI has been conducting preliminary trials incorporating commercial beneficial insects such as lacewings. Results will be provided as soon as they are available.

Chemical

Careful consideration is needed when applying control compounds during flowering to ensure minimal effect on honey bees and other beneficial insects (pollinators). Applying crop protection compounds onto flowers should be avoided where possible. If deemed necessary, then flower sprays using trichlorfon should be applied late in the afternoon after bees have finished foraging. Communication with beekeepers is essential for protecting the crop and pollinators. Early identification of MLB, e.g. at pre-flowering, means that spraying open flowers will be eliminated, thus preventing any harmful effects to bees. The chemical control options for macadamia lace bug are listed in Table 21.

Further reading

Bright J. 2019. *Macadamia lace bug management and contro*l. Primefact 1661, second edition. NSW DPI, https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/diseases-pests-disorders/macadamia-lace-bug-management-and-control

Table 21. Chemical control options for macadamia lace bug in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Diazinon (Diazinon) PER14276	S6	1B	14	High	Use at pre-flowering only. Highly toxic to bees.
Pyrethrin (Pyganic®)	NA	3A	1	High	Apply before flower opening. Dangerous to bees.
Sulfoxaflor (Transform™ Isoclast®)	S5	4C	0	Medium	Early detection is important for control. Highly toxic to bees. Use early in fruiting/ flowering stage of the crop will conserve beneficials when used as part of an IPM system.
Trichlorfon (Dipterex® 500 SL) PER13689	S6	1B	2	High	Toxic to bees.

Macadamia leaf miner

Acrocercops chionosema (macadamia leaf miner) is a moth of the Gracillariidae family. It is found in Queensland and New South Wales. It is a significant nursery pest, with the larvae feeding on macadamia, including *Macadamia integrifolia* and *Macadamia tetraphylla*.

Risk period

Table 22. Macadamia leaf miner can be present in macadamia orchards all year.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The adult moths (Figure 99) have dark forewings with three white bars across each one. The hindwings are narrow and have an extensive plume of hairs along the hind margin. The total wingspan is approximately 7 mm.

Macadamia leaf miner larvae are pale green to yellow then develop red bands when they are ready to pupate. When fully grown they will be approximately 6 mm long. They reside in the tunnelling mines they create but will leave the leaf to pupate nearby.

Figure 99. Macadamia leaf miner adult. Photo: CSIRO/ BIO Photography Group, Centre for Biodiversity Genomics, University of Guelph.

Damage

Macadamia leaf miner larvae live in the mid-tissue of the leaf where they mine nutrients from the leaves, leaving a trail or tunnel where they have been (Figure 100). The mine is created by the miner eating the leaf material between the upper and lower skin layer of the leaf. A large 'blotch mine' might be seen on the upper side of the leaf. The larvae will be present within the tunnels in fresh incursions and the tunnelling can develop into large blisters as the damage worsens. Severe infestations can retard the growth and yield of nursery and young trees. Older symptoms of leaf miner will appear as fire scorched leaves on new flush.

Figure 100. Macadamia leaf miner trails. Photo: Chris Fuller.

Management

Macadamia leaf miner is considered a minor pest. Generally the amount of damage incurred on a mature macadamia tree does not warrant control. However, in a nursery or young planting situation, the problem is more severe because the few leaves that develop carbohydrates for further growth can be destroyed by this pest. Treatment will be necessary if 60% of the leaves on a tree are damaged. Where minimal sprays have been applied, biological controls are an option. Monitoring is key and removal and destruction of affected leaves is recommended.

Cultural and physical

Remove and destroy damaged leaves to allow natural enemies to build up in sufficient numbers to maintain control of this pest. Inspect nursery material regularly and do not accept new plants with leaf miner symptoms. Ensure your on-farm biosecurity is effective. Leaf miner has not yet been found in the Bundaberg region so on-farm biosecurity is critical for this area.

Chemical

Spraying for macadamia leaf miner is made difficult as the larvae are protected by their mines and the pupae are protected by the pupal chamber. Consider sprays if young trees are heavily infested. The chemical control options for macadamia leaf miner are listed in Table 23.

Further reading

Herbison-Evans D and Crossley S. 2017. Macadamia leaf miner. Coffs Harbour Butterfly House, http://lepidoptera.butterflyhouse.com.au/grac/chionosema.html

Queensland Department of Agriculture and Fisheries. 2003. Macadamia problem solver and bug identifier, http://era.daf.qld.gov.au/id/eprint/1964/10/mac-problemsolver_Part2.pdf

Table 23. Chemical control options for macadamia leaf miner in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acephate (Lancer® 970)	S6	1B	0	High	Do not spray when bees are foraging. Toxic to bees.
Diazinon (Diazinon)	S6	1B	14	High	Do not use more than two sprays per season to avoid resistance. Toxic to bees.
Methidathion (Suprathion® 400 EC)	S7	1B	21	High	Avoid using other 1B chemistry to prevent resistance occurring. **Can only be used until 4 February 2021**.

Macadamia nut borer

The macadamia nut borer (*Cryptophlebia ombrodelta*) lays its eggs on the husk and the larvae burrow through the nut shell to eat the kernel. Macadamia nut borer (MNB) will cause premature nut fall, particularly during the oil accumulation stage (around December to February in Northern NSW). MNB also attacks mangroves, so pressure can be greater on farms adjoining mangroves.

Risk period

Table 24. The peak risk period for macadamia nut borer is from pea size nut to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The adult MNB is a moth. The female has a wingspan of up to 25 mm. They are a reddish-brown with a distinctive black triangle marking on the hind margin of each forewing (Figure 101).

Figure 101. Macadamia nut borer adult.

MNB eggs are scale-like and are laid singularly on the surfaces of green husks. Eggs can be found anywhere on the nut, but are often laid along the suture line. They are ivory white when first laid but turn red just before hatching (Figure 102). Eggs that have been parasitised by wasps will appear black after about five days (Figure 103).

Figure 102. Macadamia nut borer egg.
Photo: Chris Fuller.

Figure 103. Parasitised macadamia nut borer eggs appear black after about five days. Photo: Chris Fuller.

Larvae are legless grubs which appear pinkish (Figure 104) with dark green spots when mature. While the shell is soft the larvae will burrow into the kernel to feed. As the shell hardens, it becomes more difficult for the larvae to enter. This can be related to variety, as thinner shell and late season varieties will be more vulnerable than thicker shell varieties. The larvae will develop cocoons before pupating (Figure 105), which usually occurs within the nut. Pupae are light brown at first and darken with age. The whole life cycle takes around 5 weeks in summer.

Figure 104. Macadamia nut borer larvae.
Photo: Chris Fuller.

Figure 105. Macadamia nut borer larvae will develop cocoons before pupating. Photo: Craig Maddox.

Damage

Damage is easily identified as entry holes in the husk of nuts (Figure 106). These holes are usually close to the panicle and will have protruding frass (Figure 107). Infested nuts will drop prematurely. Greatest losses occur when the shell has not fully developed. Where thin-shelled varieties have been previously attacked and the shell compromised, MNB damage will be apparent.

Management

MNB is carried over from out of season or old nuts that have fallen and been left on the orchard floor. MNB can also be prevalent where trees have a high proportion of sticktight nuts. Regular monitoring is key to good control. Releasing beneficial insects is most useful after the last FSB spray has been applied, usually in January.

Cultural and physical

Where possible clean up old nuts to reduce the carry over populations between seasons. If you have sticktight varieties, identify ways to eliminate or reduce this. Monitoring is key and will involve setting up pheromone traps to estimate populations and movement. Employing a pest scout will ensure adequate control as they will be able to report on the problem using an area-wide approach.

Biological

Until recently, MNB was the number one enemy for the macadamia crop. It was not until the development and production of MacTrix (*Trichogrammatoidea cryptophlebiae;* Figure 108) that the pest became more manageable. MacTrix has been an excellent tool for controlling MNB with an area-wide approach. The effectiveness of MacTrix has meant that spraying after January specifically for MNB is no longer required. It should be noted the effectiveness of MacTrix may be compromised in temperatures over 35^{0}C. Wasps work well as part of an area-wide approach.

Other biological control agents include parasitic wasps such as *Apanteles briareus*, *Nixon*, *Bracon* spp., *Gotra bimaculatus* and a parasitic fly.

Figure 106. A macadamia nut borer at an entry hole. Photo: Chris Fuller.

Figure 107. A macadamia nut borer entry hole with protruding frass. Photo: Chris Fuller.

Figure 108. A female *Trichogrammatoidea cryptophlebiae* investigating an egg. Photo: R Llewellyn.

Chemical

The chemical control options for macadamia nut borer are listed in Table 25.

Table 25. Chemical control options for macadamia nut borer in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acephate (Lancer® 970)	S6	1B	0	High	Do not spray when bees are foraging. Toxic to bees.
Azinphos-methyl (Gusathion® 200 SC)	S7	1B	7	High	Contact and stomach action, moderate persistence.
Beta-cyfluthrin (Bulldock® 25 EC)	S6	3A	7	High	Do not use more than two sprays per season to avoid resistance. Dangerous to bees.
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High	Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.
Methidathion (Suprathion® 400 EC)	S7	1B	21	High	Avoid using other 1B chemistry to prevent resistance occurring. **Can only be used until 4 February 2021**.
Methoxyfenozide (Prodigy®)	PS exempt	18	28	Low	Target eggs and newly hatched larvae.
Spinetoram (Success® Neo)	S5	5	7	Medium	Insecticide with contact action. Toxic to bees. Do not apply more than four applications in any one season
Tebufenozide (Mimic)	S5	16A	28	Low	Lethally creates unsuccessful moulting process.

Macadamia seed weevil

The macadamia seed weevil (*Kuschelorhynchus macadamiae*) relies on out-of-season flowering and small soft-shell nuts for egg-laying. After the eggs are laid inside the husk, the nuts will usually fall. These nuts should be mulched and destroyed to break the cycle. If left unchecked, macadamia seed weevil (MSW) can become a major pest for macadamia. Importantly, MSW is so far confined to the Northern Rivers NSW and Mareeba districts in far north Queensland, so strict on-farm biosecurity measures should be enforced when moving any machinery or other equipment from infested areas to non-seed weevil areas.

Risk period

Table 26. The peak risk period for macadamia seed weevil adults is from pre-flowering to shell hardening.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Adult weevils are grey–brown, about 6 mm long (Figure 109) and can be in the orchard all year. During winter they will often be found in groups on the ends of branches. As the weather warms, the weevils will wait until the nuts have reached a vulnerable size, approximately 8 mm in diameter, in which to lay their eggs (Figure 110). The fully grown larva can be up to 10 mm long.

Figure 109. Macadamia seed weevil. Photo: Craig Maddox.

Figure 110. A macadamia seed weevil lays its egg on a chewed patch of husk. Photo: Craig Maddox.

Damage

The female weevil scarifies an area about 3–4 mm wide on the husk in to which she lays a single egg. This will be obvious as a triangular lay mark at the stem end of the fallen nuts (Figure 111). After egg-laying, the female weevil will chew about halfway through the stem to induce nut drop. When the egg hatches, the larva will consume the whole kernel (Figure 112), then pupate and exit the nut as an adult. Larva development depends on the period before shell hardening because once the shell hardens, the developed weevil is not able to exit. Damage after shell hardening will appear as grazing marks all over the husk, similar to a golf ball appearance (Figure 113).

Figure 111. Typical mark left by macadamia seed weevil that indicates egg-laying. Photo: Craig Maddox.

Management

Hotspot areas should be noted and controlled. Ethephon (e.g. Ethrel®) has been used successfully to promote nut drop and a return to synchronised flowering where out-of-season flowering has occurred. However, it is not advisable to use ethephon when trees are stressed.

Figure 112. Macadamia seed weevil larvae and pupae overwintering in nuts. Photo: Craig Maddox.

Figure 113. Macadamia seed weevil damage after shell hardening appears as grazing marks all over the husk, leaving a golf ball appearance. Photo: Craig Maddox.

To prevent MSW from thriving in your orchard:

- eliminate extended out-of-season flowering and nut set
- do not leave old damaged nuts on the orchard floor
- use strict on-farm biosecurity measures when moving any machinery or equipment from infested areas to non-seed weevil areas
- do not allow infection from neglected orchards.

Cultural and physical

Good orchard hygiene is key to reducing MSW numbers. Ensure the orchard floor is clean after nut shedding and, if necessary, use chemical control.

Biological

Kim Khuy Khun and Bree Wilson from the University of Southern Queensland are continuing their work on MSW control using *Metarhizium anisopliae* and *Beauvaria bassiana*.

Chemical

Best results for MSW control have been achieved with a combination of good hygiene (removing infested nuts) and targeted spraying with indoxacarb (PER86827) during spring when the nutlets are matchhead size. This should eliminate egg-laying from the adult female weevil for up to 13 weeks.

The chemical control options for macadamia seed weevil are listed in Table 27.

Further reading

Bright J. 2017. Macadamia seed weevil life-cycle and monitoring. Primefact 1586, NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/diseases-pests-disorders/sigastus-weevil,-life-cycle-and-monitoring

Bright J. 2017. Macadamia seed weevil orchard management. Primefact 1585, NSW Department of Primary Industries, https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/diseases-pests-disorders/sigastus-weevil,-orchard-management

Maddox C, McLean S, Pretorius J, Pretorius S and Khuy Khun K. 2018. Macadamia seed weevil: monitoring and control video. Queensland Agriculture, https://www.youtube.com/watch?v=4QcO8oLh9hw

Table 27. Chemical control options for macadamia seed weevil in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acephate (Lancer® 970) PER81463	S6	1B	0	High	Only apply a maximum of three applications per season using an air-blast sprayer with a minimum re-treatment interval of 14–21 days. **Ensure good orchard hygiene.**
Indoxacarb (DuPont™ Avatar®) PER86827	S6	22A	42	Low	Apply first when nuts are at pea size; best control is achieved when applied at match head size. Ensure thorough coverage. Sweep out affected nuts and expose to full sunlight. Mulch affected nuts.

Macadamia twig girdler

The larval stage of the macadamia twig girdler (*Neodrepta luteotactella*) can be very destructive, especially in nurseries and to young plantings. The macadamia twig girdler (MTG) can be in the orchard all year but causes most damage in summer and autumn.

Risk period

Table 28. Macadamia twig girdler can be in the orchard all year.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The MTG is usually identified by the damage it causes before the pest itself is seen. The larvae emerge from the egg at 1–5 mm long and develop to about 23 mm long. The head is dark-brown to black, the body is light brown with dark brown spots (Figure 114). The adult MTG is a silvery-white moth with yellow legs and a wingspan up to 26 mm. It is mostly active at night.

Figure 114. Macadamia twig girdler larva. Photo: Chris Fuller.

Damage

MTG larvae feed in webbed shelters that become cluttered with excrement (Figure 115). They can also reside in damaged foliage as larval development progresses (Figure 116). Numerous larvae at various stages will often be in one shelter, which can remain on the tree long after the life cycle is completed, giving it a ragged appearance (Figure 117). Twigs weakened by girdling readily snap off and this tends to induce bunched growth. Tunnelling in the husks and kernels causes damage similar to the macadamia nut borer.

Damage to mature trees is generally limited and compensated for by the sheer number of productive leaves. A young plant (up to 5 years old) will only have a few leaves to support growth, so these must be protected.

Figure 115. A webbed shelter made by macadamia twig girdler larvae. Photo: Chris Fuller.

Figure 116. Macadamia twig girdler damage. Photo: Chris Fuller.

Figure 117. A young macadamia tree looking ragged from macadamia twig girdler damage. Photo: Chris Fuller.

Management

Monitoring is essential, especially for new plantings and nursery plants. The suggested threshold for action is 15% of terminal shoots on young trees and 20% on mature trees (Queensland Department of Agriculture and Fisheries 2003). The normal pest and disease sprays used on mature trees will help reduce MTG numbers. Good orchard management practices such as pruning and biological controls will also help.

Cultural and physical

Inspect any nursery trees coming onto your farm. Remove and destroy any affected limbs. Regularly monitor trees for damage so you can identify the problem early and limit the spread.

Biological

Where less knock-down chemical sprays are being used in nurseries and young plantings, biological control should be encouraged. These include the parasitic wasps *Elachertus* spp., *Agathiella* spp., *Goryphus turneri* and *Stiromesostenus albiorbitalis*.

Chemical

While there are some registered chemicals for MTG control (Table 29), sprays for other pests within a season should provide control.

Further reading

Ironside DA. 1978. The macadamia twig girdler. *Queensland Agricultural Journal*, 104 (5): XXIX–XXX. https://gsajournals.org/articles/000/000/000000964-the-macadamia-twig-girdler.php

Queensland Department of Agriculture and Fisheries. 2003. *Macadamia problem solver and bug identifier*, http://era.daf.qld.gov.au/id/eprint/1964/10/mac-problemsolver_Part2.pdf

Table 29. Chemical control options for macadamia twig girdler in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High	Do not use more than two sprays per season to avoid resistance. Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.
Methidathion (Suprathion® 400 EC)	S7	1B	21	High	Avoid using other 1B chemistry to prevent resistance occurring. **Can only be used until 4 February 2021**.
Spinetoram (Success® Neo)	S5	5	7	Medium	Insecticide with contact action. Toxic to bees.

Mites

Mites are becoming more prevalent in macadamia orchards, causing branch dieback during hotter, drier times. While the mites are difficult to see with the naked eye, we often see the damage they cause such as bronzing of nuts caused by flat mites and husk silvering caused by broad mites. Mostly mite damage is cosmetic, however high populations in March to May will prevent bud initiation. In most cases the 'normal' weather pattern will wash this population away in a usual wet season.

Risk period

Table 30. The peak risk period for mites is from early flowering to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Broad mite

Broad mites (*Polyphagotarsonemus latus*) are tiny (less than 0.2 mm) and difficult to see even with a 16× hand lens. They differ from other mites in that they feed on the upper surface of plant tissue rather than on the underside.

The larval stage has six legs and is about 0.1 mm long, white and very slow moving. They moult into a clear torpedo-shaped nymphal stage that is unmoving.

Females are about 0.15 mm long, oval and initially clear, but become yellowish with a prominent white strip running down the centre of the back. The adult female has eight legs, with the hind legs reduced to thread-like appendages.

Males are much smaller and truncated near the rear end. They are often seen carrying female nymphs at right angles to their body.

When the female emerges from the nymphal stage, the male quickly mates with them. The entire life cycle can be completed in less than 7 days and within a single generation the population can increase 18-fold.

Flat mite

Flat mites are less than 0.3 mm long. They lay their eggs on the nuts and all subsequent stages can be found there. The eggs are small and light orange when first laid, but after a few minutes they darken to a bright reddish-orange. There are five different life stages including an egg stage, a six-legged larval stage, a protonymph (eight-legged), a deutonymph (eight-legged) and an adult stage. Each of the larval, protonymph and deutonymph stages have a resting stage associated with them that precedes the moult to the next stage. The life cycle can be completed in about 3 weeks under typical spring and summer conditions. When the nut is heavily damaged, mites will either be found on undamaged portions or they will have moved to adjacent undamaged nuts. Recently, eriophyid mite has become more of an issue, particularly in the A series. It causes leaf stunting and branch dieback.

Signs of damage

Broad mite

Broad mites feed on flowers, young leaves and fruit (Figure 118 and Figure 119). Flower feeding symptoms include silver-bronze colouring and deformation. Broad mites will also attack the new leaf flush and will lay on the under-side of the leaf. Symptoms will present as cupping and distortion of the leaf (Figure 119).

Figure 118. Broad mites on A16. Photo: Craig Maddox.

Figure 119. Broad mite damage to A16.

Figure 120. Eriophyid mite damage to macadamia 816 variety. Photo: Craig Maddox.

Damage on the husk is identified by silvering and this can be distinguished from other similar damage by scratching a fingernail across the fruit. If the damage is from broad mite, the scratch easily reveals the normal green surface. Other damage, such as from flat mite or red-banded thrips, will not scratch off.

Flat mite

Feeding from flat mite typically results in a bronzing or browning of the husk. Flat mites have a needle-like mouthpart that sucks up cell contents beneath the husk. In extreme cases, almost all the nuts on a tree can be affected. Unlike broad mite damage, scratching a fingernail over the surface will not remove the damage.

Management

Monitoring

Regular monitoring from pre-flowering through to nut set (July to September) is critical to treat the problem before it becomes too damaging. Inspect racemes for egg deposits. Monitor thoroughly through the block, recognising hotspots. Monitor 20 racemes with at least one raceme per tree. As eggs are only 0.5 mm, it is best to pick the raceme off the tree and examine it under 10× lens. Shaking flower racemes can often result in detecting larvae.

Cultural and physical

Infestation will be worse during warm, dry springs. Host plants include both rough and smooth shell macadamia, red bottlebrush and kahili flower (*Grevillea banksii*), silky (or silver) oak (*Grevillea robusta*), *G. pinnatifida*, *G. glauca* and woody pear (*Xylomelum pyriforme*).

Biological

The following biological controls are commercially available:

- wasps (larvae parasite) *Agathis rufithorax*, *Brachymeria* spp., *Phanerotoma* spp.
- egg parasitoids *Trichogrammatoidea flava*
- parasitic bug *Termatophylum* spp.
- syrphid fly larva *Melanostoma agrolas*.

Chemical

A timely spray to protect autumn flush may be required. The chemical control option for mites is listed in Table 31.

Table 31. The chemical control option for mites in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Abamectin (Vertimec®) PER87510	S6	6	28	High	Only apply one application per season. Dangerous to bees.

Red-shouldered leaf beetle

Red-shouldered leaf beetles (*Monolepta australis)* are a native insect that occurs sporadically in plague numbers any time during the year, but most commonly in spring and summer, particularly after rain.

Risk period

Table 32. The peak risk period for red-shouldered leaf beetles is from early flowering to shell hardening.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Red-shouldered leaf beetles are 6–8 mm long and about 3 mm wide. They are light yellow with red shoulders across the wing covers and a similarly coloured spot in the middle of each wing cover (Figure 121). The yellowish eggs are small and oval. Eggs are laid just below the soil surface, mainly in pasture such as ryegrass. The larvae feed on the grass roots and pupate in the soil. The larvae are white, slightly flattened with hard brown plates at both ends and reach 12 mm long before pupation.

Figure 121. Red-shouldered leaf beetle.

Damage

The beetle can completely destroy flower racemes. Young nuts and lush foliage are also attacked. High populations of the beetle will shred leaves. This is of particular concern for newly planted macadamia and nursery trees. Infestations are likely after heavy rain (20–40 mm) that has followed a dry spell, usually in spring and summer. Often individual trees or groups of trees are heavily infested while adjacent trees can be almost free of damage. The beetles enter the orchard from prevailing winds and collect on a few trees before dispersing. Severe damage can occur in as little as 2–3 hours.

Management

Understanding the pest's life cycle is key to controlling red-shouldered leaf beetle. It takes approximately two months to complete and this will happen around summer. Adults will lay eggs after good rain. As with other swarming pests, it is often only noticed when there are swarms of beetles in a tree. Other trees are also likely to be infested with the beetles.

Cultural and physical

Examine the whole orchard at regular intervals. Check flowers and new growth for beetles, particularly following the first substantial rain after a dry spell. If beetles are swarming in well-established orchards, only 1–2 trees may be affected. Large swarms in young orchards will spread over more trees and cause proportionally more damage.

Having *Eucalyptus torelliana* as a windbreak is highly attractive to these beetles and is useful for early detection and control. Yellow sticky traps in boundary trees provide an early indication of beetle presence.

Biological

Whilst there are several natural predators such as *Monoleptophaga caldwelli* (parasitic fly), plague level populations develop unnoticed below ground. Foliage and flowers can be stripped from the tree in just a few days, well before biological populations can take control of the pest.

Pest populations can peak while the beneficial population is building up, then the pest numbers decrease when the beneficial population is higher. The pest populations can increase so rapidly that biological control might be ineffective during plague levels. At lower levels it could be beneficial to spot spray adults to reduce the number of following populations.

Chemical

Generally you can disregard individual beetles or groups fewer than ten. It is usually only swarming beetles in a feeding frenzy that cause damage. The chemical control options for red-shouldered leaf beetles are listed in Table 33.

Table 33. Chemical control options for red-shouldered leaf beetles in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acephate (Lancer® 970) Qld, WA and NT only	S6	1B	0	High	Do not spray when bees are foraging.
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High	Do not spray when bees are foraging. Do not allow spray to drift off-target onto sensitive areas.

Further reading

Fay HAC, Storey RI, Defaveri SG and Brown JD. 1993. Suppression of reproductive development and longevity in the red-shouldered leaf beetle, *Monolepta australis* (Col.: Chrysomelidae) by the tachinid, *Monoleptophaga caldwelli* (Dipt.). *Entomophaga*, 38: 335–342, https://link.springer.com/article/10.1007/BF02374450

Hartley M. 2009. *Monolepta australis*, https://www.arboristnetwork.com.au/Fact_Sheets/Monolepta%20australis.pdf

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Scale

Scales are insects that feed on plant tissue and secrete honeydew. The term scale refers to the substance secreted over the back of the insect. Dry weather favours dispersal and establishment while heavy rain causes high mortality of crawlers. Latania scale can cause problems in young macadamia orchards, commonly affecting varieties 344, 660 and to a lesser extent 741. If left unchecked, scale can cause serious damage to young plantings.

While latania scale (*Hemiberlesia lataniae*) is the predominant scale affecting macadamia, especially the leaves, branches and nuts, there are other types including:

- long soft scale (*Coccus longulus*) which affects leaves and twigs
- macadamia mussel scale (*Lepidosaphes macadamiae*) which affects leaves
- macadamia white scale (*Pseudaulacaspis brimble*) which affects leaves and nuts
- oleander scale (*Aspidiotus nerii*) which affects leaves.

