Department of Primary Industries
and Regional Development

NSW GOVERNMENT

Macadamia plant protection guide 2025–26

NSW PRIMARY INDUSTRIES MANAGEMENT GUIDE

Jeremy Bright

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COPPOX WG

500 g/kg COPPER (Cu) present as COPPER OXYCHLORIDE

Control of Husk spot, Anthracnose husk rot and Pink limb blight.

AG COPP 750 WG
FUNGICIDE

750 g/kg COPPER (Cu) present as CUPROUS OXIDE

Control of Husk spot, Anthracnose, Pink limb blight and Phytophthora stem canker.

HYDROCOP WG

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

Control of Husk spot, Anthracnose, Pink limb blight and Phytophthora stem canker.

BORDEAUX WG

200 g/kg COPPER (Cu) present as TRIBASIC COPPER SULPHATE

Control of Husk spot, Anthracnose, Pink limb blight and Phytophthora stem canker.

TRIBASIC LIQUID

190 g/L COPPER (Cu) present as TRIBASIC COPPER SULPHATE

Control of Husk spot, Anthracnose, Pink limb blight and Phytophthora stem canker.

CROP DOC 600

600 g/L PHOSPHOROUS (Phosphonic) Acid present as Mono (and) Di Potassium

Phosphite Control of Phytophthora root rot and Trunk (Stem) canker.

KINGFISHER

250 g/L DIFENOCONAZOLE

Control of Husk spot.

PEREGRINE

240 g/L METHOXYFENOZIDE