Risk period

Table 34. The peak risk period for scales is from nut set to the end of spring flush.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

The eggs are yellow and 0.15 mm long. The first instar (or crawler) is yellowish and 0.15 mm long. It moults after approximately 14 days. The second instar looks similar to the adult female, which are variable in colour and shape, measuring 1–2 mm in diameter. On leaves they are grey to white, circular and convex (Figure 122); on stems, they are brown and slightly convex. They lay their eggs under the body. Males are oval-shaped and elongate but are not always present. The adult male is a tiny insect with one pair of wings, no mouthparts and only lives for 24 to 48 hours.

Scale insects do not usually have legs and the adult females are generally sedentary. Scale insects are typically dispersed by the first instar through crawling, but passive transport by wind, animals and humans also occurs.

Latania scale will complete its life cycle from egg to adult in about 8 weeks during spring and summer. The crawlers are active from August to November, resulting in peak adult numbers around February.

Inspect branches, leaves and nuts to find the greyish-coloured scale insects (Figure 123).

Damage

Scale insects can feed on young growing tips causing foliage distortion. Often leaves that have been infested have yellow patches indicating feeding sites. New growth on infected plants can appear smaller at the tips of twigs. These symptoms are followed by twig death on some parts of the tree and eventual leaf loss where scale infestation is heavy. Green twigs will also be infested while woodier parts of the plant are not attacked. Latania and white scale will also infest the macadamia husk, but actual damage and loss from scale is low.

Management

Generally scale insects are not considered to be a pest of major importance, although young and reworked trees can be susceptible, especially to latania scale.

There are usually sufficient biological control agents for scale insects naturally in the environment. However, overuse of broad-spectrum pesticides can kill the beneficial insects, increasing the risk of scale infestation.

The key to controlling latania scale is constant awareness of the pest situation in your trees. Crop scouts should take note of areas of higher pest prevalence. Scale insects will tend to be hard to find because they are small and often settle in cracks or beneath lichen. Look in covered areas such as under bark, spray guards or collars. Scale insects prefer to settle in these sheltered areas. The compact upright growing varieties such as 344 and 660 seem to provide ideal growing conditions for latania scale.

Cultural and physical

In young and freshly re-worked trees, prune out and destroy infested material. Thoroughly inspect incoming nursery plants for scale insects.

Encourage beneficial insect habitats in nurseries and young plantings. Other useful practices include reducing dust on the trees from nearby dusty roads and preventing ants from gaining access to trees.

Biological

Biological controls would involve the mass rearing and release in-field of the beneficials before the infestation period. Further investigation is required on the many potential options for biological control. Other options that could be worth further investigation may include trap cropping, pheromone trapping, fungal control, trunk band sprays and physical barriers.

Chemical

Frequent or inappropriate application of broad-spectrum insecticides will disrupt natural enemy populations, allowing scale insect populations to increase. The chemical control option for scale insects is listed in Table 35.

Figure 122. Latania scale adult. Photo: Lorraine Graney, Bartlett Tree Experts, Bugwood.org.

Figure 123. Latania scale multiple life stages. Photo: United States National Collection of Scale Insects Photographs, USDA Agricultural Research Service, Bugwood.org.

Table 35. The chemical control option for scale insects in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Acetamiprid + pyriproxyfen (Trivor®)	S6	4A + 7C	14	High	Do not spray when bees are foraging. Toxic to bees.

Scarab beetle

Scarab beetles appear to favour dry weather, being reported in 2013–14, 2017 and again now in the 2020 macadamia season. Although not a pest of nutlets, they will affect production through root feeding and destruction.

Risk period

Table 36. The peak risk period for scarab beetles is from nut set to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Argentinian scarab (*Cyclocephala signaticollis*) larvae are usually cream, white or light brown (Figure 124). When they hatch they are small (1–3 mm long), but generally develop until they are about 25 mm long. Digging just below the soil surface near roots will reveal curled up larvae in a characteristic C-shape (Figure 125). They have three pairs of well-developed legs and usually a hard, brown, dark red or black head.

The life cycle of these beetles can be up to 1 year, including 10–11 months as larvae in the ground.

Adults are similar in size and shape to other scarab species including the African black beetle (Figure 127). They are tan coloured with striping on the outer wing cover (Figure 127). It is not until the larvae become adults that clear identification is possible. Most scarab beetles are approximately 8–25 mm long.

Figure 124. Argentinian scarab larvae in the soil.

Figure 125. Argentinian scarab larvae.

Figure 126. African black beetle-Hanna Royals, Screening Aids, USDA APHIS PPQ, Bugwood.org.

Figure 127. Argentinian scarab adult.

Damage

Scarab beetles prefer dry seasons, similar to bark beetle and *Leptocoris* spp. Risk periods for scarab beetles include summer and early autumn, especially those with dry springs and summers as this is when populations build up. Most damage is caused by the larvae feeding on the underground roots of plants. Scarab beetles consume the roots of turf and grasses such as sweet smother grass, which is the macadamia industry's preferred ground cover because of its persistence in semi-shade environments.

Scarab beetle infestation will appear as patches of grass looking moisture-stressed, but because the beetles are active in dry periods when the grass will display these signs anyway, it might not be obvious that it is beetle damage. In extreme cases the grass will die from heavy infestations.

The flights are the most obvious sign of activity as scarab beetles tend to swarm. They will be noticed especially at night when they are attracted to lights, similar to Christmas beetles which also belong to the scarab beetle family.

Management

We know from experience that this root-feeding pest prefers the roots of turf and pastures including Kikuyu, and in the case of macadamia, the predominantly-grown sweet smother grass. In dry times it now also appears that the beetles will predate on compost and roots that are under heavily applied organic matter. However, it should be noted that as this pest is usually a dry season pest and the benefits of compost far outweigh the effects that scarab beetles could have on productivity.

The damage sustained in affected orchards will require replanting the grass to prevent future soil erosion. In heavily affected areas it is best to sow a fast germinating and growing grass such as millet or ryegrass. This will give immediate cover, and longer-term, a permanent cover crop can be established.

Biological

The entomopathogenic nematode *Heterorhabditis zealandica* can be applied to scarab beetle larvae and is commercially available through retail outlets such as Ecogrow EN. These nematodes require warm (> 15 °C) moist soil to be effective. It is recommended to apply this to populations of small larvae.

Pathogenic fungi such as *Metarhyzium* spp., *Beauveria* spp. and *Verticillium* spp. are also commercially available e.g. Nutri-Life Myco-Force™ and require warm moist soil conditions.

Chemical

At the time of writing there are no registered chemical controls for the Australian macadamia industry to control scarab beetle larvae.

Further reading

Bayer. nd. Argentinian scarab, https://www.environmentalscience.bayer.com.au/turf-management/what-to-control/argentinian-scarab

Macadamia Processing Company. 2014. The Nutshell, https://mpcmacs.com.au/media/Nutshell-May-2014.pdf

Thrips

Flower thrips (*Scirtothrips dorsalis*), greenhouse thrips (*Heliothrips haemorrhoidalis*) and redbanded thrips (*Selenothrips rubrocinctus*) will all damage macadamia. Western flower thrips (*Frankliniella occidentalis*; Figure 128) is also becoming a problem in the Bundaberg region.

Risk period

Table 37. The peak risk period for thrips is from nut set to the end of spring flush.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Thrips are small insects, ranging from 0.5–2 mm long, making them hard to see with the naked eye. They are cylindrical, the head often being narrower than the prothorax or the rest of the body (Figure 129). Adult flower thrips are orange-brown while adult greenhouse and redbanded thrips are black. Redbanded thrips nymphs are light yellow with a bright orange band (Figure 130). Flower thrips can also affect leaves.

Figure 128. Western flower thrips. Photo: David Cappaert, Bugwood.org.

Damage

Damage on the outer husk is caused when the sticky excrement hardens and gives the fruit an uneven, reddish appearance. Over time it will become a uniformly brownish rust colour (Figure 131). The damage is not known to cause yield or quality losses and is generally left unchecked. Thrips can also attack flowers and new flush, where leaf rosetting will appear (Figure 132). Continual attack on new flush is a concern as this can cause the plant to lose carbohydrates.

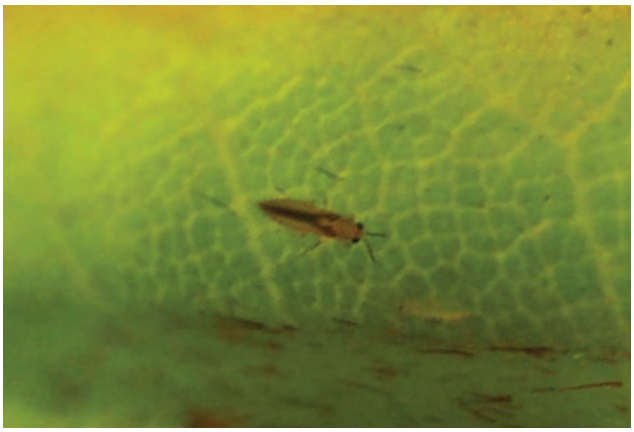

Figure 129. Adult thrips. Photo: Chris Fuller.

Management

Regular monitoring from pre-flowering through to nut set (July to September) is critical to treat the problem before it becomes too damaging. Yellow sticky traps placed within the orchard are a useful monitoring tool. The traps will give a good indication of thrips activity and can also be used to obtain a formal identification of the pest species. These should be checked weekly in high pressure times from flowering to nut set. Generally thrips will populate in 'hotspots', but are known to migrate in large numbers on the wind and can invade an orchard in a very short time. Flowers can be checked by tapping the raceme over a white surface such as paper or an ice cream container. Inspecting individual flowers can also help determine a measurable population size (i.e. number per flower) and damage, which will appear as unopened flowers or dehydrated flowers that will later fall off.

Figure 130. Thrips nymphs. Photo: Chris Fuller.

Cultural and physical

Where the inter-row has broadleaf weeds and host plants, avoid mowing just before macadamia flowering as this might drive thrips into the crop.

Biological

There are a number of natural enemies for thrips including predatory mites, brown and green lacewings, predatory thrips, lady beetles and parasitic wasps. However, these are unlikely to provide full control, particularly during periods of rapid influx.

Figure 131. Thrips damage to a macadamia nut. Photo: Chris Fuller.

Chemical

An effective control program for thrips should be based on strategic spraying informed by monitoring and observation. When spraying at or around bloom, be aware of any label warnings and recommendations for protecting bees and other off-target species. The chemical control options for thrips are listed in Table 38.

Figure 132. Thrips damage to macadamia leaves. Photo: Chris Fuller.

Table 38. Chemical control options for thrips in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Abamectin (Vertimec®) PER87510	S6	6	28	High	Do not use more than one application per season. Dangerous to bees.
Acephate (Lancer® 970)	S6	1B	0	High	Do not spray when bees are foraging.
Spinetoram (Success® Neo)	S5	5	7	Medium	Insecticide with contact action. Toxic to bees.

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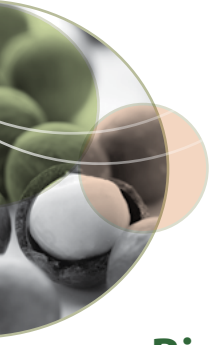


Vertebrate pests

Birds

Bird species that disrupt macadamia production directly by removing nuts or damaging plants (chewing) and infrastructure such as irrigation lines, include but are not limited to, sulphur-crested cockatoos (*Cacatua galerita,* Figure 133), galahs (*Elophus cacatua*) little corellas (*Cacatua sanguinea*), black cockatoos (*Calyptorhynchus banksia* , Figure 134) and ravens (*Corvus coronoides*). The mistletoe bird (*Dicaeum hirundinaceum*) disrupts macadamia growth by introducing mistletoe, which is a deadly parasite to the plant. Each bird species has its own movement and distribution patterns, breeding seasons and feeding strategies.

Birds mostly knock down more nuts than they consume. They also chew young wood, which affects plant growth. Birds also cause considerable damage in other nut crops including almonds and hazelnuts.

Orchards that have limited alternative food sources and good perching sites surrounding them are more likely to suffer bird damage. Once the birds have a taste for the produce, they tend to keep returning.

Monitoring

Monitoring will involve continual assessments of trees and infrastructure. It might also involve replacing damaged trees and irrigation lines. Using historical information will assist in preparing for the coming season i.e. if the crop has been damaged previously, it is likely to be damaged again. Comparing the damage to other areas in the region can also help with predicting where damage might occur.

Control

In macadamia orchards with larger trees, it is impractical to expect exclusion netting to prevent bird damage. Control will mostly depend on strategic targeted approaches, usually involving bird-scaring devices with some shooting.

Bird scaring

Birds quickly habituate to scaring devices, i.e. they fly off the first few times the device is used, but they soon learn that the device is harmless. Visual bird scaring devices rely on motion or reflection, however, most of the target species rapidly become familiar with the devices and they then become ineffective. The most effective method is to use different scaring devices, setting them up as soon as the birds show an interest in the crop and before the birds become accustomed to the food source.

Acoustics

Sound scaring devices include gas cannons, ultrasonic devices, crackers and other electronic equipment. Again, birds will become accustomed to these, especially if they are repetitive. Using shooting in conjunction with bird scarers can be a good option as birds will associate the scarer with real danger e.g. shooting. However, growers need to be aware that most bird species that damage

Figure 133. A flock of cockatoos approaching a macadamia orchard.

Figure 134. A black cockatoo.

macadamia orchards are protected and a permit from a state fauna authority will be required (link provided below). Both the shooter and the device should move around the orchard to prevent the birds from becoming too familiar with them.

Shooting

This is best used in conjunction with scaring devices as an association tool of noise and danger. It would be unusual to eliminate the problem through shooting alone.

Drones

Drones have provided some success in scaring away birds and best results are achieved if the drones are used with other deterrents. PhD candidate, Zihao Wang, from the University of Sydney (School of Aerospace, Mechanical and Mechatronic Engineering) is conducting interesting work using an unmanned aerial vehicle.

Other techniques include:

- Agri-laser systems
- Baits
- Feeders
- GPS navigation (for autonomous drone flying)
- Industrial and commercial acoustics systems
- Networked gas cannons
- Night vision systems
- Radio activated cannons
- Strobe lighting systems
- Thermal imagining equipment
- Trail cameras
- Trapping products
- Ultrasonic bird deterrents
- Visual deterrents, for example Scary Eyes Scare Balloons and Irri-Tape®.

Further information is provided in the references section, however, due to the number of commercial drone products available, we have purposely not mentioned any one in particular.

Further reading

NSW Game Hunting Guide. 2017. https://www.dpi.nsw.gov.au/hunting/rules-and-regulations/nsw-game-hunting-guide

Office of Environment and Heritage destruction licence for native species, www.environment.nsw.gov.au/wildlifelicences/OccupierLicences.htm

Tracey J, Bomford M, Hart Q, Saunders G and Sinclair R. 2007. Managing bird damage to fruit and other horticultural crops. NSW DPI, www.dpi.nsw.gov.au/agriculture/horticulture/pests-diseases-hort/information-for-multiple-crops/managing-bird-damage

Deer

Deer are usually found in fringe areas of bush, woodlands and riparian vegetation, preferring agricultural areas interspersed with forest vegetation (Figure 135). They can destroy young macadamia plants through defoliation and stripping bark from tree trunks when they rub their antlers on trunks (Figure 136) and lower limbs. Younger trees that are not yet established usually suffer the most severe damage.

Figure 135. An axis deer on a Bowraville property. Photo: Paul Trollis.

Figure 136. The result of trunk rubbing by deer.

Breeding

Males are sexually mature at 17 months but do not usually breed until they are about four years old due to competition from dominant stags. Females are usually sexually mature at 16 months and will breed once a year thereafter. The mating season is in autumn and this is when males will

become territorial. The gestation period is 8 months with a single fawn being produced. While they do not breed as prolifically as pigs, their population is still expanding.

Management

Monitoring

Depending on the species of deer, they will either be in herds dominated by a single female or will be solitary. Single males tend to form bachelor groups. Deer will usually be active in the orchards between late afternoon and early morning. Signs of deer activity will include foot pads and bark damage to trees. As deer do not have incisor teeth, their browsing will leave a jagged surface on twigs and leaves. The height of the damage (up to 1.8 m) will eliminate other potential pests.

Knowing which deer species you are dealing with will dictate your control strategies. The NSW DPI Game Hunting Guide provides information on deer species and hunting (www.dpi.nsw.gov.au/hunting/rules-and-regulations/nsw-game-hunting-guide).

Control and physical control

Exclusion fencing

Fencing is the best alternative but deer can jump well, meaning that permanent high tensile electric fencing will be required for adequate control. Fencing can be expensive so before deciding on this method of control, consider the:

- history of deer within the region: is it only a 'one off' or are there substantial numbers?
- number of deer and the prevalence of incursion: are they dependent on grazing macadamia plants? If plants are being destroyed through rutting, fencing should be strongly considered
- market value: what effect are the deer having on potential crop production and plant growth?
- area to be fenced: is it worth fencing smaller farms? Perhaps there is potential to fence a few small farms that are within the same area, thus sharing the costs of control
- tree guards to be used: usually plastic or poly mesh frames are placed around the bases of young trees. They can go to 1.2 m high and will prevent chewing by other vertebrate pests such as rabbits and wallabies.

Shooting

Check with state and regional authorities regarding the legislation that applies in relevant state jurisdictions and the protection status of deer within your region.

Remember, if you are going to have others on your property to carry out deer control, you must consider several points before allowing access to your property, including conditions of access, public liability insurance and references. Also remember that shooting must be carried out by trained personnel with appropriate firearms licences and the shooters must possess the necessary skill and judgement to kill deer with a single shot. Lactating females should not be shot, but if inadvertently shot, the young must be found and humanely euthanased.

Chemical

Temporary control through the use of spray-on repellents has shown limited success in Australia.

Further reading

Craven SR and Hygnstrom SE. 1994. The internet centre for wildlife damage management, http://icwdm.org/handbook/mammals/deer.asp

NSW Game Hunting Guide. 2017. https://www.dpi.nsw.gov.au/hunting/rules-and-regulations/nsw-game-hunting-guide

Pet Smart Connect. nd. http://www.pestsmart.org.au/pest-animal-species/deer

Sharp T. 2012. Standard operating procedure DEE001: ground shooting of feral deer, http://www.pestsmart.org.au/wp-content/uploads/2013/03/DEE001_ground-shooting-deer.pdf

Pigs

Feral pigs (*Sus scrofa*) are usually found within two kilometres of a water source, although they can cover much greater distances. Pig population densities depend on environmental conditions such as food and water sources. Pigs are most active in late afternoons and early mornings, but if they have been hunted, will become nocturnal.

Pest identification

Male pigs are sexually mature at around 18 months and they usually roam alone, seeking out new territories. Females travel in groups called sounders. They can breed from 7–12 months of age and will produce a litter of 2–10 piglets (Figure 137). In favourable conditions, they can produce up to three litters a year, leading to rapid population expansion.

Damage

Pigs can cause environmental damage such as wallowing and rooting up the ground causing erosion and are a major biosecurity risk, potentially spreading weeds and pathogens. Pigs also destroy infrastructure on the farm, including water courses. The digging done by pigs leaves depressions in the ground that make it difficult for finger wheels to harvest nuts (Figure 138).

Conversely, the only sign of pigs might be small shell segments scattered about the foraged area. If pig damage to the crop is suspected, then a bright torch at night over the area will highlight the white inside the cracked shells. Also look for other signs such as pig prints on damp ground and muddy rub marks on tree trunks.

Pigs seem content in macadamia orchards (Figure 139) and can consume macadamia nuts in large quantities. Examining gut contents reveals multiple kilograms of kernel (Figure 140). A moderate size pig can consume up to six kilograms of nuts in shell per hour. A mature pig (90–100 kg) will consume 3% of its body weight per day; smaller pigs up to 5% of body weight. Ten pigs feeding in an orchard for ten days can destroy nearly 300 kilograms of nuts in shell.

Management

Monitoring

Monitoring pig behaviour and habits is the best way to achieve control. Acceptable reduction of pig damage is achieved mostly by incorporating a number of control option strategies. These strategies are discussed in the NSW DPI Primefact 1769, Vertebrate pests in macadamia: pigs and the Vertebrate pest animals webpage.

Figure 137. Pigs can produce up to three litters per year and can have up to 10 piglets.

Figure 138. Pigs damage the orchard floor causing erosion and making it difficult to harvest.

Figure 139. Pigs making their way to macadamia trees.

Figure 140. Gut contents of a 70 kg sow containing approximately $60 of macadamia kernel.

Exclusion

Fencing is the best option but an effective pig fence needs to be robust, regularly maintained and should incorporate a high power energiser. Where properties are close to each other, consider area-wide fencing around the boundaries of the properties to increase effectiveness and assist with costs.

While the initial cost of an effective pig exclusion fence (Figure 141) might seem high, it is likely that it will be recouped in just one season based on the following example calculations:

- one pig consumes 2.5 kg of kernel in one night, which is 33% of nut in shell (NIS), which equates to 7.5 kg of NIS lost
- the NIS value is $6/kg, so in one night the pig consumes $45 of nuts
- if there are 15 pigs in the orchard, then 15 x $45 = $675 lost per night
- the season goes from March to September (approximately 230 days) and for approximately 60 days, there will be enough nuts on the ground for the pigs to take their fill of 2.5 kg, thus a loss of $40,500 from pigs
- the cost of effective fencing (mesh fencing with an electric stand out wire) is about $9,000 per kilometre
- a 40 hectare orchard might only need 2.6 km of fencing (if a square block), costing $23,400.

Therefore, you are saving almost $17,000 in the first year and $40,500 every year following (@ $6/kg NIS 10% mc).

Figure 141. An effective pig exclusion fence.

Trapping

There are several trap types for pigs including silo mesh traps, trigger traps (Figure 142) and remotely controlled traps. Traps are generally set along a well-worn pad or in an area known to be frequented by pigs. Free feeding for a time to get the pigs entering and leaving the trap is essential. It might take weeks before a trap can be set to keep pigs in. The benefit of remotely controlled trigger traps is that the pig population can be monitored from a remote camera and the door triggered with the press of a button when the full complement of pigs is inside the trap.

Traps do not work well in a macadamia orchard while there are nuts on the ground. The trap is best placed in a quiet area as far from the orchard as possible. It might be necessary to work with neighbours to find a suitable location.

Macadamia nuts in shell are an excellent food to use in traps, as there are few other animals attracted by them.

Figure 142. Pigs caught in a trigger trap.

Shooting

Shooting gives limited pig control. Ground shooting is usually opportunistic; either involving dogs to locate the pigs or ambushing pigs. If trapping strategies are being used, avoid shooting near the trap as it will disrupt the regular pattern of pig intrusion and disperse them to other areas.

Combining methods

Shooting and pig-dogging in conjunction with remote trapping is a good strategy for limiting immediate damage and reducing the pig population over time, as it encourages the pigs to feed in 'safety' at the trap location. Shooting and pig-dogging might be the only way to eliminate trap-shy pigs, which are often the large sows.

The Hunt safe, hunt legal – be a responsible pig-dogger program raises awareness of the responsibilities of pig-doggers. For further information on responsible pig hunting, refer to the DPI website: www.dpi.nsw.gov.au/hunting/game-and-pests/be-a-responsible-pig-dogger.

Further reading

Mitchell B and Balogh S. 2010 Monitoring techniques for vertebrate pests – feral pigs, www.pestsmart.org.au/wp-content/uploads/2010/03/Monitoring-techniques-for-vertebrate-pests---pigs2.pdf

NSW Game Hunting Guide. 2017. https://www.dpi.nsw.gov.au/hunting/rules-and-regulations/nsw-game-hunting-guide

Rats

The common black rat (*Rattus rattus*; Figure 143) is a major concern for the Australian macadamia industry. Rodents use resources based on availability, feeding within the trees (Figure 144) while macadamia is present and feeding and harbouring in non-crop habitats at other times.

Figure 143. The common black rat (*Rattus rattus*). Photo: The Queensland Museum.

Risk period

Rodents use on-ground resources by moving the nuts to non-crop habitats and burrows during May–September, i.e. the nut fall cycle where macadamia become plentiful on the ground.

Table 39. The peak risk period for rats is from shell hardening to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Pest identification

Despite its name, the black rat is usually brown or grey. A distinctive characteristic of rats that helps distinguish them from similarly sized carnivorous marsupials is their front teeth: they have a pair of chisel-shaped incisors with hard yellow enamel on the front surfaces. Their nests might be seen before the actual rat itself. Look for burrows within the orchard (Figure 145), thatched twigs (Figure 146) up in the canopy and the distinctively eaten out nuts.

Figure 145. A rodent burrow.

Figure 144. A rat in the tree canopy.

Figure 146. A macadamia branch damaged by rats.

Damage

Rats account for up to 30% of crop losses in high-pressure years and additional losses from orchard floor nut removal (White et al. 1997; Elmouttie and Wilson 2005). The black rat is responsible for >95% of damage across the macadamia growing region.

Management

Effectively managing rodents must take into consideration the complex crop–pest interactions throughout the orchard and be designed to reduce the populations before significant crop losses occur. This comprehensive approach needs to incorporate monitoring, habitat modification, resource (crop and non-crop) management and mortality tools. When combined, this approach results in cost-effective rodent management.

Managing rodents within orchard systems must be a season-long strategy that aims to reduce alternative food resources and nesting sites.

Growers are also encouraged to monitor for signs of rodent activity so they can quickly respond to outbreaks and manage the populations before extensive damage occurs.

Cultural and physical

Adjacent non-crop habitats must be effectively managed and maintained. Riparian zones, headlands, property boundaries and windrows must be kept void of weedy non-crop vegetation (e.g. grasses, lantana and wild tobacco) which provide essential food and nesting resources for the rodents. These areas can be maintained by slashing or revegetating to a forest type known not to support rodents.

The orchard system itself, e.g. inter-rows, must also be effectively maintained to reduce cover and alternative food resources and to encourage natural predators (e.g. owls). This can be achieved by slashing or applying a suitable herbicide.

Cultural practices such as insect refuge strips (i.e. mohawks, Figure 147) can be established to encourage beneficial insects and are compatible with rodent management strategies, although they should be maintained and limited to the areas required. If rodent activity is observed, baiting or trapping programs should be undertaken within these refuges. Once pollination

Figure 147. An insect refuge strip (i.e. a mohawk).

is over, refuges can be slashed and only re-established once required (before flowering).

Skirting trees to open up the orchard system to natural predators and reducing canopy access for foraging rodents is also recommended.

Harvest

Harvest should be conducted regularly to minimise the number of nuts on the ground, especially from May to September when rodents will remove nuts from the orchard floor. At the end of each harvest season, any remaining nuts on the ground should be mulched as soon as practical to ensure the nuts are not left for the rodents.

New plantings

When establishing new plantings, consider the possible effects of rodents. Certain tree varieties exhibit traits which make them more susceptible to rodent damage, such as thinner shells and having sticktights. Although using these varieties is not discouraged, consider where these higher risk varieties will be planted and how rodents can be managed within those orchard blocks.

Biological

There are potentially other methods for rodent control and while perhaps not considered conventional, one grower in Queensland is using snakes to help (Figure 148). Many growers also use dogs for limiting rat numbers. Establishing owl boxes along the perimeter of the orchard will also assist in controlling the rat population.

Chemical

Baiting (Table 40) should be undertaken strategically, targeting areas known for rodent activity. Rather than spreading limited baiting resources around the entire orchard system, growers are encouraged to focus on key blocks which have suffered rodent activity previously.

Early in the season, when rodents are known to be feeding in the trees (January–May), baiting programs should focus on the tree, then as the nuts become more abundant on the ground (May through to final harvest), baiting programs should target that area.

Figure 148. Snakes might contribute to rat control programs in a limited way. Photo: Paul Trollis.

Acknowledgement

This summary is extracted from the NSW DPI Primefact 1768, Vertebrate pests in macadamia: rats, which was originally published in the 2019–20 Macadamia Plant Protection Guide, authored by Dr David Elmouttie, Business Manager, BASF Professional and Specialty Solutions.

References

Elmouttie D and Wilson J. 2005. The potential importance of nut removal by rodents from Australian macadamia orchards. *Journal of Environmental Management*, 77 (1): 79–83.

White J, Wilson J and Horskins K. 1997. The role of adjacent habitats in rodent damage levels in Australian macadamia orchard systems. *Crop Protection*, 16: 727–732.

Table 40. Chemical control options for rats in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials	Remarks
Cholecalciferol (Selontra®)	S7	Vitamin-D3	0	NA	Do not place bait in open unless in a bait station. Concentrate baiting in outer three rows of crop closest to scrubby habitats and when nuts are available.
Coumatetralyl (Racumin®)	S5	Coumarin	0	NA	Do not place bait in open unless in a bait station. Concentrate baiting in outer three rows of crop closest to scrubby habitats and when nuts are available.

Table 41. The peak risk periods for pests in macadamia orchards.

Pest	Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering	Page number
Beetles (various)								Page 35
Macadamia felted coccid								Page 53
Macadamia leaf miner								Page 56
Macadamia twig girdler								Page 63
Macadamia flower caterpillar								Page 50
Macadamia lace bug								Page 53
Macadamia seed weevil								Page 61
Black citrus aphid								Page 39
Flower looper								Page 40
Banana fruit caterpillar								Page 33
Mites								Page 65
Red-shouldered leaf beetle								Page 67
Fruit spotting bug								Page 41
Green vegetable bug								Page 45
Leptocoris species								Page 53
Scale insects								Page 69
Scarab beetle								Page 71
Thrips								Page 71
Macadamia nut borer								Page 58
Kernel grub								Page 46
Rats								Page 81

Macadamia diseases

Botrytis blight (grey mould)

Cause

Caused by the fungus *Botrytis cinerea*, botrytis blight occurs mostly in mature flowers, especially during wet, humid weather with temperatures between 18–22 °C. Light rain or heavy dew can disperse the spores and outbreaks usually occur when showery weather prevails during this temperature range. Botrytis spores can dry out yet remain as inoculum on drying racemes. This inoculum can then be washed or blown onto flowers that are at susceptible development stages and have been wet for 6–8 hours.

Risk period

Table 42. The peak risk period for botrytis blight is during early and peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

Botrytis blight is more likely when flowering peaks coincide with optimal infection conditions. Diseased flowers appear dark brown and cluster together on the rachis with mycelial strands and greyish fungal spores, hence the grey mould name. Complete destruction of the raceme can follow with grey fuzzy mould overlaying dead flowers (Figure 149).

Figure 149. Botrytis blight. Photo: Femi Akinsanmi.

Management

Cultural and physical

Dense canopies can increase botrytis blight risk, therefore opening up the canopy for better air movement and thorough spray coverage will reduce infection risk. A good guide is to ensure that tree height should only be 80% of row width.

For new orchards, plan to have a canopy density that will allow sufficient air movement to prevent moisture from being trapped.

Chemical

If infection occurs in July flowering, be prepared to spray during later flowering as inoculum will be present. Temperature and moisture play an important role in deciding when to spray; the aim is to have fungicide in place before flower petals start to turn brown. The chemical control option for botrytis blight is listed in Table 43.

Table 43. The chemical control option for botrytis blight in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials	Remarks
Iprodione (Rovral® Aquaflo)	S5	2	0	Low	Apply as a thorough cover spray to flower racemes when they open. A follow-up spray might be required seven days later if wet conditions persist during flowering.

Branch dieback

Cause

Branch dieback is caused by the fungus *Dothiorella ribis* (an asexual stage of *Botryosphaeria ribis*). It is most often seen in trees over 15 years old and is becoming more prevalent. The recent dry weather during the 2019–20 season highlighted the importance of this disease. Associate Professor Olufemi Akinsanmi from the University of Queensland is working towards improving our understanding of branch dieback and its controls.

Risk period

Table 44. Branch dieback can be present in the orchard all year.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

Usually a point of gummosis (bleeding) occurs on the affected branch or main trunk and the leaves above this point turn brown with purplish blotches. Other leaves on the affected tree will appear pale and lack the healthy sheen. The plant parts become 'blighted 'and start to dieback (Figure 150). However, the disease can progress slowly and the leaves might retain colour while the disease spreads down the branch.

The bark on the diseased limb will be darker than normal with a water-soaked appearance at the edge of the infection. When the bark is peeled away, a typical brown-purple discolouration is seen in the wood. A cross-section of the branch will show this discolouration (often in a wedge shape; Figure 151).

Often the disease will appear where the tree has been stressed, such as in locations where waterlogging occurs, extreme dry weather, or a poor growing environment. However, it can also appear in orchards with good soil, perhaps through physical damage.

Figure 150. Branch dieback in macadamia. Photo: Femi Akinsanmi.

Both airborne and waterborne fungal spores can spread from diseased bark within the tree. A key indicator that the plant is suffering from branch dieback and not drought is to shake the branch. If the leaves stay on the branch it is probably dieback, if the leaves dislodge from the branch, it is probably drought.

In some cases, before obvious dieback symptoms become apparent, the trees might appear to be suffering from a nutritional disorder as the leaf veins turn reddish. In other cases, particularly trees younger than four years, the leaves can appear a dull khaki green with the whole tree

Figure 151. A discoloured cross-section potentially a *Botryosphaeriaceae* infection.

dying (Figure 152) within three to four weeks. This is common in diseases associated with Botryosphaeriaceae. Similar to phytophthora, dieback can occur more commonly at the end of the rows where waterlogging can occur or on hilltops where soil is poorer or shallower. However, symptoms can also occur on good soils. Generally, symptoms will appear from mid-summer to early autumn after prolonged warm, humid hot weather.

Management

Cultural and physical

Maintain good soil and tree health. Sap flow is essential for tree resistance to pest and disease pathogens. Prevent unnecessary wounding or stress to the tree. Different varieties have different levels of susceptibility, so where possible, select more resistant varieties.

Cut out dead branches until you identify a clean-cut cross-sectional area. If discoloured cross-sections continue to the trunk, you will need to remove the tree. Paint large exposed branches with copper and water-based white paint.

Dispose of all infected material as soon as possible. Common disposal methods include chipping or burning.

Figure 152. A macadamia tree with advanced branch dieback.

Finely chipped dead and decaying timber can be incorporated into a composting pile where the temperature ranges between 50 to 65 °C before turning. This should kill any beetles that could potentially be associated with this disease. For more information about composting, see NSW DPI Primefact 'How to compost on farm'.

If you choose to burn the infected material, do not make a burn pile that is left in the orchard for months as this provides a perfect breeding environment for bark beetles that may be associated with this disease.

Chemical

There are currently no products with label registration or permits to control branch dieback.

Flower blight

Cause

Flower blight (Figure 153), also called dry flower or raceme blight, is caused by both *Pestalotiopsis macadamiae* and *Neopestalotiopsis macadamiae* fungal species. The disease was first observed in the Bundaberg production region in 2009 and it resulted in total crop failure. The disease now occurs in all macadamia producing regions in the Australian east coast. Dry flower disease poses a serious threat to macadamia production.

Risk period

Table 45. The peak risk period for flower blight is from pre-flowering to peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

As its name suggests, dry flower disease is characterised by the dry appearance of the raceme (Figure 153). Infections can occur at any stage of raceme development but the symptoms will mostly be seen from pre-flowering to peak flowering. Diseased flowers will easily dislodge from the rachises when shaken, but dried racemes can persist in the tree canopy between seasons and serve as a source of inoculum in the following season (Akinsanmi et al. 2017).

Figure 153. Rachis dieback and early dry flower from the tip. Photo: Femi Akinsanmi.

Management

Cultural and physical

Dense canopies can increase flower blight risk, therefore ventilating the tree through opening up the canopy for better air movement and thorough spray coverage will reduce infection risk.

The risk is less for younger trees. For new orchards, plan the orchard density so that ventilation is achieved throughout the canopy.

Chemical

There are currently no products with label registration or permits for flower blight.

Reference

Akinsanmi OA, Nisa S, Jeff-Ego OS, Shivas RG and Drenth A. 2017. Dry flower disease of macadamia in Australia caused by *neopestalotiopsis macadamiae* sp. nov. and *pestalotiopsis macadamiae* sp. nov. *Plant disease*, 101: 45–53, DOI: 10.1094/pdis-05-16-0630-re

Green mould

Cause

Cladosporium gleosporoides is a dark coloured mould that can attack the leaves and fruits of many plants. It produces asexual spores in delicate, branched chains that break apart readily and drift in the air. It can grow in a range of conditions. While a raceme blight epidemic has been reported in South Africa, in Australia, green mould is of minor importance (van den Berg et al. 2008).

Risk period

Table 46. The peak risk period for green mould is from pre-flowering to peak flowering.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

Green mould is characterised by small water-soaked specks on the flower that later become necrotic. The diseased racemes will be covered in olive grey patches of mycelia and conidia (Akinsanmi et al. 2018; Figure 154). It is most likely to appear at the end of pollination.

Figure 154. Cladosporium blight in macadamia raceme. Photo: Femi Akinsanmi.

Management

Cultural and physical

As with other flower diseases, dense canopies can increase disease risk. The longer moisture is on the flower, the more likely disease will exist. Therefore, ventilating the tree through opening up the canopy for better air movement will reduce infection risk.

Chemical

As green mould is so far considered of minor importance, a chemical control is not necessary. There are currently no products with label registration or permits for green mould.

References

Akinsanmi F. 2018. Macadamia disease identification and management workshop series. Hort Innovation, 10–14 September, https://www.horticulture.com.au/globalassets/hort-innovation/resource-assets/mc16018-disease-identification-guide.pdf

van den Berg N, Serfontein S, Christie B and Munro C. 2008. First report of raceme blight caused by *Cladosporium cladosporioides* on macadamia nuts in South Africa. *Plant Disease*, 92(3): 484, doi:10.1094/PDIS-92-3-0484C

Husk rot and canker

Cause

Husk rot and canker are caused by various fungi including *Diaporthe* spp. (sexual state), *Phomopsis* spp. (asexual state) and *Anthracnose* spp., all of which are more likely after wet weather and warm temperatures. The prevalence of husk rot is increasing in macadamia orchards.

Risk period

Table 47. The peak risk period for husk rot and canker is close to harvest.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

Soft and spongy black lesions up to 10 mm diameter will appear on the green fruit pericarp (Figure 155). These lesions can form greasy decay of the entire fruit pericarp.

The husk rot fungi can spread rapidly and will discolour the whole husk. Phomopsis husk rot is distinguishable from Anthracnose husk rot (caused by *Colletotrichum gloeosporioides*) by the absence of concentric rings on the lesion. Wounds created by insect pests such as nut borer or other injuries, such as hail damage or wind rub, can predispose the husk to infection.

Husk rot is different from the husk spot caused by *Pseudocercospora macadamiae*. If pressure is applied to the damaged area, husk rot is quite soft, whereas, husk spot lesions are hard.

Figure 155. Husk rot on macadamia nuts.

The *Phomopsis* fungus is also responsible for canker in macadamia. Rapid death of branches up to 15 mm in diameter can occur. The leaves will turn brown and remain attached to the dead branches. When the bark is peeled back from the infected area, a pattern of narrow dark lines is often seen on and in the woody tissue. A cross-section of the branch might show a wedging appearance.

Management

Always insist on certified disease-free material. Maintain good soil and tree health. Monitor and control pests and protect the plant from being wounded. Once the disease is developed on an injured husk, it cannot be cured, it can only be suppressed.

Cultural and physical

Good orchard hygiene and insect control will help prevent husk rot. Removing old 'sticktight' husks from the tree is a good practice to avoid this fungus as it is dispersed through rain splash. Prune trees to give good ventilation and remove and destroy old branches and cankers.

Where branches with husk rot are identified, they should be cut out of the tree. Ensure that the cut is at least 15 cm below the lesion/good wood intersection. Disinfest between trees as the disease can be spread through pruning cuts. Protect freshly cut wounds.

Chemical

Control plant stress before direct chemical application. As always, good coverage is essential. The chemical control option for husk rot and canker is listed in Table 48.

Further reading

The Pest Identification Tool. nd. Developed by Nursery and Garden Industry Queensland, with support and assistance from Greenlife Industry Australia and Hort Innovation, https://www.pestid.com.au/preview/disease/phomopsis-husk-rot-and-canker

Table 48. The chemical control option for husk rot and canker in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials	Remarks
Copper based fungicides (various)	S6	M1	1	Low	Preventative not curative.

Macadamia husk spot

Cause

Macadamia husk spot is caused by the fungal pathogen *Pseudocercospora macadamiae*. Most macadamia varieties are prone to husk spot, but it is more prevalent in those with sticktight husks. Rain splash easily spreads fungal spores from diseased sticktights to developing nuts in the tree canopy. Macadamia husk spot can cause heavy premature nut shedding.

Risk period

Table 49. The peak risk period for macadamia husk spot is from pre-flowering to nut set.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

Early symptoms appear as pale yellow flecks with a diffuse halo on the husk. These spots become a darker yellow to tan-brown and expand to approximately 5–10 mm in diameter (Figure 156). The spots will appear later in the season on three-quarter to full-size nuts. Dry husk spots are woody and hard to cut through compared to an unaffected husk. While the shell and kernel are not affected, macadamia husk spot can result in nuts dropping 4–6 weeks early. These nuts will be immature due to low oil accumulation and will not be suitable for processing.

Management

Macadamia husk spot lesions on green and dried husks, including sticktights, can produce viable fungal spores for many years. Appearing as a greyish mat in the centre of the dark brown spots, the spores are easily dispersed by rain splash onto developing nuts. Studies have shown that removing sticktights from the trees significantly reduces husk spot infections.

Varieties such as A16 and A38 are highly susceptible to the husk spot fungus while varieties such as 344 are less so.

Cultural and physical

Cultural practices are important in limiting macadamia husk spot damage. Growing varieties that do not support sticktights reduces infection risk. Pruning to open the tree canopy can increase ventilation and hasten nut drying. However, A38 has quite an open canopy and still suffers husk spot, which suggests that combining cultural and chemical controls is critical. Ideally we need to reduce favourable conditions for spore development. Removing sticktights limits infection. Avoid moving husks with macadamia husk spot between farms as this can introduce the infection to new orchards. In areas where there is a history of husk spot, start preventative sprays when the crop is at match head stage then monitor conditions.

Chemical

Chemical spray decisions should be based on the weather, if conditions are favourable for infection, variety susceptibility and infection history.

The chemical control options for husk spot are listed in Table 50.

Figure 156. A macadamia nut with macadamia husk spot damage.

Further reading

Akinsanmi OA. 2018. Husk spot in macadamia. *Hort Innovation Fact Sheet*, https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/husk-spot-in-macadamia/

Fitzell RD. 1994. Diseases and disorders of macadamias. NSW Agriculture.

Miles A. 2011. Husk spot disease of macadamia. PhD Thesis, The University of Queensland, School of Biological Sciences.

O'Hare P, Quinlan K, Stephenson R and Vock N. 2004. *Macadamia grower's handbook*. Queensland Department of Primary Industries, http://era.daf.qld.gov.au/id/eprint/1964/6/mac-growing_guide_Part6.pdf

Table 50. Chemical control options for macadamia husk spot in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials	Remarks
Azoxystrobin + tebuconazole (Custodia®)	S5	3 + 11	15	Low	Beware of resistance, do not apply more than two consecutive sprays of either group 3 or 11 fungicides.
Carbendazim (Spin Flo®)	S7	1	28	Medium	Do not apply more than two consecutive applications.
Copper based fungicides (various)	S6	M1	1	Low	Ensure adequate coverage.
Difenoconazole (Score®)	S5	3	0	Low	Use in a protective fungicide program containing fungicides from different chemical groups.
Penthiopyrad (DuPont™ Fontelis®)	S6	7	14	Low	Apply the first application when the crop is at match head stage and the second application 14 to 28 days later, depending upon prevailing weather conditions. DO NOT apply more than two sequential applications of a Group 7 fungicide before rotating to a fungicide with a different mode of action.
Pyraclostrobin (Cabrio®)	S5	11	0	Low	DO NOT apply more than two sprays per season as part of a complete disease control program. Start application at match head stage and a repeat application at 14 to 28 days later. Ensure that fungicides from an alternative chemical group are included in the spray program each season.
Pyraclostrobin + fluxapyroxad (Merivon®)	S5	7 + 11	21	Low	Start applications at match head growth stage. Do not apply more than three applications a year and no more than two consecutive applications per year. Ensure that fungicides from an alternative chemical group are included in the spray program each season.

Phytophthora disease

Cause

Phytophthora disease is caused by the fungus *Phytophthora cinnamomi*, a soilborne water mould. Phytophthora can reduce tree vigour, productivity and ultimately kill the tree. It will often appear at the bottom of slopes where water can pond, as well as on drainage lines and at the tops of slopes where soil has been eroded. Phytophthora becomes more apparent when trees are suffering, such as from nutritional or moisture stress.

Risk period

Table 51. Phytophthora can occur throughout the year.

Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering

Symptoms

Affected trees will look pale green and sickly. They will lack vegetative vigour, leaves will turn yellow and drop off. Trees can also be stunted.

Trunk canker mostly occurs on the main trunk but can also spread to the limbs of the tree. It appears as cracking up the length of the trunk from the ground. Red resin will often ooze from these vertical cracks (Figure 157). Over time, the bark will become corky and deeply furrowed, when it can be easily peeled away, revealing a reddish colour wood. The affected trees often have healthy suckers sprouting from the rootstock at ground level. The death from trunk canker results from the cankers girdling the trunk.

Management

Unfortunately, the *Phytophthora* fungus is spread quite easily through many pathways. It is soil-borne and can spread through mud, muddy water, soil-based potting mix, rain splash, machinery and dust. It gains entry through wounds and or natural openings in immature bark. Once the *Phytophthora* pathogen is in the soil, it can never be eliminated.

Cultural and physical

Start clean and only use clean planting material. Nurseries supplying tree stocks should use sterile (steamed material) that will eliminate *Phytophthora* pathogens. Ensure new plants have a strong, well developed root system. Try to plant trees where you can achieve adequate drainage so that there is no water logging. Compost, chicken manure and urea assist by improving soil health and inhibiting phytophthora.

Trunk canker generally results from wounds near the base of the tree. Try to avoid cutting or wounding the tree near ground level. Place guards around the base to prevent weed whacker damage.

Chemical

Control plant stress before direct chemical application. As always, good coverage is essential. The chemical control options for phytophthora are listed in Table 52.

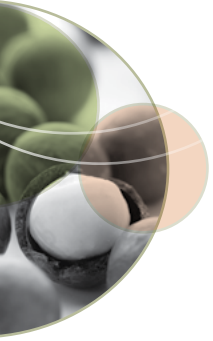
Figure 157. Ooze sap from a severe case of phytophthora. Photo: Femi Akinsanmi.

Table 52. Chemical control options for phytophthora in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials	Remarks
Copper as cuprous oxide (various)	S6	M1	1	Low	Preventative not curative. Do not use more than five applications per season.
Metalaxyl (Ridomil Gold® 25G)	S5	4	28	Low	Best results will be achieved when this is used in conjunction with good soil health management practices.
Metalaxyl + copper oxychloride (Axiom® Plus)	S5	4 + M1	28	Low	Best results will be achieved when this is used in conjunction with good soil health management practices.
Phosphorous acid (Agri-fos® 600)	S5	33	28	Low	Do not apply to trees under severe water stress or during hot weather.

Table 53. The peak risk periods for macadamia diseases.

Disease	Pre-flowering	Early flowering	Peak flowering	Nut set	Pea size nut and spring flush	Shell hardening to harvest	Harvest to pre-flowering	Page number
Branch dieback								Page 86
Phytophthora								Page 93
Flower blight								Page 88
Green mould								Page 89
Macadamia husk spot								Page 93
Botrytis blight (grey mould)								Page 85
Husk rot and canker								Page 90



Non-bearing and nursery trees

Young trees that are not bearing nuts (Figure 158) do not need the same intensive spray schedule as bearing trees, however, they still require continual monitoring for pests and disease. Below are the types of problems most likely to be encountered with young, non-bearing macadamia trees (Table 54).

Table 54. Problems most likely to be encountered with young non-bearing macadamia trees.

Pest or disease	Damage	Control
Hares	Tree growth is reduced and the tree can die from ring-barking.	Protecting the tree with trunk guards and/or wire netting fence are the most reliable means of preventing an attack.
Macadamia felted coccid	Can cause severe setback to developing young trees. Can enter through infested nursery stock. Heavy infestation will stunt and distort growth.	Inspect nursery stock thoroughly before planting into the orchard. Spray infested trees and look at promoting natural enemies.
Macadamia leaf miner	Appearance of tunnelling under the leaf surface, causing the leaf to crinkle. Generally seen on fresh new flush, it can cause reduced photosynthesis.	Softer sprays can be used if the damage is widely spread across the orchard or nursery.
Macadamia twig girdler	Damage to branch forks and leaf whorls. Leaves skeletonised and webbed together.	Inspect and spray only affected plants. There are many natural enemies to twig girdler.
Phytophthora	Leaves will appear yellowish. In severe cases, ooze sap will exude from the trunk.	Ensure effective soil preparation before planting.
Red-shouldered leaf beetle	Generally will swarm orchard. The affected leaves will appear scorched, causing premature leaf drop and poor tree establishment.	Monitor trees, especially after rain in spring and summer. Only treat affected trees.
Scale	Many types of scale can affect macadamia. Check nursery stock before planting. Look carefully along leaf stems and undersides. Also look for sooty mould.	Only treat infected nursery stock because blanket spraying will reduce beneficials within the orchard or nursery.

Figure 158. Young trees require continual monitoring for pests and disease.

Nutrient disorders

Jeremy Bright (NSW DPI) and Andrew Sheard (Technical Manager at Mayo Macs, South Africa)

Introduction

Ensuring good soil health and nutrition for macadamia plants will help them to resist attack from insect pests and diseases. Healthy soils require adequate nutrition, which is an important component for any crop protection strategy.

Good soil nutrition begins before planting so site preparation is vital. Before planting, soil tests should be taken across the whole orchard, separating samples that might vary due to changes in soil characteristics. Sampling depths should be about 0–20 cm and 20–40 cm pre-planting. In well-drained red soils in higher rainfall areas, you could go to 40–60 cm to determine subsoil acidity. In planted orchards, ideally try to include samples from different tree varieties and ages. Given the two year lead time from ordering plants to delivery, growers have plenty of opportunity to perform complete horticultural soil tests and act on the information received. This will allow the amendments enough time to be effective.

Soil and plant tissue analyses, along with nutrient budgets, can help with planning annual fertiliser programs. Foliar nutrient sprays can be an important component of an orchard fertiliser program but should be seen as supplementing soil nutrition deficiencies rather than being a substitute for them.

The images in this section are intended to display some of the symptoms that can be seen in the field where specific nutrients are either deficient or at toxic levels. It is hoped they can assist growers and macadamia orchard staff to identify the disorders and what actions they should take regarding crop nutrition and tree health.

Growers should also be aware that this section is intended as a guide to nutrient deficiencies and toxicities. It is not a replacement for soil and leaf sampling nor a visual assessment of the orchards, especially for iron deficiency. Soil and leaf samples will inform the grower if an element is deficient or whether it is just not available to the plant due to soil pH or nutrient interaction complexes.

Nitrogen

Nitrogen (N) is essential for plant growth. It is a key component of protein and chlorophyll, the latter being required for the synthesis of plant hormones, which control tree growth.

Deficiency: lack of nitrogen reduces photosynthetic capacity and therefore growth. It is quite mobile in plants so younger leaves recycle it from older leaves which then go yellow (Figure 159) and drop off prematurely. Nitrogen deficiency can cause reduced flowering and fruit set, therefore decreased production (Figure 160).

Toxicity: too much nitrogen, especially in late summer, can cause excessive growth, reduced flower bud formation and flowering.

Figure 159. Older and younger leaves all show general yellowing, but it is worse on older leaves. Photo: Andrew Sheard.

Figure 160. Nitrogen deficiency in a macadamia tree. Photo: Andrew Sheard.

Phosphorus

Phosphorus (P) is important for cell division and growth. It is involved with sugar and starch formation as well as moving carbohydrates around the plant.

In certain acidic ferrosols, the low pH (usually below pH 5 $CaCl_2$) can bind the phosphorus, making it unavailable to the plant. However, it is not the actual amount of P that might be low, but rather the availability of the P to the plant. This is further compounded when the tree has exposed roots (Figure 161). These roots indicate minimal proteoid roots and therefore an inability to extract available P, thus leading to deficiency.

Deficiency: macadamia plants deficient in phosphorus will have large amounts of leaf drop, poorly developed new growth and reduced yields. Other symptoms of P deficiency can include dieback of new shoot growth.

Toxicity: soils high in P often induce iron deficiencies.

Figure 161. Exposed roots indicate decreased proteoid roots, creating an environment less able to absorb phosphorus. Photo: Andrew Sheard.

Potassium

Potassium (K) regulates the water balance in plants by controlling the opening and closing of stomata. It is important for synthesis and movement of starch, sugars and oils. Potassium directly affects nut yield and quality.

Cation exchange capacity (CEC) and the amount of potassium available are key to whether plants will suffer from potassium deficiency. Potassium is essential for nut development and oil accumulation. Ensure you have the correct CEC ratio and sufficient available potassium in the soil.

Deficiency: potassium is mobile in the plant so deficiency symptoms will appear on older mature leaves as light brown necrotic areas between the veins and along leaf margins (Figure 162).

Figure 162. Necrotic areas between the veins and along leaf margins are signs of potassium deficiency. Photo: Andrew Sheard.

Calcium

Calcium (Ca) is required for cell division and is an important constituent of cell walls and membranes. Low Ca levels cause abnormal development of new leaves, nuts and root tips.

Ideally you should check the calcium levels in the soil as well as the exchangeable calcium in comparison with other nutrients (cation exchange ratio). The amount of calcium in the soil can affect the availability of other nutrients such as potassium and magnesium.

Deficiency: low levels of calcium can be associated with leached, low pH soils. Amendments for low pH will depend on the availability of other elements such as magnesium. Calcium is not very mobile in the plant so deficiencies appear on the new growing points and include yellowing of the leaf tips (Figure 163 and Figure 164).

Figure 163. Calcium deficient leaves. Photo: Andrew Sheard.

Figure 164. Yellowing leaf tips is a symptom of calcium deficiency. Photo: Theunis Smit.

Magnesium

Magnesium (Mg) is an important component of chlorophyll, which is the pigment that gives plants their colour. Magnesium is essential for photosynthesis, it regulates plant nutrient uptake and essential cellular functions.

Deficiency: magnesium is readily mobile in the plant, moving from older to newer plant tissues (Figure 165). Magnesium deficiency will appear as interveinal yellowing from the leaf tips and edges towards the central midrib areas (Figure 166). Exchangeability and the ratio of magnesium in relation to other nutrients such as calcium and potassium will influence its uptake. Deficiencies mainly occur in high rainfall areas with low pH sandstone soils and ferrosols. Heavy applications of potassium can also induce magnesium deficiency.

Figure 165. Magnesium deficiency in macadamia, note that older leaves are most affected as magnesium is quite mobile within the plant. Photo: Andrew Sheard.

Figure 166. Interveinal yellowing from leaf tips to the midrib is a symptom of magnesium deficiency. Note the leaf base area remains green. Photo: Andrew Sheard.

Iron

Iron (Fe) is required for chlorophyll production.

Deficiency: macadamia plants deficient in iron will display interveinal yellowing with the leaf veins remaining green (Figure 167). In severe cases, young leaves can turn almost white with dieback of the leaf tip and shoot growing point, and young nut husks will lose their green lustre to become pale yellow (Figure 168). As iron is not very mobile within the plant, these symptoms will be displayed on the younger leaves.

Iron deficiency is induced by high soil pH and phosphorus. Low organic matter can also contribute to iron deficiency, although organic matter compounds can form iron complexes that improve availability. Excessive amounts of phosphorus fertiliser can reduce iron uptake.

Toxicity: poorly aerated soils that are acidic can create iron toxicity.

Figure 167. Yellowing of iron-deficient plants due to the lack of chlorophyll. Remember iron deficiencies can be induced through high levels of competing elements such as phosphorus. Photo: Andrew Sheard.

Figure 168. Iron deficiency in macadamia nutlets showing chlorosis due to lack of chlorophyll. Photo: Andrew Sheard.

Boron

Boron (B) is important for cell division and growth, especially for root tip development, shoot and nut growth as well as flowering.

High soil pH reduces boron availability while low soil pH increases availability. Boron is easily leached from coarse-textured acid soils and organic matter in the soil can hold boron to make it available to the plant.

Deficiency: as boron is not very mobile within the plant, younger leaves will display symptoms first, becoming leathery and having split veins. In severe cases, poor internodal growth and leaf dieback (Figure 135) become apparent. To rectify the deficiency, boron is best applied by spreading on the ground, but its uptake is determined by water uptake so the application should be timed with irrigation or rain. Boron deficiency might affect pollination success and therefore a quick-fix foliar application could be timed for just before peak flowering. Regular leaf and soil analysis will confirm whether this is warranted*.

There is a fine line between boron deficiency (Figure 169) and boron toxicity (Figure 170).

**Work by Russ Stephenson showed that a foliar boron spray gave clear benefits in terms of first grade kernel yield and kernel recovery (when these were low).*

Figure 169. Boron deficiency showing poor internode growth and leaf dieback. Photo: Andrew Sheard.

Figure 170. Marginal leaf burn from boron toxicity. Photo: Andrew Sheard.

Zinc

Zinc (Zn) is required to produce enzymes and plant hormones, especially auxin which determines leaf size. Therefore it is required for new growth.

Deficiency: zinc is relatively immobile in the plant so symptoms will appear on younger shoots first, as rosetting of leaves at the end of shoots and stunted leaves with intercellular chlorosis (Figure 171 and Figure 172).

Zinc availability decreases as pH increases. High phosphorus, calcium or potassium levels will also contribute to zinc deficiency. Ideally you should aim to build up zinc levels in the soil to be used by the plant over time. However, if regular leaf analysis shows deficient zinc levels (especially in ferrosols), then foliar applications may be warranted. Zinc should be applied on the summer flush.

Figure 171. Distinct intercellular chlorosis which is typical with zinc deficiency. Little leaf or rosetting is also present. Photo: Andrew Sheard.

Figure 172. Intercellular chlorosis caused by zinc deficiency. Photo: Andrew Sheard.

Manganese

Manganese (Mn) is necessary to form chlorophyll and assimilate carbon dioxide in photosynthesis. It is an essential part of the plant enzyme system and is directly involved in iron and ascorbic acid uptake. Manganese assists in fruiting and nut growth and development.

Deficiency: manganese is relatively immobile so deficiency symptoms will appear on young leaves as interveinal chlorosis close to the midrib (Figure 173). Leaves usually maintain a distinct band of darker green along the midrib and veins. High pH soils will reduce Mn availability and high organic matter can also tie up manganese.

Toxicity: in north coast soils, particularly where pH is low (<5), we have seen many plants displaying manganese toxicity. Toxicity symptoms include interveinal brown spots along the outside edge of older leaves (Figure 174). Leaves may eventually brown off and die back. Addressing low soil pH and increasing organic matter in the soil will alleviate Mn toxicity.

Figure 173. Chlorosis with dark green along the midrib. Photo: Andrew Sheard.

Figure 174. Manganese toxicity showing brown spots along the outer edges of the leaves. Photo: Alan Mason.

Copper

Copper (Cu) is necessary for energy transfer for photosynthesis and nitrogen metabolism. It is also necessary for lignin production, which provides strength to the growth of lateral branches. It is a constituent of several enzyme systems involved in building and converting amino acids to proteins.

Copper is usually evenly distributed throughout the plant but is not very mobile in the soil or the plant. Anything that inhibits new root growth will also inhibit copper uptake.

Deficiency: as copper is key to lignin production, deficiencies will be displayed as twisted or distorted lateral branches. The most obvious indicator of copper deficiency is the appearance of a 90-degree branch angle of new flush (Figure 175); almost in the shape of a 'C'. Acidic soils will increase copper uptake while high pH soils will inhibit copper.

Figure 175. A 90-degree branch angle of new flush is a typical sign of copper deficiency. Photo: Andrew Sheard.

Further reading

O'Hare P, Quinlan K, Stephenson R and Vock N. 2004. *Macadamia grower's handbook*. Queensland Department of Primary Industries, http://era.daf.qld.gov.au/id/eprint/1964/6/mac-growing_guide_Part6.pdf

Weir RG, Cresswell GC and Loebel MR. 1995. *Plant nutrient disorders 2*: *tropical fruit and nut crops*. NSW Agriculture (Inkata Press).

Pollination with native stingless bees

Chris Fuller, Kin Kin Native Bees

New research on macadamia pollination in Australia has not only confirmed previous results but also added to our knowledge on the topic. Hort Innovation (HI) engaged The New Zealand Institute for Plant and Food Research Ltd for the project. Trial sites were chosen in the Bundaberg, Gympie, Glass House Mountains and Northern Rivers regions and trial work commenced in June 2014. The paper, titled *Optimising pollination of macadamia and avocado in Australia* (Project Number MT13060), is now available on the HIA website (https://horticulture.com.au/wp-content/uploads/2017/07/MT13060-Final-Report-Complete.pdf).

Part of the trial work involved controlled self- and cross-pollination treatments using glass tubes to transfer pollen. These were then compared to open-pollinated treatments that relied on pollinators to transfer pollen. In all cases, both open- and cross-pollinated treatments resulted in higher nut set than the self-pollinated treatments.

Manual cross-pollination (a technique that growers can do themselves with minimal equipment) resulted in greater nut set than open-pollination, although if this process is deemed necessary, then it probably indicates a lack of insect pollinators that should be doing the job. Introducing bees will increase pollen transfer and therefore increase orchard productivity.

An inventory of insects that visited macadamia flowers at the different trial sites was compiled. Stingless bees and honey bees were by far the most significant floral visitors during the trials, and of these, stingless bees were the most efficient pollinators. Consequently, growers could increase nut set by introducing hives of managed pollinators to their orchards.

There is a developing pollination industry based around using native stingless bees. Hives can either be rented or brought in for the flowering period, or alternatively, some growers are choosing to purchase their own hives (Figure 176). When hives are kept on the farm all year, growers should consider planting alternative forage from which the bees can collect nectar and pollen when the macadamias are not flowering (see Figure 177 for an example).

This is especially important in areas such as Bundaberg where many orchards have little surrounding natural forests. These forage areas also provide harbourage and food for beneficial predatory insects that help with pest insect control and add to the overall biodiversity on the orchard. Stingless bees are generalist foragers and are very good at finding feed, provided it is in reasonably close proximity. Weeds such as cobblers pegs or billy goat weed (also known as blue top) can provide pollen and nectar over winter when little else is available.

Figure 176. As hive numbers grow on orchards, stands are created for multiple hives. This stand will eventually house 20 hives.

Figure 177. A mohawk of alternative forage for bees.

For further information on the availability and use of native stingless bees in macadamia orchards, please contact Chris Fuller at info@nativebees.com.au.

Honey bee best practice management

Honey bees are vital in agriculture, pollinating countless food crops including macadamia (Figure 178). Honey bees and other pollinating insects, birds and mammals are attracted to crops in bloom. Special consideration is required regarding the danger of pesticides to beehives in or near orchards. Legally, pesticides must not be applied during bloom when bees are foraging. Consequently, cooperation between growers, spray operators and beekeepers is necessary.

Figure 178. A honey bee pollinating a macadamia flower.

Communication to organise beehive placement timing and location before flowering is essential

Communication between beekeepers, growers, spray operators and neighbours is vital, especially as honey bees can easily fly two kilometres from their hive to forage on flowers. In addition to word of mouth and written pollination contracts, the BeeConnected app (Figure 179) is a valuable tool for farmers who would like to be informed of, and connected with, beekeepers near their farm, contractors spraying the crop protection products and beekeepers who want to be informed of crop protection activities near their beehives (Figure 180). After registering as a user, farmers can enter the location of their property and if this is within 10 km from where a beekeeper registers the location of their beehives, then both parties will be notified, prompting a discussion about their activities. This can be done using the secure messaging service.

Figure 179. The BeeConnected app.
Source: CropLife Australia.

Farmers can register the time and location of their planned crop protection activities, such as pesticide spraying. Using a smart phone, farmers can find their paddock by exploring near their current location, a registered property, or searching GoogleMaps. Switching between street and satellite view makes it easier to find specific paddocks using nearby roads and geographical features. BeeConnected is optimised for Android and Apple smart phones (http://beeconnected.org.au/).

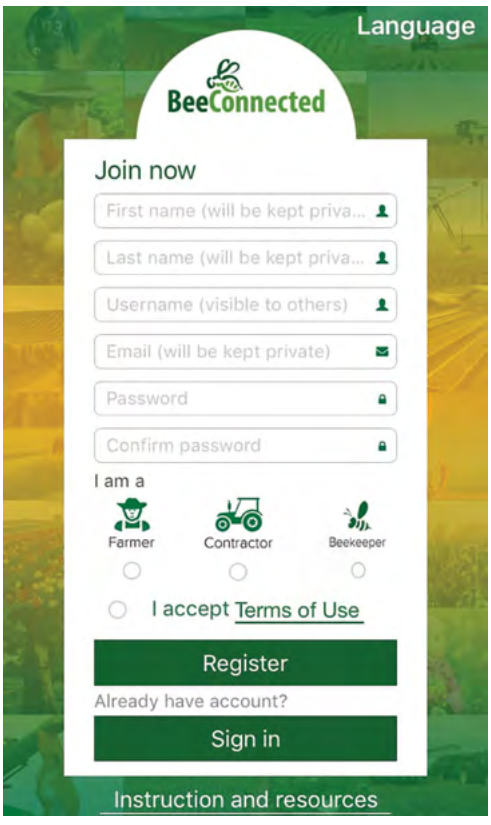


Figure 180. The BeeConnected app enables farmers, contractors and beekeepers to be connected.
Source: CropLife Canada.

Monitoring

Pre-flowering

Monitor crops and green racemes. If spraying is required, ensure it is completed before bees enter the orchard. Always check the chemistry you intend to use is not residual through to flowering.

During flowering

Ideally, if no pests were observed during pre-flower monitoring, then no further action should be required. However, if pests are identified through flowering, then a short acting chemical could be applied; but certain rules apply for bee protection including:

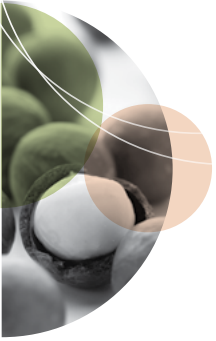
- always choose short acting chemicals
- finish your application at least 6 hours before bee activity begins
- spray late in the afternoon or evening, when bees are not foraging and pollen is not present
- turn off nozzles when near beehives, even if at night
- avoid directly spraying bees in flight (Figure 181) or beehives
- remove hives at nut set when no pollination is occurring (bees will travel long distances (8 km) to find alternate food sources and can come in contact with insecticide treated crops).

Figure 181. A native bee in flight honing in on a macadamia flower. Photo: Chris Fuller.

Other ways to help bees

To ensure bees spend more time pollinating the crop than searching for water and to guard the bees from drinking pesticide-contaminated water, beekeepers and growers should provide clean water; a practice that includes covering or removing water sources for bees before a pest control treatment, or emptying and refilling water after a treatment is made. Water supplies will need to be cleaned and refreshed regularly (possibly daily).

Provide alternative pollen sources before and after macadamia flowering (for good colony strength and bee health) and always place hives away from areas prone to shade and flooding.



Biosecurity: inspect, detect and report

Inspecting crops, detecting pests and reporting suspect plant pests are three simple, yet vital steps required to reduce the risk of a biosecurity incursion from happening on your property.

Australia is unique as it has an isolated geographic location and a strong national quarantine system in place. However, there is always a risk of exotic pests entering Australia by natural dispersal, assisted dispersal from tourism, imports and illegal activity. Therefore, growers need to be actively inspecting crops and paying extra attention to unhealthy plants or unusual pests.

Biosecurity is a shared responsibility that is in everyone's capable hands.

Identifying a problem is the first step to combating biosecurity risks and it is easier to identify new problems if you are carrying out regular inspections.

Inspections involve actively checking and observing your crop regularly. Inspection routines can easily be tailored to suit you and your production practices. For example, you may choose to undertake more frequent inspections during the juvenile stages of your crop's life, or you may choose an experienced staff member to do the inspections during harvest. How you implement inspection activities is up to you, but they should be a regular practice on your farm.

Making sure you and your staff are familiar with commonly found and exotic pests and diseases within your industry will drive successful surveillance and increase the likelihood of detecting anything 'out of the ordinary' if it were to occur.

Detection is identifying the presence of something new or unusual that you were previously unaware of. This is where being familiar with common pests and diseases for your industry is important, as well as being aware of some of the exotic industry pests and diseases. If you are unsure about a pest you find, or you are observing unusual and unexplained health deterioration in your plants, it is best practice to report anything suspected of being exotic.

A second opinion from an agronomist or consultant can sometimes be helpful and it is also appropriate if you are unsure whether what you have found is something that needs to be reported.

Reporting is a simple, established process in place for anyone who suspects they have found an exotic pest or one that is previously unknown in their region. Reports are treated confidentially and are appropriately discussed and investigated with the reporter to confirm sound suspicions before any biosecurity measures are taken.

Exotic pest reports can be made in NSW by:

1. calling the Exotic Plant Pest hotline on **1800 084 881**. This number will automatically divert you to the relevant state authority based on where you are calling from. A photo, sample of the pest or the affected plant material might be requested for further identification. The hotline in NSW is monitored during business hours and callers should be prepared with the following details:
   - name, contact number and location of the suspect pest or disease
   - the plant affected and a description of the damage on the plant
   - whether there is a pest present (e.g. insect) that may be causing the damage
   - description of the pest
2. submitting a report online by visiting www.dpi.nsw.gov.au/biosecurity/report-a-pest-or-disease. You will be given an option to include a photo of the pest or affected plant as part of your report.
3. contacting a Local Land Services (LLS) or DPI officer for advice if you have a local contact. LLS and DPI staff can assist you with following up on your suspicious pest and ensure it is reported through the appropriate methods if required.

EXOTIC PLANT PEST HOTLINE
1800 084 881

An exotic pest to look out for:

Tropical nut borer (*Hypothenemus obscurus*)

Tropical nut borer beetles are exotic to Australia. They are very small, dark brown and oblong-shaped, with adults growing to around 1.5 mm long (Figure 182). Initial evidence of tropical nut borer is seen with small (0.5 mm) holes in the husk of the nuts. The borers live and breed inside the nut (Figure 183), making produce unmarketable and exposing it to further fungal infection. The pest is spread to new regions by flying or spread can occur with transporting infested macadamias and other host species.

Tropical nut borer is one of the most important pests of macadamia production overseas. The borers live and feed beneath the husk making them difficult to target with spray. In heavily infested areas tropical nut borers can damage up to 60% of a macadamia crop. Up to 190 beetles have been found in a single nut.

Figure 182. Tropical nut borer. Photo: Pest and Diseases Image Library, Bugwood.org.

Figure 183. Tropical nut borers and associated tunnelling damage inside a macadamia nut. Photo: Craig Maddox.

An exotic disease to look out for:

Bacterial leaf scorch (*Xylella fastidiosa*)

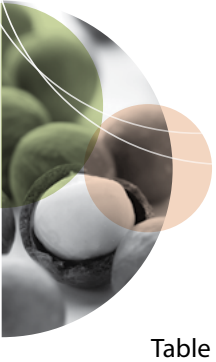
The bacterial leaf scorch strain of *Xylella fastidiosa* is exotic to Australia. It is a bacterial disease where the bacterium lives and multiplies in the sap, blocking water uptake to the leaves. There is no cure for this disease and infected trees will eventually die.

Look for leaves with symptoms of 'burn' or 'bleaching' at the leaf tip and margins (Figure 184). The damage will progress towards the midrib and leaf base, leaving zones of necrotic (dead, brown) tissue and a golden band between the part of the leaf still green and the scorched area.

Xylella fastidiosa bacteria are carried in the sap of host plants and can be spread between plants by grafting, pruning or sap-feeding insects.

Bacterial leaf scorch is a serious threat to Australia's almond, macadamia and pecan industries.

Figure 184. Bacterial leaf scorch symptoms in almond. Photo: Sam Livingston, Department of Plant Pathology, UC DAVIS, California.



Macadamia pesticides

Table 55. Chemicals registered[1] for managing macadamia pests in NSW. Always read the label.

For managing...	IPM rating	Active ingredient	Comment[2,3]
Banana fruit caterpillar	3	Methomyl	Systemic and contact insecticide PER12796 expires 30.6.21 **QLD ONLY**
Fruit spotting bug	3	Acephate	Contact insecticide with stomach action
	3	Acetamiprid + pyriproxyfen	Contact and ingestion, targets insect central nervous system
	3	Azinphos-methyl	Insecticide with contact and stomach action, moderate persistence
	3	Beta-cyfluthrin	Systemic and contact insecticide with stomach action
	2	Sulfoxaflor	Systemic and contact insecticide with stomach action
	3	Trichlorfon	Insecticide and acaricide with contact and stomach action PER13689 expires 30.9.21
Green vegetable bug	3	Trichlorfon	Insecticide and acaricide with contact and stomach action PER13689 expires 30.9.21
Macadamia feltid coccid	3	Diazinon	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
	1	Petroleum oil	Insecticide and acaricide with ovicidal activity PER11635 expires 30.6.2025
Macadamia flower caterpillar	3	Acephate	Contact insecticide with stomach action
	1	*Bacillus thuringiensis*	Stomach poison
	1	Methoxyfenozide	Insecticide that lethally accelerates the moulting process
	2	Spinetoram	Insecticide with contact action
	1	Tebufenozide	Insecticide that lethally creates unsuccessful moulting process
	3	Trichlorfon	Insecticide and acaricide with contact and stomach action
Macadamia lace bug	3	Diazinon	Non-systemic insecticide, acaricide with contact, stomach and respiratory action PER14276 expires 30.11.2020
	3	Pyrethrin	Contact insecticide with stomach action
	2	Sulfoxaflor	Systemic and contact insecticide with stomach action
	3	Trichlorfon	Insecticide and acaricide with contact and stomach action PER13689 expires 30.9.21
Macadamia leaf miner	3	Acephate	Contact insecticide with stomach action
	3	Diazinon	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
Macadamia nut borer	3	Acephate	Contact insecticide with stomach action
	3	Azinphos-methyl	Insecticide with contact and stomach action, moderate persistence
	3	Beta-cyfluthrin	Systemic and contact insecticide with stomach action
	3	Carbaryl	Contact insecticide with stomach action
	1	Methoxyfenozide	Insecticide that lethally accelerates the moulting process
	2	Spinetoram	Insecticide with contact action
	1	Tebufenozide	Insecticide that lethally creates unsuccessful moulting process

For managing...	IPM rating	Active ingredient	Comment[2,3]
Macadamia seed weevil	❸	Acephate	Contact insecticide with stomach action PER81463 expires 31.1.2021
	❶	Indoxacarb	Contact insecticide with stomach action PER86827 expires 30.9.2021
Macadamia twig girdler	❸	Carbaryl	Contact insecticide with stomach action
	❷	Spinetoram	Insecticide with contact action
Mites	❸	Abamectin	Acaricide with stomach action and translaminar movement PER87510 expires 30.6.2024
Rats	NA	Cholecalciferol	Elevates blood calcium and causes kidney failure
	NA	Coumatetralyl	Inhibits blood coagulation
Red shouldered leaf beetle	❸	Acephate	Contact insecticide with stomach action **Qld, WA and NT only**
	❸	Carbaryl	Contact insecticide with stomach action
Scale insects	❸	Acetamiprid + pyriproxyfen	Contact and ingestion, targets insect central nervous system
Thrips	❸	Abamectin	Acaricide with stomach action and translaminar movement PER87510 expires 30.6.2024
	❸	Acephate	Contact insecticide with stomach action **Qld, WA and NT only**
	❷	Spinetoram	Insecticide with contact action

Table 56. Chemicals registered[1] for managing macadamia diseases in NSW. Always read the label.

For managing...	IPM rating	Active ingredient	Comment[2,3]
Botrytis blight (grey mould)	❶	Iprodione	Contact fungicide with protective and curative action
Husk rot	❶	Copper as cuprous oxide	Protective fungicide
Macadamia husk spot	❶	Azoxystrobin + tebuconazole	Systemic fungicide with protective and curative action
	❷	Carbendazim	Protective fungicide
	❷	Copper hydroxide	Protective fungicide
	❶	Difenoconazole	Systemic fungicide with protective and curative action
	❶	Penthiopyrad	broad spectrum fungicide with preventative, curative and locally systemic activity
	❶	Pyraclostrobin	Protective and curative fungicide
	❶	Pyraclostrobin + fluxapyroxad	Protective and curative fungicide
Phytophthora	❶	Copper as cuprous oxide	Protective fungicide
	❶	Metalaxyl	Protective fungicide with slow release activity
	❶	Metalaxyl + copper oxychloride	Systemic fungicide with protective and curative action
	❶	Phosphorus acid	Systemic protective fungicide

[1] Source: InfoPest http://infopest.com.au and APVMA Pubcris https://portal.apvma.gov.au/pubcris

Coloured dots before the chemical common name denote that chemical's compatibility with IPM:

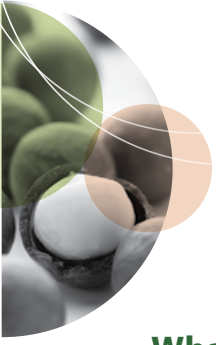
❶ indicates that, when used with care, a chemical will have little impact on beneficials and is recommended in an IPM program.

❷ indicates that this pesticide can be used with caution in an IPM program, but the chemical's effect on beneficials present should be assessed before application.

❸ indicates that this chemical is likely to have a negative off-target effect including on beneficial arthropods.

[2] Adapted from *The Pesticide Manual,* 15th Edition, British Crop Protection Council 2009.

[3] The APVMA website https://portal.apvma.gov.au/permits



Managing spray drift

What is spray drift?

Spray drift is the airborne movement of chemicals with the potential to cause injury or damage to humans, plants, animals, the environment or property, onto a non-target area. All pesticides are capable of drift. People have a moral and legal responsibility to prevent pesticides from drifting and contaminating or damaging neighbours' crops and sensitive vegetation areas. In areas where a range of agricultural enterprises co-exist, conflicts can arise, particularly from pesticide use. Some labels now carry spray drift management instructions including buffer zones. Anyone using any chemicals must read and follow all label instructions.

Types of drift

Droplet drift is the easiest to control because, under good spraying conditions, droplets are carried down by air turbulence and gravity to collect on plant surfaces. Droplet drift is the most common cause of off-target damage from pesticide application.

Particle drift occurs when water and other pesticide carriers evaporate quickly from the droplet leaving tiny particles of concentrated pesticide. Particle drift has damaged susceptible crops up to 30 km from the source.

Vapour drift is confined to volatile herbicides such as 2,4-D ester. Vapours can arise directly from the spray or evaporation from the sprayed surfaces. Using 2,4-D ester in summer can lead to vapour drift damage to highly susceptible crops such as tomatoes, sunflowers, soybeans, cotton and grapes. This can occur hours after the herbicide has been applied.

Vapours and minute particles float in the airstream and are poorly collected on catching surfaces. They can be carried for many kilometres in thermal updraughts before being deposited.

Factors affecting chemical spray drift

Any herbicide, fungicide or insecticide can drift. The drift hazard, or off-target potential of a chemical in a particular situation depends on the following factors:

Volatility of the formulation being applied: Volatility refers to the likelihood that the chemical will evaporate and become a gas. Esters volatilise (evaporate) more readily than amine formulations. Many ester formulations are highly volatile when compared with the non-volatile amine, sodium salt and acid formulations. Some low volatile ester formulations can contain high volatile esters, so caution should be exercised when using these products.

Proximity of crops susceptible to the chemical being applied and their growth stage.

Application method and equipment used:

- aerial application releases spray at ~3 m above the target and uses relatively low application volumes
- ground rigs have lower release heights and generally higher application volumes, with a range of nozzle types
- misters produce large numbers of very fine droplets that use wind to carry them to the target.

Amount of active ingredient applied: the more applied per hectare the greater amount available to drift or volatilise.

Efficiency of droplet capture: bare soil does not have anything to catch drifting droplets compared with crops, erect pasture species and standing stubbles.

Weather conditions during and shortly after application.

Sensitive crops can be up to 10,000 times more susceptible than the crop being sprayed. Even small quantities of drifting herbicide can cause severe damage to highly sensitive plants.

Minimising spray drift

Successfully managing spray drift will require a range of complementary strategies to be adopted, including:

Before spraying

- Always check for susceptible crops and sensitive areas such as houses, schools and riparian areas.
- Notify neighbours of your spraying intentions.
- Under the Records Regulation of the Pesticides Act it is essential that weather and relevant spray details are recorded. An example spray record form is provided in Table 57 on page 119.

Identify sensitive areas

Sensitive areas are those where spray drift is likely to have the greatest adverse effects, such as:

- lakes, ponds and waterways
- wildlife habitats and wetlands
- neighbouring houses
- public roads (e.g. those used by school buses)
- schools and other public amenities
- travelling stock routes and reserves
- organic and alternative farming systems.

The potential adverse effect will depend on the exact nature of the sensitive area in relation to the toxicity and formulation of the chemical.

Establish appropriate buffer zones

Buffer zones help to minimise drift into sensitive areas. A buffer zone can consist of fallow, pasture, a non-sprayed strip of the crop or purpose-planted vegetation. Vegetative buffer zones should be sufficiently open to allow the spray to penetrate and of sufficient depth to trap the bulk of any drift.

Property planning

Property plans are a tool for communicating to others, such as spray contractors and neighbours, the factors that need to be considered when applying chemicals on the property. A property plan would include:

- houses and farm buildings
- neighbouring properties
- sensitive areas
- roads and access points
- public roads and public places
- watercourses and storage
- cropping and grazing paddocks
- powerlines and other hazards to aircraft.

Communication

Communicating with adjoining land users is critical in avoiding the conflict that can ensue from drift incidents. Communication can embrace:

- pre-season discussions with neighbours to identify the chemicals to be used and potential adverse effects on neighbours' activities
- notifying neighbours before applying chemicals
- an agreement on the conditions in which chemical application will not proceed or will be discontinued
- a clearly defined process and timetable for resolving any conflict that might arise
- an agreed process for recourse to regulatory action, if required.

During spraying

- always monitor meteorological conditions and understand their effect on drift hazard
- do not spray if conditions are not suitable, and stop spraying if conditions change and become unsuitable
- record weather conditions (especially temperature and relative humidity), wind speed and direction, pesticide and water rates, and operating details for each paddock. it is highly recommended that all macadamia farms have a weather station installed on-farm for monitoring conditions during spray application.
- do not spray when temperatures exceed 28 °C
- supervise all spraying, even when a contractor is employed. Provide a map marking the areas to be sprayed, buffers to be observed, sensitive crops and areas
- use the largest droplets that will give adequate spray coverage. Where droplet size is mentioned on the label, follow the label instructions
- always use the least-volatile pesticide formulation available
- maintain a down-wind buffer that could be in-crop. Where buffer zones are mentioned on the label, follow label instructions.

Minimising spray drift and achieving ideal coverage

A significant part of minimising spray drift is selecting the right equipment to reduce the number of small droplets produced. However, this can affect target coverage and the possible effectiveness of the pesticide application. This needs to be carefully considered when planning to spray. As the number of smaller droplets decreases, so does the spray coverage. The water rate might also need to be increased to compensate for coverage.

Use appropriate nozzles: nozzles at the top of an air-blast sprayer should be delivering coarse droplets that have less chance of spray drift. These can include air induction nozzles or cannons. Lower nozzles would have finer droplet delivery when required. Coverage should be checked for the appropriate nozzle selection with the correct spray rates applied.

Pressure: always operate within the pressure range recommended by the nozzle manufacturer. Fine droplet production increases with increased operating pressure. Lower volumes produce a higher percentage of fine droplets than higher spray volumes at the same pressure and nozzle design.

Consider the size of the area treated: when large areas are treated, large amounts of pesticide are applied and the total spraying time is increased. This increases off-target risks and the likelihood that conditions such as temperature, humidity and wind direction will fluctuate during spraying. Applying volatile formulations to large areas also increases the chances of vapour drift damage to susceptible crops and pastures.

For information on managing chemical application to avoid and minimise spray drift, farmers and applicators should read label directions carefully.

Weather conditions affecting spraying

Midday turbulence: updraughts during the heat of the day cause rapidly shifting wind directions. Spraying should usually stop by 11.00 am during summer.

High temperatures: avoid spraying when temperatures exceed 28 °C.

Humidity: avoid spraying when relative humidity is low i.e. when Delta T (the difference between wet and dry thermometers; Figure 185) exceeds 10 °C. Spraying when Delta T is between 8–10 °C is considered high risk. High humidity extends droplet life and can greatly increase the drift hazard from fine droplets under inversion conditions. This results from an increased life of droplets smaller than 100 microns.

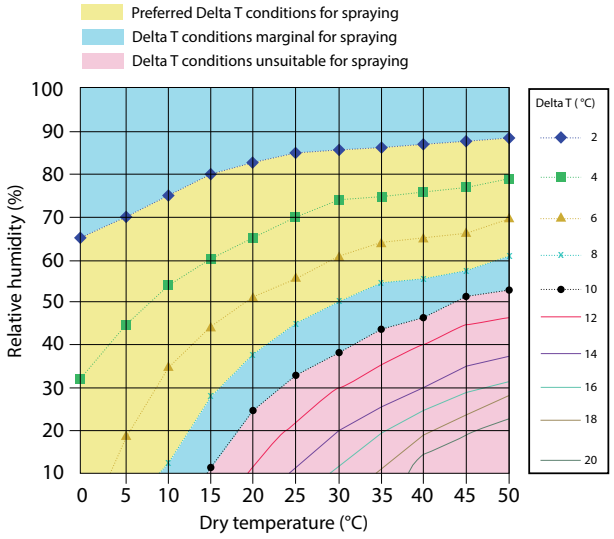


Figure 185. Delta T conditions for spraying. Source: Bureau of Meteorology.

Wind: avoid spraying during calm or still conditions as this is when droplets are more likely to remain suspended in the air. The ideal safe wind speed is 7–10 km/h. Leaves and twigs are in constant motion (a light breeze). Wind speeds of 11–14 km/h (moderate breeze) are suitable for spraying if you are using low drift nozzles or higher volume application. Small branches move, dust is raised and loose paper is moving. When wind speed is greater than 15 km/h, avoid spraying. For detailed information on wind speeds, see the Beaufort scale (www.bom.gov.au/lam/glossary/beaufort.shtml).

Surface inversions

What are surface inversions?

Surface inversions are layers of the atmosphere at the earth's surface in which temperature increases with height (Figure 186). This is the opposite (inverse) of the normal temperature decrease with height.

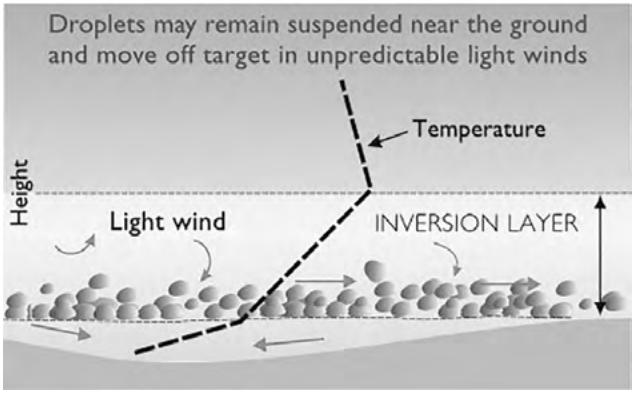


Figure 186. Surface inversion layer. Source: Bureau of Meteorology.

Hazards of surface inversions

Surface inversions strongly suppress airborne pesticide (and similar) dispersion. Surface inversions can cause airborne pesticides to:

- remain at high concentrations for long periods over and close to the target
- travel close to the surface for many kilometres in light breezes
- move downslope and concentrate into low lying regions
- be transported, often in unpredictable directions.

Radiation inversions – the most hazardous

Surface inversions usually begin to occur near sunset after heat energy through infrared radiation moves upward into space and causes the ground to cool. That radiation passes through clear air with little effect. As the ground cools, the air in contact with the ground begins to cool directly through conduction, leading to the

lowest layer of air being cooler than higher layers. This is radiation cooling or a radiation inversion.

Inversions caused by radiation cooling are the most hazardous to pesticide applications because they can severely restrict dispersion and promote transport (drift) of the airborne pesticides at high concentrations.

Radiation inversions occur most nights. Only when winds are strong enough to completely mix the lowest layers of the atmosphere, or cloud cover severely restricts surface heating and cooling, is there a chance that surface radiation inversions will not form overnight.

Radiation inversions also form over sloping terrain when the air in contact with the ground is cooled by terrestrial radiation. The cooled layer remains shallow, often only 2–10 m deep, because gravity continually pulls it down causing drainage winds. Drainage wind advection (horizontal convection) of cool air away from the slope and over or into lower lying regions can initiate a drainage inversion or intensify an existing radiation inversion. Once formed, drainage inversions have similar attributes to radiation inversions. Drainage winds can transport airborne pesticides long distances downhill, over flat terrain toward the lowest lying regions and into valleys.

Radiation and drainage inversions typically begin in the evening at about sunset as the ground surface cools and the air in contact with the surface loses sufficient heat by conduction to become colder than the air immediately above. With continued overnight cooling, inversions usually intensify and deepen up to the time of the overnight minimum temperature. Radiation and drainage inversions have caused substantial damage in northern river valleys to cotton crops and to vineyards in the Murray Valley.

How to anticipate and recognise radiation inversions

The potential for inversions to occur and to adversely hold high concentrations of airborne pesticides near the surface should always be anticipated between sunset and up to an hour or two after sunrise; unless one or more of the following conditions occur:

- there is continuous overcast, low, heavy cloud
- there is continuous rain
- wind speed remains above 11 km/h for the whole period between sunset and sunrise. However, be aware that established inversions can sometimes still occur when winds are greater than 11 km/h.

For more information on inversions, refer to:

- the Cotton Map factsheet on temperature inversions (www.cottonmap.com.au/Content/documents/Temperature%20Inversions.pdf)
- the GRDC factsheet on inversions and spraying (https://grdc.com.au/Resources/Factsheets/2014/08/Surface-temperature-inversions-and-spraying)
- the Bureau of Meteorology (BOM) factsheet: Weather for pesticide spraying (www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf).

Never spray during a surface inversion.

Where to find helpful meteorological information

Ideally, real time data should be collected in the paddock when spraying. This can be done with handheld units, on-farm weather stations or mobile phone apps that measure temperature, Delta T and wind speed.

Hourly data

Forecasts are available from a number of websites. Hourly data from the Bureau of Meteorology (BOM) weather stations for the previous 72 hours can help with planning spray activities and is useful for developing an understanding of the current daily patterns of meteorological conditions.

However, if the closest weather station being used for the information is many kilometres away from the spray site, the information might not be as accurate as required. Therefore growers would benefit from investing in a weather station (Figure 187) on farm (around $3,000) as this data will be more accurate and thus assist with spraying decisions.

As well as a weather station, another measure to prevent spray drift would be to install wind socks throughout the orchard. You can take a video (on your mobile) of the current conditions and refer the video to the Beaufort wind scale. This will give you an accurate account of conditions throughout the orchard on the day of spraying. To see the Beaufort scale, visit http://www.bom.gov.au/lam/glossary/beaufort.shtml.

Meteograms™

Meteograms™ are very helpful in planning spray programs for periods of lowest drift risk and highest pesticide efficacy. They are mostly available by subscription. Some examples can be found at Weatherwise (www.weatherzone.com.au/models/meteogramdrill.jsp), or Spraywise decisions (www.spraywisedecisions.com.au). Meteograms™ provide seven-day forecasts of:

- temperature
- relative humidity
- Delta T
- rainfall
- wind speed and direction.

Source: M Scott, former Agricultural Chemicals Officer, NSW DPI, Orange.

Further reading

Further information about weather conditions and spraying can be found at:

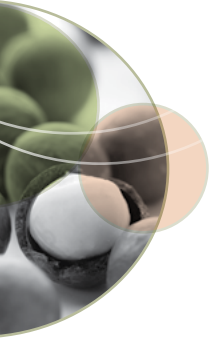
Cook T. 2015. Reducing herbicide spray drift (originally written by Andrew Storrie). NSW DPI, https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift

Gordon B. 2014. Practical tips for spraying. *GRDC Fact Sheet*, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/08/practical-tips-for-spraying

Primary Industries Standing Committee. 2002. *Spray drift management principles, strategies and supporting information*. CSIRO Publishing, www.publish.csiro.au/book/3452

Tepper G. 2017. Weather essentials for pesticide application. *GRDC Fact Sheet*, https://grdc.com.au/__data/assets/pdf_file/0024/248181/GRDC-Weather-Essentials-for-Pesticide-Application-2017.pdf

Figure 187. A weather station in a macadamia orchard. Photo: Graham Wessling.



Legal responsibilities when applying pesticides

Farm Chemicals Section, Biosecurity and Food Safety, NSW DPI

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

Agricultural and Veterinary Chemicals Code Act 1994 (Commonwealth)

The APVMA is responsible for import, registration and labelling of pesticides.

States and territories regulate pesticide use.

Permits for off-label use

Where there is a need to use pesticides outside the registered use pattern, the APVMA can approve off-label use by issuing a minor use, emergency or research permit.

In NSW, the Pesticides Act does not allow off-label use unless a permit is approved by the APVMA.

A list of current permits and registered products are available at https://portal.apvma.gov.au/pubcris.

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

All permits referred to in this guide are included from Page 137 onwards.

The label

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

Signal heading

All pesticides carry a signal heading. Pesticides fall into three of the 10 schedules in the Poisons Standard:

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

Re-entry intervals

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

Pesticides and the environment

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

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

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

Withholding periods

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

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

Managing spray drift

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

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

Safety instructions

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

Note: before opening and using any farm chemical, consult the label and the SDS for safety directions.

Applying pesticides by aircraft

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

More information on the legal requirements for aerial application is available on the EPA website: www.epa.nsw.gov.au/pesticides/aerialapplicators.htm

Pesticides Act 1999 (NSW)

The Environment Protection Authority administers the *Pesticides Act 1999* and Pesticides Regulation 2017, which controls pesticide use in NSW. It aims to minimise risk to human health, the environment, property, industry and trade.

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

The Act and Regulation require pesticide users to:

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

Training

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

Record keeping

All people who use pesticides for commercial or occupational purposes must make a record of their pesticide use.

- date, start and finish time
- the operator details – name, address and contact information
- the crop treated e.g. macadamia
- the property address and a clear delineation of the area where the pesticide was applied
- type of equipment used to apply the pesticide e.g. knapsack, air-blast sprayer, boom spray
- full name of the product or products (e.g. Transform™ Isoclast® – not just Transform)
- the total amount of concentrate product used
- the total amount of water, oil or other products mixed in the tank with the concentrate
- size of the block sprayed and the order of blocks treated
- an estimate of the wind speed and direction at the start of spraying
- weather conditions at the time of spraying and weather conditions specified on the label
- changes to wind and weather conditions during application
- records must be made in English and kept for 3 years.

An example spray record from SMARTtrain is provided in Table 57.

Globally Harmonised System of classification and Labelling of Chemicals – GHS (International)

The GHS is an international system for classification of hazards and communication for dangerous goods and hazardous substances.

The GHS replaces the old hazardous substances and dangerous goods classification

WorkSafe Australia have a Code of Practice for Labelling Workplace Hazardous Chemicals and another for Preparation of Safety Data Sheets on their website to provide guidance for industry on how to comply with the GHS.

Work Health and Safety Act 2011 (Commonwealth)

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

The Act defines the responsibilities of employers or the person conducting a business or undertaking and the responsibilities of workers.

The Regulation covers hazardous substances and dangerous goods, including the application of the GHS in Australia.

SafeWork Australia have published several Codes of Practice for different industries and situations, as well as the Australian Dangerous Goods Code. These codes provide guidance for industries.

Work Health and Safety Act 2011 (NSW)

SafeWork NSW administer the *Work Health and Safety Act 2011* (WHS Act) and the Work Health and Safety Regulation 2017.

The Act implements the commonwealth WHS Act in NSW. It outlines the primary responsibility of the employer or the PCBU (person conducting business or undertaking) to maintain a safe workplace. There is emphasis on consultation with workers, assessment and management of risk, and attention to worker training and supervision.

The WHS Regulation 2017 addresses management of hazardous substances, including most pesticides. It covers identification of hazardous substances in the workplace, assessment and management of risks associated with their use. A copy of the Work Health and Safety Act 2011 is available at this link: https://www.legislation.nsw.gov.au/#/view/act/2011/10.

The WHS Regulation2017 includes responsibilities for managing risks to health and safety at a workplace, including:

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

Dangerous Goods (Road and Rail Transport) Act 2008

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

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

The Australian Dangerous Goods code provides guidance for businesses transporting large quantities of chemical including marking vehicles and other conditions required by the Act.

Acknowledgements

Bruce Browne, author of previous versions
Brian McKinnon, Lecturer Farm Mechanisation
Natalie O'Leary, Profarm Trainer

Analytical laboratories

In some situations a chemical analysis of fruit might be required. Listed below are laboratories which undertake this type of work.

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

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

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

Other laboratories are listed at the National Association of Testing Authorities (https://www.nata.com.au/).

Information sources

APVMA www.apvma.gov.au

Australian Code for the transport of dangerous goods by road and rail www.ntc.gov.au/heavy-vehicles/safety/australian-dangerous-goods-code/

Environment protection authority www.epa. nsw.gov.au/

Hazardous substances information system hcis.safeworkaustralia.gov.au/

Managing risks of hazardous chemicals in the workplace www.safeworkaustralia.gov.au/

National association of testing authorities www.nata.com.au/

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

Safe use and storage of chemicals in agriculture www.safework.nsw.gov.au/health-and-safety/safety-topics-a-z/hazardous-chemical

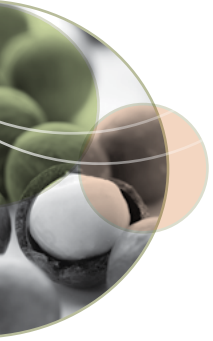
Work Health and Safety Act 2011 www.legislation.gov.au/Details/C2017C00305

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

Table 57. An example spray record form.

Chemical application record							
Property address:						Date:	
Owner:		Address:				Phone:	
Person applying chemical:		Address:				Phone:	
Spray application area				**Situation of use**			
Spray map including sensitive areas, wind direction, order of treatment				Area sprayed and order of spraying			
				Block name/ number	Area (ha)	Crop	Growth stage
				Pest(s)		Pest growth stage	Pest density
GPS reference: S E				**Application equipment**			
Comments (including risk control measures for sensitive areas):				Equipment type	Nozzle	Pressure	Speed
No-spray zone (metres):				Water quality (eg. pH, hardness)	Droplet size	Boom height (above target)	Other
Chemical details							
Full product name (including additives)	Chemical rate	Water rate	Total amount of concentrate	Total amount of chemical mix used	Mixing order	Re-entry period	WHP (days)
Weather details							
Rainfall (amount and time from spraying)	Before: mm		During: mm		After: mm		
Time of spraying:	Temperature ºC	Relative humidity%	Delta T	Wind direction from	Wind speed	Variability e.g. gusting speed and direction	
Start:							
Finish:							
Start:							
Finish:							
Clean up							
Disposal of rinsate:				Decontamination of sprayer:			

Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.



Disposing of farm chemicals and their containers

After chemicals have been applied according to the label directions, empty chemical containers and any unused chemicals must be disposed of in an environmentally responsible manner. Containers can be recycled through drumMuster while chemicals can be disposed of through ChemClear.

drumMUSTER

drumMUSTER provides Australian agricultural and veterinary (agvet) chemical users with a recycling pathway for eligible empty agvet chemical containers. Developed with the environment in mind, the drumMUSTER program collects and recycles eligible, clean agvet containers.

Working with local councils and other collection agencies, drumMUSTER has established collection facilities all over Australia. Since its inception in 1998, 32 million containers have been recycled.

Once containers are collected, they are recycled into re-usable products such as wheelie bins, road signs, fence posts and bollards.

The drumMUSTER service benefits users, the environment, industry and the wider community by providing a reliable, cost-effective and sustainable option for recycling empty eligible agvet chemical containers.

Disposing of these containers in the right way is crucial to the reputation and sustainability of the agricultural industry in Australia. By using the drumMUSTER recycling program you can turn your unwanted containers into useful, sustainable products rather than having them placed into landfill or building up on-farm.

Only containers with 'drumMUSTER eligible container' printed on the label, as a sticker or embossed on the container are accepted (Figure 188). To contact drumMUSTER, visit the drumMUSTER website (www.drummuster.org.au) or phone 1800 008 707 or 02 6230 6712.

Cleaning containers for collection

When rinsing chemical containers, the personal protective equipment (PPE) specified on the label for application, mixing or loading the pesticide should be worn. This is because the chemical remaining in a container is the concentrate, which is the most toxic form of the chemical, even though it is diluted during rinsing.

Rinsing is the most effective method while the containers are still moist inside. The longer the residues have to dry and cake on the inside of containers, the more difficult they are to remove. This is the reason for rinsing during mixing and loading because the rinsate can be emptied into the spray or mixing tank of the application equipment. Using the rinsate this way avoids the necessity for having to dispose of the container residues separately.

To **triple rinse** a container up to 20 L to meet drumMUSTER standards:

1. remove the cap, invert the container and allow it to drip drain into the mixing tank for 30 seconds
2. add rinse water – 20% of container volume (e.g. 1 L per 5 L)
3. replace the cap and shake vigorously for one minute
4. remove the cap, invert and drip drain into mixing tank for 30 seconds
5. repeat twice
6. wash the cap separately and replace on the container.

Note: Triple rinsing is only suitable for small containers, up to 20 L.

Alternatively, use a pressure nozzle to triple rinse small containers. There are two main types of nozzle. One has a rotating spray head which can be used either to rinse an inverted container in the induction hopper or directly over the tank. The other type has a hardened, pointed shaft to pierce drums and the hollow shaft itself has four holes at 90° to spray the water around the container.

To **pressure rinse** a container up to 20 L:

1. remove the cap, invert the container and allow it to drip drain into the mixing tank for 30 seconds
2. ensure clean rinse water is at 35 – 60 psi
3. insert the pressure rinsing probe either into the container opening or through the pierced base of the container (depending on type of nozzle)
4. invert the container over the mixing tank and rinse for 30 seconds or longer if the water coming from the container is not clear, moving the probe about to ensure all inner surfaces are rinsed
5. wash the cap in clear rinse water
6. turn off the water, remove the probe and drip drain the container into the mixing tank for 30 seconds
7. replace the lid on the container.

Large containers, e.g. 200 L, are best rinsed with a chemical transfer probe that has a flushing cycle as well as the primary suction cycle. Such probes are standard on many boom sprays, and options on most others. The drums might have to be slightly inclined to ensure all rinsate is removed. Typical rinse time for a 200 L drum would be 3–5 minutes.

Non-rigid containers, i.e. bags and cartons, have to be buried. Plastic bags should be rinsed first, and paper bags punctured or shredded. Cartons also have to be punctured or shredded before burial.

Burning is specifically prohibited.

For more information, visit www.drummuster.org.au or call 1800 008 707.

ChemClear

ChemClear provides Australian agvet chemical users with a collection and disposal pathway for their unwanted chemicals. ChemClear complements drumMUSTER by providing agvet chemical users with a recycling and disposal option. Both programs are funded by AgStewardship Australia Limited through a 6 cents per litre levy placed on participating manufacturers' products and passed on to consumers at the point of sale.

ChemClear® collects two categories of agvet chemicals:

Group 1 chemicals are those currently registered products manufactured by participating companies signed into the Industry Waste Reduction Agreement. These products are collected free of charge.

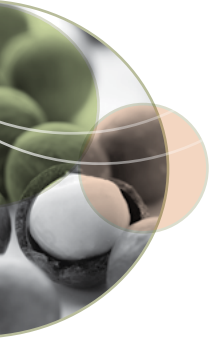
Group 2 chemicals are those products manufactured by non-participating companies, or, deregistered, unknown, mixed or out of date products (by two years). A per litre/kilogram fee for disposal applies.

For more information or to register for the program, visit www.chemclear.org.au or call 1800 008 182.

Disposal of rinsate or dilute chemical

Labels contain a prohibition on disposing of concentrate on-site or on-farm, as per state environmental legislation. Unused chemical has first to be diluted and, if not applied in terms of the label use pattern, has to be disposed of in an environmentally responsible manner, such as an evaporation pit. This pit should be a metre deep, lined with plastic sheeting over which has been spread hydrated lime, and any waste covered with at least half a metre of soil. Disposal pits are only suited to small volumes and for diluted chemicals. In the case of a concentrate spill, the chemical would have to be diluted to at least standard label rates before transfer to the disposal pit.

Figure 188. A chemical container (closest one) with a 'drumMUSTER eligible container' printed on the label.



Avoiding pesticide resistance

Resistance in an insect, mite or disease to a specific chemical has occurred when the chemical no longer provides the control it did previously. Populations of pests and diseases that are repeatedly sprayed with a particular chemical group can develop resistance to that chemical. All populations contain a small number of individuals that are resistant to a given pesticide. Continuing to use that pesticide will kill susceptible individuals, but it will also promote resistant forms. Once a critical proportion of a population is resistant, the chemical will be ineffective.

Preventing resistance

Avoiding resistance for all pesticides is now an important consideration when choosing a control strategy. One strategy used is to rotate the chemical groups so that the weed, fungus, insect or mite is not being continually treated with the same type of chemical. Repeated treatment with the same chemical group could lead to the organism developing resistance to that group.

In the past, it has often been difficult for growers to distinguish between chemical groups and their different modes of action; a factor important in successful rotation. An identification scheme now exists for both herbicides and fungicides.

All registered pesticides have an activity group identification symbol on the label. This helps growers to choose a product from a different chemical activity group when seeking to rotate chemicals in a program.

Case study: mites in macadamia

Other industries have shown that mites are particularly successful in developing pesticide resistance and have overcome almost every miticide produced since the 1950s. This is certainly the case for macadamia where mites have recently become an issue due to certain effective broad-spectrum chemicals becoming unavailable.

The NSW DPI, funded by Hort Innovation, has successful obtained a permit for the active ingredient Abamectin, which has a different mode of action (6) from other chemicals used for mite control. To achieve control and long-term value of Abamectin, chemical rotation of products used for other pests must be used, i.e. regularly changing the mode of action.

The macadamia industry has limited choices for miticides, which means that growers need to be more strategic about when to apply the product. Decisions such as:

- which flush would be most useful to protect?
- how bad is the damage?
- what are the other pests that might be targeted?

become important options when considering long-term effective control.

Insecticides

Unfortunately the macadamia industry relies heavily on a limited number of chemicals from the same groups, mainly 1A and 1B, limiting our options. However, there are options and we must use them to prevent resistance to the few chemicals that are available to the industry. In the early stages of tree production, such as pre-flowering and flowering, pest options are limited to a range of 1B chemicals. There should be a conscious decision at the later stages of nut development to use the available alternative options to 1B chemicals.

A typical scenario could be to spray lace bug early with a 4C product. Continue monitoring regularly for pests at this critical stage; there could be a requirement for a 1B product to be used around later flowering. Then at premature nut drop, continue monitoring for fruit spotting bug. This is when there is an opportunity to use a different chemical group, being 3A or 4A + 7C.

The chemical tables for each of the pests and diseases should help growers decide how to rotate their chemicals to avoid resistance. Ideally the industry needs to use available researchers to continually screen new chemical formulations as they become available. Not only will this screen the effectiveness of new formulations but will also identify ways that new chemicals can be incorporated into the spray program system to achieve better IPM strategies.

Fungicides

Fungicide resistance arises because most of the newer fungicides are very specific in their effects on fungal cells. In any collection of spores, a very low number will be resistant to a particular fungicide. If we use the same fungicide repeatedly, we allow these spores to multiply, while killing those which are susceptible to the chemical, until almost all the spores are resistant to, and unaffected by, the fungicide. If we then use a fungicide with a different mode of action, we can control the new strain but damage to the crop is already done.

Avoiding fungicide resistance

Generally horticultural crops have a variety of fungicides from different chemical groups to prevent resistance occurring. Unfortunately, in macadamia there are limited options to prevent husk spot, which is the industry's main fungal concern.

Management strategies for husk spot control, including which chemicals should be used when to maintain resistance, have been developed by Associate Professor Olufemi Akinsanmi, plant pathologist at the University of Queensland. These strategies are outlined in Table 58.

The clear message is that there should be no more than two consecutive applications of the same chemical group. This includes within season sprays one to four, and between season e.g. 4th spray to 1st spray the following year. Also, never rely solely on one type of fungicide for whole of season disease control, no matter how effective it seems; use at least two fungicides with different modes of action.

Specific recommendations for avoiding fungicide resistance are now shown on many labels and chemicals are now classified into groups. The principal groups adopted by the agrochemical industry through the APVMA and CropLife Australia are shown in Table 59 and Table 60. Only fungicides referred to in this guide are shown.

Table 58. Spray strategy for the control of husk spot to avoid resistance. Always read the label.

Spray strategy	1st spray (match head stage)	2nd spray (14–28 days after 1st spray)	3rd spray (14–28 days after 2nd spray)	4th spray (14–28 days after 3rd spray)
1	Carbendazim + copper	Carbendazim + copper	Cabrio only OR copper only	Copper only
2	Cabrio only	Cabrio only	Copper only OR carbendazim + copper	Copper only OR carbendazim + copper
3	Cabrio only	Carbendazim + copper	Cabrio only OR carbendazim + copper OR copper only	Copper only
4	Carbendazim + copper	Cabrio only	Cabrio only OR copper only OR carbendazim + copper	Copper only OR carbendazim + copper

Table 59. Insecticide groups[1,2]. Always read the label.

Group	Chemical class	Common name	Example trade name*
1A	Carbamate	Carbaryl	Bugmaster® Flowable
		Methomyl	Lannate®-L
1B	Organophosphate	Acephate	Lancer®
		Azinphos-methyl	Gusathion®
		Diazinon	Diazinon®
		Methidathion	Suprathion® 400 EC
		Trichlorfon	Lepidex®
3A	Pyrethroid	Beta-cyfluthrin	Bulldock®
		Pyrethrin	Pyganic®
4A + 7C	Neonicotinoids + pyriproxyfen	Acetamiprid + pyriproxyfen	Trivor®
4C	Sulfoximines	Sulfoxaflor	Transform™
5	Spinosyn	Spinetoram	Success® Neo
6	Acermectin	Abamectin	Vertimec®
11C	Microbial	*Bacillus thuringiensis*	Bacchus®
16A	Hydrazide	Tubufenozide	Mimic®
18	Diacylhydrazine	Methoxyfenozide	Prodigy®
22A	Oxadiazine	Indoxacarb	DuPont™ Avatar®

Table 60. Fungicide groups[1,2]. Always read the label.

Group	Chemical class	Common name	Example trade name*
1	Benzimidazole	Carbendazim	Spin Flo®
2	Dicarboximide	Iprodione	Rovral®
3	Triazole	Difenoconazole	Score®
3 + 11	Triazole + strobilurin	Azoxystrobin + tebuconazole	Custodia®
4	Phenylamide	Metalaxyl	Ridomil Gold®
4 + M1	Phenylamide + inorganic	Metalaxyl + copper oxychloride	Axiom® Plus
7	Pyrazole carboxamide	Penthiopyrad	DuPont™ Fontelis®
7 + 11	Pyrazole carboxamide + strobilurin	Pyraclostrobin + fluxapyroxad	Merivon ®
11	Strobilurin	Pyroclostrobin	Cabrio®
33	Ethyl phosphonate	Phosphorous acid	Agri-fos®
M1	Inorganic	Copper fungicides	Kocide®

[1] Trade names which include the common name are not listed. Source: www.apvma.gov.au and CropLife Australia.

[2] The information in the table shows insecticide groups based on mode of action only. For a chemical's compatibility with IPM please see the chemical listings for individual crops.

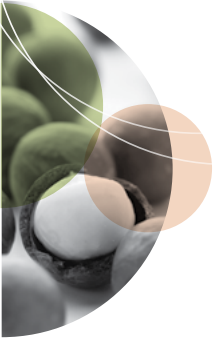
* Example only. Other products are registered.

Minimising glyphosate resistance in Australian orchards and vineyards

This information (Table 61) on glyphosate resistance has been produced by the Australian Glyphosate Sustainability Working Group, a collaborative initiative aimed at promoting the sustainable use of glyphosate in Australian agriculture. The AGSWG gratefully acknowledges the financial support of the GRDC.

Table 61. Tip the scales in your favour to minimise glyphosate resistance risk.

	Risk increasing	Risk decreasing
Orchards and vineyards	Continually relying on glyphosate knockdown as a control agent under tree or under vine	Strategic use of alternative knockdown groups
	Not using alternative herbicide mode of action groups, including residual herbicides	Using alternate mode of action herbicides including residual herbicides
	Relying on herbicides for weed control instead of other means e.g. mowing, mulching, tillage or grazing	Using a double knock technique: full glyphosate rate followed by tillage or a full label rate of paraquat (Group L)
	Allowing weed control escapes to set seed	Adopting non-herbicide practices for weed control e.g. mowing, mulching, tillage or grazing
	Entering the cropping phase with high weed numbers	Preventing weed control escapes from setting seed
	Poor farm hygiene (machinery and stock coming onto farm) which leads to movement of resistant seed	Entering the cropping phase with low weed numbers
	Lack of crop competition on weeds	Ensuring that all machinery and stock coming onto the farm are 'clean'
	All group M herbicides are glyphosate herbicides	Using cover crops to compete with weeds



Timing, calibration and spray coverage

Achieving effective pest and disease control requires an understanding of the significance and interaction of calibration, coverage and timing. Each of these is individually essential and if any one of these is missing, the pest and disease control strategy will fail.

Calibration is making sure you get the right amount of product hitting the target.

Coverage is ensuring that your spray application covers the whole target area, including the high production front at the tops of the trees.

Timing is understanding the life cycle of the pest and identifying the correct time to spray in order to achieve maximum efficiency and the least amount of product loss.

Where all three elements align, we achieve effective control (Figure 189).

We need to physically check our coverage to ensure it is reaching the tops of the trees. This is where our production front predominates and therefore needs to be covered.

Inspect your orchard regularly and look for pests and diseases. No one knows the orchard better than the person working the orchard. A pest scout or consultant will also complement this knowledge.

Finally we need to ensure we calibrate the spray equipment. Just as we check other machinery, (e.g. your car every 10,000 km and tractor every 1,000 hours) we also need to check our sprayer every year. When we calibrate we can be sure that the right amount of chemical is hitting our target pest.

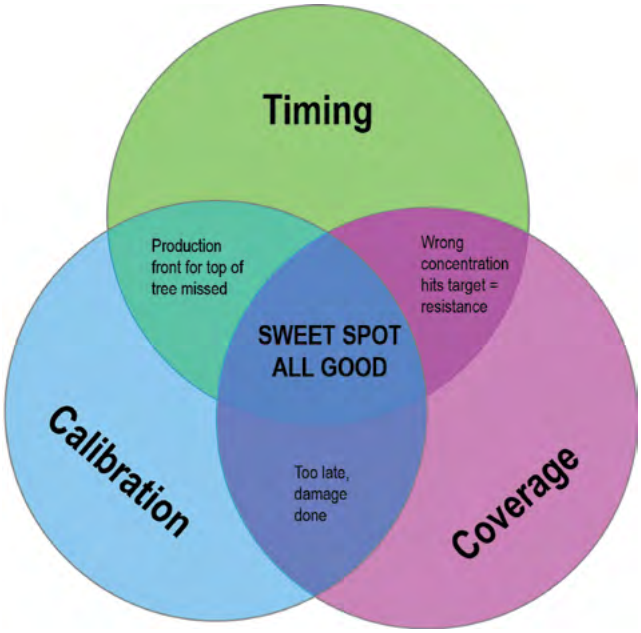


Figure 189. The three components needed to interact to achieve good control and production.

Chemical compatibility

Scott Herd, Northern AgriServices Casino

The importance of understanding tank mixing and compatibility

Effectively controlling pests and diseases can mean the difference between producing a valuable, successful crop or a mediocre, disappointing outcome. Applying pesticides effectively requires some understanding of the pest, the product you are applying and the sprayer's ability to hit the target.

Many growers believe they can save money by applying a number of products in the one tank mix. However, this can present problems if the products are not compatible or compromise the efficacy of the products applied. For instance, a chemical applied to control macadamia lace bug can be compromised by adding fungicides and foliar fertilisers (which defeats the purpose of applying the insecticide in the first place).

If you are a farm manager, contractor or advisor, the grower will not measure your success by the number of products you have applied; they want a protected crop that produces a good yield.

It is critical that all growers and contractors read the label of the products they apply. Be aware that over time the instructions on product labels can change.

Checking spray tank water:

- what is the water source?
- is the pH (the measure of acidity/alkalinity) of the water stable?
- do you check it regularly? (simple pool test kits or pH test strips can be used)
- do you have adequate agitation in your spray tank?

When mixing products, a series of steps should be followed in order (Table 62) and remember 'dilution is the solution'. Always:

- add the product to water under agitation
- never add water to the product
- never mix products before adding to water.

If you are unsure about the compatibility of products (can they be mixed together and in what order should you put them in) you should read the label, ask your chemical supplier or contact the manufacturer.

A simple jar test (Table 63) can give some indication of whether products are physically compatible, but does not guarantee that you will not cause injury to the plant or that the mix will be effective against the desired targets. Once again, chemical suppliers, consultants or manufacturers might need to be contacted.

To conclude, remember to always read product labels and adhere to the instructions, prepare well and understand:

- the target pest
- your equipment
- your use of products and techniques.

Table 62. Multiple tank mix solutions guide.

Step	Action
Step 1	Fill the spray tank to at least 70% full, run agitation
Step 2	Add any water conditioners e.g. acidifier
Step 3	Add any water-dispersable granular products and allow 10 minutes or more for complete dispersion
Step 4	Add any suspension concentrate products
Step 5	Add any emulsifiable concentrate products
Step 6	Add any soluble liquid products
Step 7	Fill the spray tank to nearly full
Step 8	Add any adjuvants
Step 9	Fill the tank

Table 63. A simple jar test to check for compatibility.

	Final quantity	Option one	Option two	Option three	Option four
Tank mix	50 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	160 mL	400 mL	10 mL	0.8 mL
Tank mix	100 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	80 mL	200 mL	5 mL	0.4 mL
Tank mix	200 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	40 mL	100 mL	2.5 mL	0.2 mL
Tank mix	500 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	16 mL	40 mL	1 mL	0.08 mL
Tank mix	1000 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	8 mL	20 mL	0.5 mL	0.04 mL

Tank mixing chemicals

Mark Whitten, Marquis Macadamias, Agricultural Liaison

Introduction

Mixing different chemicals into a single spray application is a common way for growers to increase efficiencies and reduce costs. When done correctly, tank mixing is an effective way of reducing the number of spray operations needed. Done incorrectly, incompatibility issues can lead to poor results and/or a big mess to clean out of your tank, filters, screens, nozzles and lines.

Top tank mixing tips

1. Keep mixes simple i.e. only 2–3 products
2. Know your water quality and pH
3. Know the product formulation
4. Follow the correct mixing order
5. Have enough water in the tank before mixing
6. Ensure you have adequate agitation (determined by the chemicals being thoroughly mixed)
7. Allow plenty of time between additions (3–5 minutes)

If you are unsure about compatibility, ask your crop protection consultant or reseller.

Pesticide spraying is an unfortunate necessity of modern-day agriculture and it is an operation that is rarely viewed with much excitement or enthusiasm. To increase efficiencies and reduce costs, often multiple agricultural chemicals will be combined into a single spray application. These chemicals include crop protection products, adjuvants, fertilisers, plant growth regulators and bio-stimulants.

This article aims to provide a general guide on correct tank mixing to ensure your spray operations are both efficient and effective. The information is of a general nature only. If in doubt about the compatibility of certain products, first check the label. If the information you need is not on the label, either conduct a jar compatibility test (Table 63) or contact the reseller or manufacturer.

Spray tank incompatibility

There are two basic types of tank-mix incompatibility: physical and chemical.

Physical incompatibility prevents products from properly dispersing or suspending within the tank. These are visible and usually identified by separation of products into layers, or the formation of gels, crystals or solids (Figure 190).

Figure 190. Physical incompatibilities in tank mixes are evident when the chemicals fail to mix thoroughly. Photos: Purdue University.

Chemical incompatibility can be invisible in the spray tank and will often only become apparent after spraying, showing up as crop burn (phytotoxicity) and/or reduced efficacy of the spray application.

To reduce the potential for spray tank incompatibilities, it is important to consider:

- product formulation
- tank mixing order
- time between additions
- water quality and volume
- agitation.

Product formulation

Pesticides come in many different formulations. The solubility of the active ingredient (AI) and its intended use will generally determine the product formulation. It is important to note that the same AI can be manufactured in different formulations. A recent example for the macadamia industry is the active, indoxacarb, which is available in solid (e.g. Avatar®) and liquid (e.g. Steward® EC) formulations. Table 64 lists registered pesticides used in macadamia management, the active ingredient, an example trade name and formulation. Regardless of the product you use, you should always check the label for any comments about mixing and compatibility.

Dry or solid formulations include

- **wettable powders (WP) and water-dispersible granules (WG)** typically use fine clay as a carrier in combination with wetting and dispersing agents. Importantly, these products do not dissolve but are dispersed through the water to form a suspension. They require constant agitation to remain dispersed in the spray tank.
- **water-soluble powders (SP)** and **water-soluble granules (SG)** dissolve in the spray tank and, once dissolved, do not require agitation.

Wet or liquid formulations include

- **suspension concentrates (SC)** are essentially solid products that have been pre-mixed in a slurry. These will settle out in both the drum and the spray tank. Ensure you shake the drum before use and maintain agitation when in the tank.
- **emulsifiable concentrates (EC)** consist of an oil-soluble AI in a solvent. To stop these products from separating in water, EC formulations include an emulsifying agent, which gives a milky appearance and requires agitation to remain dispersed in the tank.
- **soluble concentrates/liquids (SL)** are true solutions and once fully mixed, do not require agitation.

If you are unsure about the product formulation, check the label, or you can look it up on the Australian Pesticides and Veterinary Medicines Authority (APVMA) PubCRIS database.

Tank mixing order

When you are looking to add multiple products to the spray tank, these products must be added in a specific order to ensure they can be properly mixed. The order that products are added to the spray tank relates to their solubility and formulation type. If products are added in the incorrect order, there is a risk that they will interact and this can reduce their efficacy or affect their stability in the tank mix.

As a general rule, add dry products first and wet products second. This is especially important when using oil-based products and/or adjuvants because when dry products are added after wet products, the oils and adjuvants already in the mix can coat the dry formulation and reduce its ability to properly disperse. The undispersed product will often form clumps or a layer of precipitate that can clog nozzles and filters.

Macadamia tank mixing guide

Step 1
- Fill the tank to about 70% full with water
- Run agitation

Step 2
- Add dry products
  - Water conditioners, e.g. LI-700, Companion surfactant (do not mix with coppers)
  - Wettable powders (WP), e.g. some coppers
  - Water-dispersible granules (WG), e.g. Avatar®
  - Water-soluble granules (SG) or granules (GR), e.g. Lancer®

Step 3
- Allow adequate agitation and mixing (determined by the chemicals being thoroughly mixed)

Step 4
- Add wet products
  - Suspension concentrates (SC), e.g. Spin Flo®
  - Dispersible concentrates (DC), e.g. Trivor®
  - Emulsifiable concentrates (EC), e.g. Bulldock®
  - Solutions or soluble concentrates (SL), e.g. Agri-fos

Step 5
- Fill tank to ~95% with remaining water

Step 6
- Add adjuvants and crop oils, e.g. wetters, stickers, Summer Oil

Step 7
- Finish filling tank with water.

- Do not add oils, surfactants or ECs before dry formulations because they can prevent adequate wetting and dispersion of the dry products.
- Always ensure there is plenty of time and water between tank additions.
- Due to the huge range of foliar fertilisers and variation in formulations, you should contact the manufacturer or reseller to determine where the product should be added in the tank mixing order.

Table 64. Registered chemicals used in macadamia management, their active ingredient, an example trade name, its formulation and chemical group (mode of action). Always read the label.

Active ingredient (AI)	Example product	Formulation*	Chemical group
Insecticides			
Abamectin (PER87510)	Vertimec®	EC	6
Acephate (PER81463)	Lancer® 970	SG	1B
Acetamiprid and pyriproxyfen	Trivor®	DC	4A, 7C
Bacillus thuringiensis	Bacchus® WG	Various	11C
Beta-cyfluthrin	Bulldock® 25	EC	3A
Carbaryl	Bugmaster® Flowable	SC	1A
Diazinon (PER14276)	Diazol® 800	EC	1B
Indoxacarb (PER86827)	DuPont™ Steward®	EC, WG	22A
Methidathion	Suprathion® 400	EC	1B
Methomyl (PER12796 Queensland only)	DuPont™ Marlin®	SL	1A
Methoxyfenozide	Prodigy®	SC	18
Petroleum oil (PER11635)	Summer Oil	Oil miscible liquid	Insecticide, spreader
Spinetoram	Success® Neo	SC	5
Sulfoxaflor	Transform™ Isoclast®	SC	4C
Tebufenozide	Mimic 700	WP	16A
Trichlorfon (PER13689)	Dipterex® 500	SL	1B
Fungicides			
Carbendazim	Spin Flo®	SC	1
Copper ammonium acetate	Cop-IT™	SL	M1
Copper hydroxide	Kocide® Opti™	WG	M1
Copper oxychloride	Coppox	WP, WG	Y
Copper sulphate (tribasic)	Tri-base Blue®	SL	M1
Cuprous oxide	Nordox™ 75	WG	M1
Difenoconazole	Digger®	EC	3
Iprodione	Rovral® Aquaflo	SC	2
Metalaxyl	Ridomil Gold® 25G	GR	4
Metalaxyl + copper oxychloride	Axiom® Plus	WP	M1
Penthiopyrad	DuPont™ Fontelis®	SC	7
Phosphorus acid	Agri-Fos 600®	SL	33
Pyraclostrobin	Cabrio®	EC	11
Pyraclostrobin and fluxapyroxad	Merivon®	SC	7, 11
Growth regulator			
Ethephon (PER11462)	K-ethephon	SL	PGR

* WP/WG = Wettable powder or water-dispersible granule
SP/SG = Water-soluble powders or granules
GR = Granules
SC = Suspension concentrate
DC = Dispersible concentrates
EC = Emulsifiable concentrate
SL = Soluble concentrate/liquid.

Time between adding products

While no one wants to be spending extra time filling tanks for spraying, it is important to allow enough time between each product addition to ensure products are fully dispersed in the spray tank. If you add products too quickly, even in the correct order, you might end up with physical incompatibility. This is particularly important when the AI is suspended and does not dissolve in water (like many copper fungicides). You should allow at least 3–5 minutes between tank additions and ensure adequate agitation so the products properly disperse/mix throughout the spray tank.

Water temperature will also influence tank mixing; the colder the water, the longer it will take for products to properly dissolve, disperse, emulsify and flow. This is especially important for dry formulations and liquid flowables.

Water quality

Water quality will affect pesticide efficacy. Herbicides typically have the highest requirement for good quality water and, as a rule, you should always use tank water when mixing herbicides, especially glyphosate (e.g. Roundup®), as hard or muddy water will reduce its performance.

Water pH affects the breakdown (hydrolysis) of many pesticides. Generally, the target pH for most tank mixes should be near neutral or slightly acidic (pH 5–7). Some organophosphates (group 1B) are especially sensitive to high water pH. For example, trichlorfon (e.g. Lepidex) has a half-life of 3.7 days at pH 6, and a half-life of only 63 minutes at pH 8. So if your spray-tank water has a pH of 8, half of the AI is inactive after 63 minutes.

The risk of alkaline hydrolysis means it is important to know not only the initial pH of your water source, but also the pH of the products being added. Table 65 compares two different water sources and their pH as well as the effect of various products. Seasol® for example, has a pH of 10.4–11.4 and when used at rates of 250 mL/100 L of water (5 L/2,000 L) can increase the pH above 7. However, if this influence is known it can be easily adjusted with a buffer. The influence that LI-700 (buffer/acidifier) has on tank pH with and without the addition of Seasol® for the two different water sources is shown in Table 65. Note the dramatic change only 50 mL/100 L of LI-700 has on tank pH when combined with 250 mL/100 L of Seasol®.

Both the initial water pH and its buffering capacity (i.e. the water's resistance to change) will vary depending on the water source. Therefore, it is important to measure the starting water pH and tank pH after product additions using either pH strips or a calibrated pH pen. If your starting pH is above 7 and you are using products that are likely to increase the pH, consider using a buffer.

Water volume

The amount of water used directly affects the concentration of the products in a spray tank. The more concentrated the mix, the higher the chance of an incompatibility problem. This can be an issue when concentrate spraying and/or not having enough water in the tank before beginning to add any product. This is particularly important for WG formulations as they first need to absorb water before they can properly breakdown and disperse. If these products are not surrounded by enough water, their wetting and dispersing agents will not work. As a result, they can form clumps, gels and/or can settle to the bottom of the tank. This is why you do not pre-mix WG formulations (e.g. Avatar® or Kocide®) in a slurry. Instead, with thorough agitation, slowly add them directly to the tank.

Ensure your pest consultant writes out spray recommendation combinations in the order of mixing. Information about the correct mixing order can often be found on the product label. However, for some tank mix combinations, further information may be required from the reseller, manufacturer or through technical notes and product guides.

Table 65. The effect of buffers on different water sources and product combinations.

Product	Rate (mL/100 L)	Dam water (pH)	Change	Rain water (pH)	Change
Initial water pH		**7.7**		**5.6**	
LI-700	100	5.1	−2.6	3.8	−1.8
LI-700	200	4.6	−3.1	3.7	−1.9
Seasol®	250	9.1	+1.4	10.1	+4.5
Seasol® + LI-700	250 + 50	6.1	−3.0	5.0	−5.1
Seasol® + LI-700	250 + 100	5.2	−3.9	4.5	−5.6

Note: these water sources are examples only and will differ across time and location.

To avoid issues with water volume, always ensure spray tanks are 70% full before adding products. Additionally, when concentrate spraying, look to simplify tank mixes to reduce the chance of adverse product interactions and do not go over 5× the concentration.

Do not mix copper fungicides and acidifiers as the low tank pH created will spike the release of elemental copper ions, which can burn plant tissue.

Agitation

Adequate agitation is essential. Poor agitation will inhibit thorough mixing of products within the spray tank and create pockets of higher and lower concentrations. High product concentration can lead to incompatibilities when tank mixing and/or crop damage while lower concentrations will reduce the efficacy of spray products.

A good example of this is when using products such as ethephon (e.g. K-ethephon) or phosphorus acid (e.g. Agri-fos®), where higher application rates can cause significant crop damage. Additionally, poor agitation will cause suspensions to settle over time (Figure 191). Generally, 10% of the pump's capacity is required for agitation, so this must be considered when calibrating the spray unit.

Figure 191. Copper fungicide that has settled due to inadequate agitation.

Take home message

Tank mixing mistakes cost you time and money, but they can easily be avoided if you follow the basic principles of correct tank mixing. This will improve your orchard efficiencies and ensure your spray applications are effective.

Further reading

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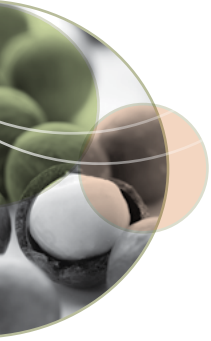


Macadamia growers' resources

NSW DPI Primefacts are available free from NSW Department of Primary Industries website (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

NSW Macadamia plant protection guide (this book) can be collected from the NSW DPI Wollongbar office, from processors and is available for free download (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

Macadamia integrated orchard management practice guide introduces canopy, orchard floor and drainage management as the three pillars of integrated orchard management. It also introduces stages of orchard development and provides a framework for assessing orchard blocks across the three pillars. The guide encourages growers to recognise important 'red flags'; signs that production decline is imminent. It describes currently used management practices (Toolkits) in the macadamia industry and the appropriate circumstances for their use. This book can be collected from the NSW DPI office at Wollongbar or processors, and can also be downloaded free at (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management).

Macadamia integrated orchard management case studies 2016 is a companion to the ***Macadamia integrated orchard management guide 2016***. Where the guide details the 'what to do' and 'when to do it', the case study booklet details the 'how to do'. It is designed to give growers considering integrated orchard management (IOM) the confidence to start planning. It involves 10 orchard case studies (two from each of the Australian macadamia growing regions). The book can be collected from the NSW DPI Wollongbar office, from processors and can also be downloaded free at (www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/667812/macadamia-iom-case-studies-2016.pdf).

Macadamia integrated orchard management drainage 2017. This book is available for free download (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts). It is regarded as the best resource for planning IOM strategies and its popularity meant that the first print run was quickly depleted.

Effective orchard drainage systems keep productive soil in place and create a synergy between the orchard and the landscape, ensuring

- minimal soil movement occurs during rain
- concentrated water flows are managed away from macadamia trees
- blocks are protected from run-on water
- good conditions for macadamia feeder roots are maintained
- the orchard floor is trafficable and harvestable.

Spray Sense a publication providing information on pesticide use, including sprayer calibration, testing for residues, storing pesticides, disposal of empty containers, how to read a label and a number of other topics. The *Spray Sense* series of leaflets can be downloaded free (www.dpi.nsw.gov.au/agriculture/farm/chemicals/general/spray-sense-leaflet-series).

MacSmart a range of more than 50 short and informative YouTube video interviews with growers and researchers covering topics including canopy management, innovative farm practices, orchard floor management, top performing farms, the latest research and other interesting topics. Go to www.macsmart.com.au.

Macadamia grower's handbook This publication (2004) details what is involved from establishing a new planting right through to harvesting the crop. It gives useful technical information, key points and commonly asked questions. Download free here http//era.daf.qld.gov.au/id/eprint/1964/4/mac-growing_guide_Part4.pdf

Macadamia problem solver and bug identifier An excellent reference for pest and disease identification. The book is available for purchase as a booklet or can be downloaded free with the grower's handbook in several sections (era.daf.qld.gov.au/1964).

Macadamia variety identifier A useful resource that helps with identifying 24 specific macadamia varieties. The publication is free to download (http//era.deedi.qld.gov.au/1964/14/mac-varieties.pdf).

Macadamia culture in NSW a useful introductory resource for growing macadamias. It is available for free download (www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-culture-nsw).

Australian Macadamia Society Grower Resources, an up to date industry resource library containing fact sheets, grower case studies and manuals, research reports and updates, videos and more. Compiled by the Australian Macadamia Society with the assistance of industry experts. Can be downloaded free (to members) www.australianmacadamias.org/industry/resources

Establishing and managing smothergrass on macadamia orchard floors, 2008 A guide on how to establish smothergrass, including costs and management. Download for free (www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/establishing-managing-smothergrass).

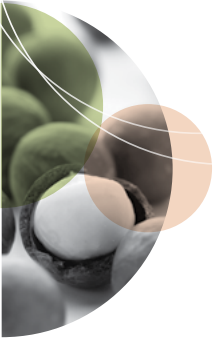
Reducing erosion and other soil degradation in macadamia orchards describes methods for reducing erosion. Download for free (https//www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/soil-macadamia).

The good bug book (second edition) is a valuable reference of the beneficial organisms commercially available for biological control in Australia. It includes illustrations of many of the beneficials as well as tables of information on their susceptibility to pesticides. It is published by Integrated Pest Management Pty Ltd for the Australasian Biological Control Association Inc. and can be purchased from Bugs for Bugs (www.goodbugs.org.au).

Internet sites for macadamia growers

Agricultural industry organisations	
Australian Macadamia Society	www.australianmacadamias.org/industry
Australian Nut Industry Council	www.nutindustry.org.au
Horticulture Innovation	www.horticulture.com.au
International Nut and Dried Fruit Council Foundation	www.nutfruit.org
macSmart	www.macsmart.com.au
National Farmers' Federation	www.nff.org.au
NSW Farmers' Association	www.nswfarmers.org.au
Alternative systems (organics)	
Australian Certified Organic	www.aco.net.au
Australian Organic	www.austorganic.com
Australian Organic Certification and Grower Groups	www.nasaa.com.au
Organic Federation of Australia	www.ofa.org.au
Climate	
Climate Outlook BOM	www.bom.gov.au/climate/ahead
Commonwealth Bureau of Meteorology	www.bom.gov.au
National Centers for Environmental Prediction	wxmaps.org/pix/aus.vv.html
The Long Paddock	www.longpaddock.qld.gov.au
Economic information	
Australian Bureau of Statistics	www.abs.gov.au
Department of Agriculture and Water Resources	www.agriculture.gov.au
Environment	
Department of the Environment and Energy	www.environment.gov.au
NSW Environment Protection Authority	www.epa.nsw.gov.au
Office of Environment & Heritage	www.environment.nsw.gov.au
QLD Department of Environment and Heritage Protection	www.ehp.qld.gov.au
Federal government	
ABC Rural Department	www.abc.net.au/rural
Australian Pesticides and Veterinary Medicines Authority	www.apvma.gov.au

Australian Trade Commission	www.austrade.gov.au
Department of Agriculture and Water Resources	www.agriculture.gov.au
Land & Water Australia	www.lwa.gov.au
Plant Health Australia	www.planthealthaustralia.com.au
Grower services	
Suncoast Gold Macadamia (Aust) Ltd	www.suncoastgold.com.au
Integrated pest management	
Australasian Biological Control Association Inc.	www.goodbugs.org.au
Bugs for Bugs	www.bugsforbugs.com.au
Bioresources	www.bioresources.com.au
Processors	
CL Macs	www.clmacs.com
Freshcare Australia	www.freshcare.com.au
GB-Commtrade Pty Ltd	www.gbcommtrade.com.au
Macadamia Direct	www.macnut.com.au
Macadamias Australia	www.macadamiasaustralia.net
Marquis Macadamias	www.mpcmacs.com.au
MWT Foods	www.mwtfoods.com
Nambucca Macnuts	www.macnuts.com.au
Nutworks	www.nutworks.com.au
Pacific Farm Services	www.macadamia.com.au
Proteco Gold Pty Ltd	www.proteco.com.au
Stahmann Farms	www.stahmann.com.au
Suncoast Gold Macadamia (Aust) Ltd	www.suncoastgold.com.au
Swiss Gourmet	www.swissgourmet.com
Waliz Nuts	www.waliznuts.com
Rural assistance	
Centrelink	www.centrelink.gov.au
Health NSW	www.health.nsw.gov.au
NSW Rural Assistance Authority	www.raa.nsw.gov.au
QLD Health	www.health.qld.gov.au
QLD Rural Assistance Authority	www.qraa.qld.gov.au
Rural Skills Australia	www.ruralskills.com.au
State government	
Department of Agriculture and Fisheries (QLD)	www.daf.qld.gov.au
Local Land Services NSW	www.lls.nsw.gov.au
NSW Department of Primary Industries	www.dpi.nsw.gov.au
WorkCover Authority of NSW	www.workcover.nsw.gov.au
WorkCover Queensland	www.worksafe.qld.gov.au



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NSW Local Land Services (Horticulture)

Local Land Services (LLS), launched in January 2014, delivers quality, customer-focused services to farmers, landholders and the community across rural and regional New South Wales. LLS bring together agricultural production advice, biosecurity, natural resource management and emergency management into a single organisation. LLS horticulture officers help producers address the challenges they face today and take advantage of future opportunities to achieve improvements in crop yields, orchard management and market access.

Producers can contact their nearest LLS office by phoning 1300 795 299 or the website: https://www.lls.nsw.gov.au/

NSW DPI Biosecurity and food safety

NSW DPI Biosecurity and Food Safety is the contact point in this state for anyone who requires advice on intrastate or interstate movement of fruit or plants and other issues of a biosecurity nature. In previous editions of this guide, we published contact details for regulatory officers at various locations across New South Wales. The method of contacting NSW DPI Biosecurity and Food Safety has changed, and all enquiries should now be directed via Plant Health Australia's Domestic Quarantine Line 1800 084 881. This phone number will connect you with an automated system to allow you to choose the state or territory that your report or enquiry relates to.

EXOTIC PLANT PEST HOTLINE
1800 084 881

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF A REGISTERED AGVET CHEMICAL PRODUCT FOR PROMOTION OF NUTFALL IN MACADAMIAS

PERMIT NUMBER – PER11462

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows the Permit Holder and any person stipulated below to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 7 MAY 2009 TO 30 JUNE 2025

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 7, 141 Walker Street
NORTH SYDNEY NSW 2060

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
ETHIN GROWTH REGULATOR (APVMA No. 62058)
PLUS OTHER REGISTERED PRODUCTS
Containing: 480 g/L ETHEPHON as the only active constituent.

FARMALINX ETHON 720 GROWTH REGULATOR (APVMA No. 64360)
PLUS OTHER REGISTERED PRODUCTS
Containing: 720 g/L ETHEPHON as the only active constituent.

PROMOTE PLUS 900 GROWTH REGULATOR (APVMA No. 69487)
PLUS OTHER REGISTERED PRODUCTS
Containing: 900 g/L ETHEPHON as the only active constituent.

RESTRAINT:
Refer to product labels.

Directions for Use:

Crop	Purpose	Rate
Macadamias (Do not use on Teddington variety)	Promote nutfall after maturity reached	<u>480 g/L products:</u> 65 – 250 mL /100 L water Refer critical use comments below. <u>720 g/L products:</u> 55 – 165 mL /100 L water Refer critical use comments below. <u>900 g/L products:</u> 44 – 132 mL /100 L water Refer critical use comments below.

Critical Use Comments:

- DO NOT spray trees if they are stressed.
- DO NOT spray close to flowering or after flower buds have begun to expand.
- Spray at the first sign of natural nut drop. Ethephon is more effective if used when natural abscission has begun. Applications should be made before the end of May.
- Add a non-ionic wetter at 20 mL/100 L (e.g. *Agral Spray Adjuvant*). As an alternative to non-ionic wetter, an adjuvant such as *Spraytech Oil Multipurpose Spray Adjuvant* can be added at 125 mL/100 L water. Addition of urea at 70 g/100 L-water can be useful for some varieties.

480 g/L products:

- Many varieties require 150 – 200 mL/100 L. However, cultivars 842 and 814 seem to be more sensitive and so require a lower rate of 65 – 100 mL/100 L. The higher rates may be required for colder climates and less responsive cultivars such as A16.

720 g/L products:

- Many varieties require 100 – 135 mL/100 L. However, cultivars 842 and 814 seem to be more sensitive and so require a lower rate of 44 – 67 mL/100 L. The higher rates may be required for colder climates and less responsive cultivars such as A16.

9000 g/L products:

- Many varieties require 80 – 105 mL/100 L. However, cultivars 842 and 814 seem to be more sensitive and so require a lower rate of 35 – 75 mL/100 L. The higher rates may be required for colder climates and less responsive cultivars such as A16.

Withholding Period:
Harvest: Do not harvest for 7 days after application.

Jurisdiction:
NSW, QLD, NT and WA only.

Additional Conditions:
This permit allows for the use of a product in a manner specified on the permit. Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit. Unless otherwise stated, the use of the product must be in accordance with the product label.

To Avoid Crop Damage
The sensitivity of the crop to be treated under this permit has not been fully evaluated. It is advisable to only treat a small area to ascertain the reaction before treating the whole crop.

Export of treated produce
Maximum Residue Limits (MRLs) have been established to allow treated produce to be used for human consumption. An MRL has been established for ETHEPHON in MACADMIAS. MRLs can be found in the *Agricultural and Veterinary Chemicals Code Instrument No. 4 (MRL Standard)*. MRLs apply only to produce marketed and consumed in Australia. If treated produce is to be exported, residues must not exceed the limits/tolerances of the importing country.

Issued by the Australian Pesticides and Veterinary Medicines Authority.

Note: 17/04/2015 –Permit expiry extended to 30/06/2020. Permit issued as Version 2.

13/04/2020 –Permit holder amended and permit expiry extended to 30/06/2025. Permit issued as Version 3.

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF A REGISTERED AGVET CHEMICAL PRODUCT

FOR CONTROL OF FELTED COCCID IN MACADAMIA NUT PLANTATIONS

PERMIT NUMBER – PER11635

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows the Permit Holder and any person stipulated below to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 01 JULY 2010 TO 30 JUNE 2025

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 7, 141 Walker Street
NORTH SYDNEY NSW 2060

Persons who can use the product under this permit:
Persons generally

CONDITIONS OF USE

Products to be used:
D-C-TRON PLUS-A PREMIUM QUALITY HORTICULTURAL MINERAL OIL (APVMA No. 57033)
PLUS OTHER REGISTERED PRODUCTS
Containing between 763 and 861 g/L PETROLEUM OIL as the only active constituent.
Including those described as PARAFFINIC OIL and MINERAL OIL
(Note: Products to be used include only those referred to as summer spray oils)

RESTRAINT:

- **DO NOT** apply when temperatures exceed 32 degrees Celsius or when soil is dry and trees are suffering from moisture stress.
- **DO NOT** apply product during flowering.
- Tank agitation is required to ensure product remains in suspension.
- Thorough coverage in essential. Apply to the point of run off ensuring thorough coverage.
- Apply only as dilute spray application using ground based application equipment.

Directions for Use:

Crop	Pest	Rate
Macadamia Nut (*Macadamia* species)	Macadamia Felted Coccid (*Eriococcus ironsidei*)	Apply 1 L product per 100 L water

Withholding Period:
Not required when used as directed.

Jurisdiction:
QLD and NSW only.

Additional Conditions:
This permit allows for the use of a product in a manner specified on the permit. Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit. Unless otherwise stated, the use of the product must be in accordance with the product label.

To Avoid Crop Damage
The sensitivity of the crop to be treated under this permit has not been fully evaluated. It is advisable to only treat a small area to ascertain the reaction before treating the whole crop.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Note: 17/04/2015 – Permit expiry extended to 30/06/2020. Permit issued as Version 2.

06/04/2020 – Permit updated to amend permit holder details. Permit expiry extended to 30/06/2025. Permit issued as Version 3.

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR CONTROL OF BANANA FRUIT CATERPILLAR IN MACADAMIA ORCHARDS

PERMIT NUMBER - PER12796

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 22 JULY 2011 to 30 JUNE 2021

Permit Holder:
AUSTRALIAN MACADAMIA SOCIETY LTD
Suite 1/113, Dawson Street
LISMORE NSW 2480

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
DUPONT MARLIN INSECTICIDE
Plus ALL OTHER REGISTERED PRODUCTS
Containing: 225 g/L METHOMYL as their only active constituent.

Directions for Use:

Crop	Insect Pest	Rate
MACADAMIA	Banana Fruit Caterpillar (*Tiracola plagiata*)	1.5-2.0 L/ha Spraying ground mulch/soil surface up to treelines only

Critical Use Comments:
- Ground surface treatment only using spray boom or equivalent application equipment.
- Apply one application only during late flowering/early fruit development.
- Time spray to coincide when larvae activity is initially observed.
- Ensure thorough coverage of all leaf litter and soil surface along treeline.
- Use higher rate when large larvae or higher numbers are present.
- DO NOT spray tree foliage, flowers or developing nutlets.

Withholding Period:
Not required when used as directed.

Jurisdiction:
QLD only.

Additional Conditions:

THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

Export of produce:
To allow treated produce to be supplied or otherwise made available for human consumption the APVMA has established a temporary Maximum Residue Limit (MRL) at T1.0 mg/kg for methomyl on macadamia nuts. This temporary MRL applies only to produce marketed and consumed in Australia. Therefore if treated produce is to be exported, due account should be taken of the residue definition and residue limits/import tolerances of importing countries and that any residues must not exceed those requirements of the importing country.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Note:
09/02/2016. Expiry date extended to 30/06/2021. Issued as version 2.

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT TO CONTROL, LACE BUG, FRUIT SPOTTING BUG, BANANA SPOTTING BUG AND GREEN VEGETABLE BUG ON MACADAMIAS

PERMIT NUMBER - PER13689

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 14 MAY 2013 TO 30 SEPTEMBER 2021.

Permit Holder:
AUSTRALIAN MACADAMIA SOCIETY LIMITED
C/- HORTICULTURE INNOVATION AUST LTD
PO BOX 12996, GEORGE STREET
BRISBANE QLD 4003

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
DIPTEREX 500 SL INSECTICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 500 g/L TRICHLORFON as their only active constituent.

Directions for Use:

Crop	Pest	Rate
Macadamia nut	Macadamia Lace Bug, Fruit spotting bug, Banana spotting bug and Green vegetable bug.	200 mL/100 L

Critical Use Comments:

- Monitor crops and commence applications once local thresholds are reached
- Apply a maximum of 4 applications at a minimum of 14 day intervals
- Apply to point of run off ensuring complete penetration and coverage of the tree canopy
- DO NOT apply to plants in flower, while bees are foraging. Treat in the late afternoon after bees have finished foraging.

Withholding Period:
DO NOT HARVEST FOR 2 DAYS AFTER APPLICATION

Jurisdiction:
NSW, QLD only.

Additional Conditions:
THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

Issued by the Australian Pesticides and Veterinary Medicines Authority.
Version 2: issued 5 August 2013 to include lace bug.
Version 3: issued 14 May 2014 to reduce WHP from 14 weeks to 2 days
Version 4: issued 30th August 2016 to extend expiry date and update products to include all registered 500g/L Trichlorfon products.

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR CONTROL OF MACADAMIA LACE BUG IN MACADAMIA PLANTATIONS

PERMIT NUMBER - PER14276

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 1 DECEMBER 2013 TO 30 NOVEMBER 2020.

Permit Holder:
AUSTRALIAN MACADAMIA SOCIETY LTD
c/- HORTICULTURE AUSTRALIA LIMITED
PO Box 12996 George St
BRISBANE QLD 4003

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
FARMOZ DIAZOL 800 INSECTICIDE
COUNTRY DIAZINON 800 INSECTICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 800 g/L DIAZINON as their only active constituent

Directions for Use:

Crops	Insect Pests	Rate
MACADAMIA Plantations	Macadamia Lace Bug (*Ulonemia concava* and *Physatochelia spp*)	120 mL product / 100 L

Critical Use Comments:

- Apply at pre-flowering, immediately prior to main flower opening. Repeat spray treatment (if required) prior to second flower opening.
- Ensure spray application provides thorough coverage of all foliage and racemes.
- Ground-based application only, using suitable air-blast sprayer or equivalent.
- Diazinon is HIGHLY TOXIC to bees and other beneficial insects. DO NOT spray trees while bees are actively foraging. Apply spray in the late-afternoon or early evening.
- Diazinon residues on flowers can remain dangerous to bees for up to 1 week post-application.
- Refer to the diazinon label for further precautions that need to be observed to ensure safe and effective use of the product.
- Use in accordance with current Integrated Pest Management (IPM) strategies and in accordance with best practice.

Withholding Period:
Harvest: DO NOT harvest for 14 DAYS after final application.
Grazing: DO NOT graze or cut treated areas for stockfeed for 14 DAYS after final application.

Jurisdiction:
NSW, QLD and WA only.

Additional Conditions:

THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and **CONDITIONS** of this permit.

Other matters:
Approval is granted on the condition that it is subject to any relevant outcomes from the diazanon review. Users should be aware that the APVMA will take steps to apply relevant review outcomes to any approved permits.

Issued by the Australian Pesticides and Veterinary Medicines Authority.
Note: 30 September 2015; Version 2 issued; expiry date extended until 30 November 2020.

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR THE CONTROL OF SIGASTUS WEEVIL IN MACADAMIA

PERMIT NUMBER - 81463

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 24 DECEMBER 2015 TO 31 JANUARY 2021.

Permit Holder:
AUSTRALIAN MACADAMIA SOCIETY LTD.
C/- HORTICULTURE AUSTRALIA LIMITED
SUITE 1/113
DAWSON STREET
LISMORE NSW 2480

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
LANCER 970 INSECTICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 970 g/kg ACEPHATE as their only active constituent.

LANCER 750 DF INSECTICIDE
Containing: 750 g/kg ACEPHATE as their only active constituent.

Directions for Use:

Crop	Pest	Rate
Macadamia nuts	Sigastus weevil (*Sigastus* spp.)	**970 g/kg product** 80 g/100 L **750 g/kg product** 100 g/100L

Critical Use Comments:

- Apply a maximum of 3 applications per season using an air-blast sprayer with a minimum re-treatment interval of 14-21 days.
- Make the first application when nuts are pea sized using a spray volume of 500 to 1000 L/ha.
- Apply with sufficient water to obtain thorough and uniform coverage of foliage and branches.

Withholding Period:
Harvest: Not required when used as directed.

Jurisdiction:
NSW and QLD only.

Additional Conditions:
This Permit provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR THE CONTROL OF SEED WEEVIL IN MACADAMIA

PERMIT NUMBER – PER86827

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 13 SEPTEMBER 2018 TO 30 SEPTEMBER 2021.

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 8, 1 Chifley Square,
Sydney, NSW, 2000

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
DUPONT STEWARD EC INSECTICIDE (59573)
PLUS OTHER REGISTERED PRODUCTS
Containing: 150 g/L INDOXACARB as their only active constituent.

AVATAR INSECTICIDE (52546)
PLUS OTHER REGISTERED PRODUCTS
Containing: 300 g/kg INDOXACARB as their only active constituent.

Directions for Use:

Crop	Pest	Rate
Macadamia	Macadamia seed weevil (*Kushelorhynchus macadamiae*)	**150 g/L product:** 50 mL/100 L **300 g/kg product:** 25 g/100 L

Critical Use Comments:

- Apply 1500-3000 L/ha as a foliar spray using air-blast sprayer or equivalent.
- Add a non-ionic wetter at label rates.
- DO NOT exceed a maximum of two applications per season.
- Make the first application at the beginning of nut set when nuts are pea sized. Make the second application 10-14 days later if required.
- Apply via orchard air-blast/mister sprayer applying sufficient water to obtain thorough and uniform coverage of foliage and branches.
- Combine with good farm hygiene (removal of infested nuts from the ground) prior to flowering and nut set.
- It is recommended that fallen nuts be swept into a windrow and mulched to provide a mechanical control for the larvae/eggs in the nuts in the September to December period.

Withholding Period:
Harvest: DO NOT harvest for 6 weeks after application
Grazing: DO NOT allow livestock to graze treated macadamia orchards during the season of application.

Jurisdiction:
NSW and QLD only.

Additional Conditions:
This Permit provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

Issued by Australian Pesticides and Veterinary Medicines Authority

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF A REGISTERED AGVET CHEMICAL PRODUCT

FOR CONTROL OF MITES AND THRIPS IN MACADAMIAS

PERMIT NUMBER – PER87510

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 17 JUNE 2019 TO 30 JUNE 2024

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LIMITED
Level 8, 1 Chifley Square
SYDNEY NSW 2000

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
VERTIMEC MITICIDE/INSECTICIDE (APVMA No. 50772)
PLUS OTHER REGISTERED PRODUCTS
Containing: 18 g/L ABAMECTIN as the only active constituent.

VANTAL UPGRADE MITICIDE/INSECTICIDE (APVMA No. 67524)
PLUS OTHER REGISTERED PRODUCTS
Containing: 36 g/L ABAMECTIN as the only active constituent.

Directions for Use:

Crop	Pest	Rate
MACADAMIAS	Thrips (*Scirtothrips* spp.) Broad mites (*Brevipalpus* spp.) Flat mites (*Polyphagotarsonemus* spp.)	**18 g/L product**: 750 mL / ha Plus 5 L summer spray oil / ha **36 g/L product**: 375 mL / ha Plus 5 L summer spray oil / ha

Critical Use Comments:
- Make no more than one (1) spray application per season.
- Abamectin should not be applied in two (2) consecutive seasons without a chemical from a different MoA Group being used in between.
- Apply in July as protection for the spring flush, or in December as protection for the summer flush.
- Apply via orchard airblast/mister sprayer applying sufficient water to obtain thorough and uniform coverage of foliage and branches. May be applied in dilute or concentrate sprays, but in not less than 1,000 L/ha.
- Use in accordance with existing insecticide resistance management strategies and in accordance with best practice.
- DO NOT allow entry to treated areas until the spray has dried.
- DO NOT use if rainfall is expected before spray has dried as this may result in reduced efficacy.
- Dangerous to bees. DO NOT spray trees during flowering, while bees are foraging.
- DO NOT apply under weather conditions or from spraying equipment that may cause spray to drift from the target area.

Withholding Period:
Harvest: DO NOT harvest for 28 DAYS after application.
Grazing: DO NOT graze interrows or cut for stock food for 14 days after last application.

Jurisdiction:
ALL STATES, except VIC.
Note: Victoria is not included in this permit, as their *Control-of-Use* legislation does not require a permit to legalise this off-label use in this state.

Additional Conditions:
This permit provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

To Avoid Crop Damage:
The sensitivity of some macadamia nut varieties to be treated under this permit has not been fully evaluated under all growing conditions. It is advisable to only treat a small number of trees to ascertain their reaction before treating the whole crop.

Export of Treated Produce:
To allow treated produce to be supplied or otherwise made available for consumption, a temporary Maximum Residue Level (tMRL) of 0.01 mg/kg has been established for abamectin in macadamias. This TMRL limit applies only to produce marketed and consumed in Australia. Where abamectin treated produce is to be exported, due account should be taken of the residue definition and residue limits/import tolerances of importing countries. Any residues must not exceed requirements of the importing country.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW EMERGENCY USE OF A REGISTERED AGVET CHEMICAL PRODUCT FOR CONTROL OF FALL ARMYWORM IN VARIOUS CROPS

PERMIT NUMBER – PER89241

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows the Permit Holder and any person stipulated below to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 06 MARCH 2020 TO 31 MARCH 2023

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 7, 141 Walker Street
NORTH SYDNEY NSW 2060

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
SUCCESS NEO INSECTICIDE (APVMA No. 64109)
Containing: 120 g/L SPINETORAM as the only active constituent.

DELEGATE INSECTICIDE (APVMA No. 61717)
Containing: 250 g/kg SPINETORAM as the only active constituent.

Restraints:
Comply with all restraints on the product label.

Directions for Use:

Crop	Pest / Disease	Rate
Sweet corn Brassica vegetables Leafy vegetables Cotton Cucurbits Fruiting vegetables Legume vegetables Stalk and stem vegetables Culinary herbs Root and tuber vegetables	Fall Armyworm (*Spodoptera frugiperda*)	120 g/L product 400 mL/ha
Citrus fruits		120 g/L product 40 mL/100L 250 g/kg product 20 g/100L
Soybean Pulses (excluding chickpeas)		120 g/L product 300 mL/ha
Chickpeas		120 g/L product 200 mL/ha
Bananas		120 g/L product 20 mL/10L
Ornamentals Tropical and sub-tropical fruits (inedible peel, including avocado, mango and kiwifruit) Macadamias Berryfruit Coffee		120 g/L product 40 mL/100L

Pistachios		120 g/L product 1 L/ha
Forage brassicas		120 g/L product 100 mL/ha
Canola		120 g/L product 150 mL/ha
Grapes		250 g/kg product 10 g/100L
Pome fruit Stone fruit		250 g/kg product 20 g/100L

Critical Use Comments:

- Regularly scout crops to monitor for eggs and larvae. Treat when pests appear, targeting eggs at hatch or small larvae (prior to third instar stage) before the pest becomes entrenched.
- Follow instructions on the product label for the target crop, including re-treatment intervals.
- Comply with the maximum number of applications per crop specified on the product label. DO NOT make more than four (4) applications to any crop in one season.
- Refer to the Insecticide Resistance Management statement on the product labels to prevent or delay the development of resistance.

Withholding Period:

HARVEST: Comply with withholding periods on the product label for each crop.
GRAZING AND STOCKFOOD: Comply with withholding periods and Export Slaughter Intervals on the product label for each crop.

Jurisdiction:

All States and Territories, except VIC.

Note: Victoria is not included in this permit, as their Control-of-Use legislation means a permit is not required to legalise this off-label use in that State.

Additional Conditions:

This permit allows for the use of a product in a manner specified on the permit. Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit. Unless otherwise stated, the use of the product must be in accordance with the product label.

Export of treated produce

MRLs can be found in the *Agricultural and Veterinary Chemicals Code (MRL Standard) Instrument 2019*. MRLs apply only to produce marketed and consumed in Australia. If treated produce is to be exported, residues must not exceed the limits/tolerances of the importing country.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW EMERGENCY USE OF A REGISTERED AGVET CHEMICAL

PRODUCT FOR CONTROL OF FALL ARMYWORM IN VARIOUS CROPS

PERMIT NUMBER – PER89278

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows the Permit Holder and any person stipulated below to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 13 MARCH 2020 TO 31 MARCH 2023

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 7, 141 Walker Street
NORTH SYDNEY NSW 2060

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
AVATAR INSECTICIDE (APVMA No. 52546)
Containing: 300 g/kg INDOXACARB as the only active constituent.

Restraints:
Refer to restraints on the label.

Directions for Use:

Crop	Pest	Rate	Critical Use Comments
Broccoli Brussels sprouts Cabbage (closed head varieties only) Cauliflower	Fall Armyworm (*Spodoptera frugiperda*)	250 g/ha	DO NOT exceed a maximum of four (4) applications per crop with a seven (7) day re-treatment interval.
Celery			DO NOT exceed a maximum of three (3) applications per crop with a seven (7) day re-treatment interval.
Capsicum Eggplant Peppers Tomato (field or trellis)			
Leafy vegetables Chinese leafy vegetables		170 g/ha	
Apples Nashi pear Pears		25 g/100L	DO NOT exceed a maximum of six (6) applications per crop with a ten (10) day re-treatment interval.
Apricot Nectarine Peaches Plums			DO NOT exceed a maximum of three (3) applications per crop with a ten (10) day re-treatment interval.
Grapes		17 g/100L	
Cherries			DO NOT exceed a maximum of two (2) applications per crop with a ten (10) day re-treatment interval.
Blueberries and Rubus species			DO NOT exceed a maximum of two (2) applications per crop with a seven (7) day re-treatment interval.
Strawberries			
Macadamia nuts		25 g/100L	DO NOT exceed a maximum of two (2) applications per crop with a ten (10) day re-treatment interval.

Critical Use Comments:

- Regularly scout crops to monitor for eggs and larvae. Treat when pests appear, targeting eggs at hatch or small larvae (prior to third instar stage) before the pest becomes entrenched.
- DO NOT apply more than the maximum number of consecutive treatments per crop as listed on the product label.
- Follow all label instructions for crops included on the product label.
- Apply in sufficient volume to achieve thorough coverage
- Dangerous to bees. DO NOT apply when bees are actively foraging. Avoid direct application or drift of the spray mix onto bee hive. After spray has dried, bees can safely forage flowering crops.
- DO NOT enter treated areas until spray has dried, unless wearing cotton overalls buttoned to the neck and wrist (or equivalent clothing) and chemical resistant gloves. Clothing must be laundered after each days use.
- Refer to the Insecticide Resistance Management (IRM) on the product label to prevent or delay the development of insecticide resistance.

Withholding Period:

HARVEST:

- Crops included on the product label
  Follow the withholding periods and trade advice on the product label.
- Celery
  DO NOT harvest for 7 DAYS after application.
- Cherries
  DO NOT harvest for 14 DAYS after application.
- Blueberries and Rubus spp.
  DO NOT harvest for 3 DAYS after application.
- Strawberries
  DO NOT harvest for 2 DAYS after application.
- Macadamias
  DO NOT harvest for 6 WEEKS after application.

GRAZING:

- All crops
  DO NOT graze or cut for stock food.

Jurisdiction:

All States and Territories, except VIC.

Note: Victoria is not included in this permit, as their Control-of-Use legislation means a permit is not required to legalise this off-label use in that State.

Additional Conditions:

This permit allows for the use of a product in a manner specified on the permit. Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit. Unless otherwise stated, the use of the product must be in accordance with the product label.

Export of treated produce

MRLs can be found in the *Agricultural and Veterinary Chemicals Code (MRL Standard) Instrument 2019*. MRLs apply only to produce marketed and consumed in Australia. If treated produce is to be exported, residues must not exceed the limits/tolerances of the importing country.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW EMERGENCY USE OF A REGISTERED AGVET CHEMICAL

PRODUCT FOR CONTROL OF FALL ARMYWORM IN VARIOUS CROPS

PERMIT NUMBER – PER89293

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows the Permit Holder and any person stipulated below to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 10 APRIL 2020 TO 30 APRIL 2023

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 7, 141 Walker Street
NORTH SYDNEY NSW 2060

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
LANNATE-L INSECTICIDE (APVMA No. 47336)
PLUS OTHER REGISTERED PRODUCTS
Containing: 225 g/L METHOMYL as the only active constituent.

EUROCHEM SENECA ULTRA 400 SP INSECTICIDE (APVMA No. 83859)
PLUS OTHER REGISTERED PRODUCTS
Containing: 400 g/kg METHOMYL as the only active constituent.

RESTRAINT:
DO NOT apply as a fog or mist.
DO NOT use in protected cropping situations.
DO NOT use on crops that are grown hydroponically.
DO NOT apply if bees are actively foraging. Ensure beehives are removed from the area to be treated and from adjacent paddocks.
DO NOT allow entry into treated areas for at least 24 hours after treatment.
Mangoes: DO NOT apply after early fruit set.
Macadamias: DO NOT spray tree foliage, flowers or developing nutlets.
Turf: DO NOT graze treated turf or lawn; or feed turf or lawn clippings from any treated area to poultry or livestock.

Directions for Use:

Crop	Pest	Rate	Maximum number of treatments	Retreatment interval (days)
Apples Pears	Fall Armyworm (*Spodoptera frugiperda*)	225 g/L product: 150-200 mL/100L 400 g/kg product: 84-113 g/100L	N/A	N/A
Blueberries		225 g/L product: 100 mL/100L 400 g/kg product: 56 g/100L	N/A	N/A
Strawberries		225 g/L product: 1.5 L/ha 400 g/kg product: 0.84 kg/ha	N/A	N/A
Citrus Stone fruit Cherries		225 g/L product: 200 mL/100L 400 g/kg product: 113 g/100L	N/A	N/A
Non-bearing ornamentals			3	N/A
Mango Persimmon			3	10-14

Grapes		225 g/L product: 150 mL/100L 400 g/kg product: 84 g/100L	N/A	N/A
Brassica vegetables Capsicums (sweet peppers) Sweet corn Beans (legume only) Peas (legume only) Potatoes		225 g/L product: 1.5-2 L/ha 400 g/kg product: 0.84-1.13 kg/ha	N/A	N/A
Macadamia			1	N/A
Turf		225 g/L product: 2 L/ha 400 g/kg product: 1.13 kg/ha	4	N/A
Tomatoes Shallots Spring onion			N/A	N/A
Fruiting vegetables (including cucurbits) Fruiting vegetables (excluding cucurbits) Legume vegetables (snow and sugar snap peas)		225 g/L product: 1-2 L/ha 400 g/kg product: 0.56-1.13 kg/ha	6	7
Sweet potato				3
Radish Swede Turnip			4	7

Lettuce (head and leafy lettuce)			4	3
Root and tuber vegetables Celeriac Silverbeet Myoga Ginger Rakkyo Parsley			3	7
Spinach Fennel Brassica leafy vegetables Bulb onion Fennel bulb Leeks				N/A
Avocado		<u>225 g/L product:</u> 50-100 mL/100L <u>400 g/kg product:</u> 28-56 g/100L	N/A	N/A
Celery		<u>225 g/L product:</u> 1 L/ha <u>400 g/kg product:</u> 0.56 kg/ha	3	N/A

Critical Use Comments:

- Regularly scout crops to monitor for eggs and larvae.
- Target sprays against eggs and newly hatched larvae (prior to third instar stage) before they become entrenched.
- Persimmon
  - Apply foliar cover spray treatment from early flowering to early fruit development only; phenological growth stages BBCH 61 to 72.
  - Apply using an accurately calibrated air-blast sprayer or similar equipment.
  - Apply to the point of run off and ensure thorough coverage of all branches, foliage and developing fruit.
- Macadamia
  - Apply as a ground surface treatment only.
  - Apply using boom spray or equivalent application equipment.
  - Ensure thorough coverage of all leaf litter and soil surface along tree line.
- All other crops
  - Apply as a foliar spray.
  - Apply using boom spray or equivalent application equipment.
  - Use sufficient water to ensure thorough coverage of entire crop
- Refer to the Insecticide Resistance Management (IRM) on the product label to prevent or delay the development of insecticide resistance.

Withholding Periods:

Crop	Harvest WHP	Grazing WHP
Apples Stone fruit Cherries Brassica vegetables Tomatoes Capsicum Beans (except adzuki and soya beans) Peas (except cow, pigeon and field peas)	1 day	Nil
Adzuki beans Soya beans Cow peas Pigeon peas Field peas	7 days	Nil
Sweet Corn	1 day	3 days
Pears Citrus	2 days	Nil
Strawberries	3 days or 10 days*	Nil
Blueberries	5 days	Nil
Grapes Lettuce	7 days	Nil
Fruiting veg (inc. cucurbits) Fruiting veg (exc. cucurbits) Legume veg (snow and sugar snap peas) Sweet potato Parsley Shallots Spring onions Avocados	3 days	-
Root and tuber veg Ginger Rakkyo Bulb onions leeks	7 days	-
Silverbeet Myoga Spinach Fennel Fennel bulb Brassica leafy vegetables	14 days	-
Celeriac Radish Swede Turnip Celery Ornamentals	1 day†	-
Mangoes Macadamias Persimmons Potatoes	Not required when used as directed	-
Turf	N/A	DO NOT graze treated turf or lawn; or feed turf or lawn clippings from any treated area to poultry or livestock.

*__Strawberries – Harvest__: To avoid the possibility of taint in strawberries to be frozen, do not apply later than 10 days before harvest.

†__Radish, swede and turnip – Harvest__: leaf material must be trimmed prior to supply. **DO NOT** harvest tops of supply bulbs with leaf material attached for human or animal consumption.

Jurisdiction:
All States and Territories.

Additional Conditions:
This permit allows for the use of a product in a manner specified on the permit. Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit. Unless otherwise stated, the use of the product must be in accordance with the product label.

To Avoid Crop Damage
The sensitivity of the crop to be treated under this permit has not been fully evaluated. It is advisable to only treat a small area to ascertain the reaction before treating the whole crop.

Export of treated produce
Temporary Maximum Residue Limits (TMRLs) have been established to allow treated produce to be used for human and animal consumption. TMRLs have been established for METHOMYL in ALL COMMODITIES LISTED ON THIS PERMIT. MRLs can be found in the *Agricultural and Veterinary Chemicals Code (MRL Standard) Instrument 2019*. MRLs apply only to produce marketed and consumed in Australia. If treated produce is to be exported, residues must not exceed the limits/tolerances of the importing country.

Issued by the Australian Pesticides and Veterinary Medicines Authority

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW EMERGENCY USE OF A REGISTERED AGVET CHEMICAL PRODUCT FOR CONTROL OF FALL ARMYWORM IN VARIOUS CROPS

PERMIT NUMBER – PER89353

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows the Permit Holder and any person stipulated below to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 5 MAY 2020 TO 31 MAY 2023

Permit Holder:
HORTICULTURE INNOVATION AUSTRALIA LTD
Level 7, 141 Walker Street
NORTH SYDNEY NSW 2060

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
ALTACOR HORT INSECTICIDE (APVMA No. 69957)
Containing: 350 g/Kg CHLORANTRANILIPROLE as the only active constituent.

CORAGEN INSECTICIDE (APVMA No. 61519)
Containing: 200 g/L CHLORANTRANILIPROLE as the only active constituent.

SPRAY DRIFT RESTRAINTS
Specific definitions for terms used in this section of the label can be found at apvma.gov.au/spraydrift.

DO NOT allow bystanders to come into contact with the spray cloud.

DO NOT apply in a manner that may cause an unacceptable impact to native vegetation, agricultural crops, landscaped gardens and aquaculture production, or cause contamination of plant or livestock commodities, outside the application site from spray drift. The advisory buffer zones in the relevant buffer zone table/s below provide guidance but may not be sufficient in all situations. Wherever possible, correctly use application equipment designed to reduce spray drift and apply when the wind direction is away from these sensitive areas.
DO NOT apply unless the wind speed is between 3 and 20 kilometres per hour at the application site during the time of application.

DO NOT apply if there are surface temperature inversion conditions present at the application site during the time of application. These conditions exist most evenings one to two hours before sunset and persist until one to two hours after sunrise.

DO NOT apply by a boom sprayer unless the following requirements are met:
- Spray droplets are not smaller than a MEDIUM spray droplet size category.
- Minimum distances between the application site and downwind sensitive areas are observed (see 'Mandatory buffer zones' section f the following table titled 'Buffer zones for boom sprayers').

Buffer zones for boom sprayers

Application rate	**Boom height above the target canopy**	**Mandatory downwind buffer zones for natural aquatic areas**	
		WG formulation ALTACOR HORT INSECTICIDE	**SC formulation** CORAGEN INSECTICIDE
Up to maximum permit rate	0.5 m or lower	Not required.	Not required.
	1.0 m or lower	20 metres	25 metres

DO NOT apply by a vertical sprayer unless the following requirements are met:
- Spray is not directed above the target canopy.
- The outside of the sprayer is turned off when turning at the end of rows and when spraying the outer row on each side of the application site.
- For dilute water rates up to the maximum listed for each type of canopy specified, minimum distances between the application site and downwind sensitive areas are observed (see 'Mandatory buffer zones' section of the following table titled 'Buffer zones for vertical sprayers').

Buffer zones for vertical sprayers

Type of target canopy and dilute water rate	**Mandatory downwind buffer zones for natural aquatic areas**	
	WG formulation ALTACOR HORT INSECTICIDE	**SC formulation** CORAGEN INSECTICIDE
2 metres tall and shorter, maximum dilute water rate of 1000 L/ha	10 metres	10 metres
Taller than 2 metres (not fully-foliated), maximum dilute water rate of 1700 L/ha	25 metres	30 metres
Taller than 2 metres (fully-foliated), maximum dilute water rate of 1700 L/ha	20 metres	20 metres

Directions for Use:

Crop	Pest	Rate
Rubus spp. (field and protected)	Fall Armyworm (*Spodoptera frugiperda*)	350 g/kg product 18 g/100 L + 15 g a.i./100 L of non-ionic surfactant/wetting agent 200 g/L product 30 mL/100 L + 15 g a.i./100 L of non-ionic surfactant/wetting agent
Tree nuts (except almonds)		
Strawberries (field and protected)		350 g/kg product 6 g/100 L or 60 g/ha + 15 g a.i./100 L of non-ionic surfactant/wetting agent 200 g/L product 10 mL/100 L or 100 mL/ha + 15 g a.i./100 L of non-ionic surfactant/wetting agent
Parsley (field and protected)		
Root and tuber vegetables (except potatoes) (field only)		

Critical Use Comments:

- Regularly scout crops to monitor for eggs and larvae. Treat when pests appear, targeting eggs at hatch or small larvae (prior to third instar stage) before the pest becomes entrenched.
- Apply by boom spray or air-blast sprayer or equivalent.
- DO NOT apply more than 3 applications per crop.
- DO NOT apply more than 2 consecutive sprays per crop, with a minimum interval of 7 days.
- Further treatments should be made with a alternative mode of action insecticide.
- DO NOT apply less than 7 – 14 days after the initial treatment.
- Use enough water to ensure thorough coverage of the crop.
- Use a non-ionic surfactant/wetting agent at 15 g active/100 L, (e.g. Agral 600 @25 ml/100 L).
- DO NOT use BS1000 or Activator as it may cause phytoxicity.
- Refer to the Insecticide Resistance Management (IRM) on the product label to prevent or delay the development of insecticide resistance.
- Very toxic to aquatic life. DO NOT contaminate wetlands or watercourses with this product or used containers.

Withholding Period:
Parsley, Rubus spp. and Root and tuber vegetables (except potato):
Harvest: Do not harvest for 3 days after application.
Strawberries:
Harvest: Do not harvest for 1 day after application.
Tree nuts (except almonds):
Harvest: Do not harvest for 10 days after application.

All crops:
Grazing: Do not graze or cut for stock food.

Jurisdiction:
All States and Territories, except VIC.
Note: Victoria is not included in this permit, as their Control-of-Use legislation means a permit is not required to legalise this off-label use in that State.

Additional Conditions:
This permit allows for the use of a product in a manner specified on the permit. Persons who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit. Unless otherwise stated, the use of the product must be in accordance with the product label.

To Avoid Crop Damage
The sensitivity of the crop to be treated under this permit has not been fully evaluated. It is advisable to only treat a small area to ascertain the reaction before treating the whole crop.

Export of treated produce
Maximum Residue Limits (MRLs) and Temporary Maximum Residue Limits (TMRLs) have been established to allow treated produce to be used for human and animal consumption. An MRL has been established for CHLORANTRANILIPROLE. MRLs can be found in the *Agricultural and Veterinary Chemicals Code Instrument No. 4 (MRL Standard)*. MRLs apply only to produce marketed and consumed in Australia. If treated produce is to be exported, residues must not exceed the limits/tolerances of the importing country.

NOTE: Version 2 issued to include *Rubus* spp. protected cropping.

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Stephen McLean
Macadamia grower and consultant

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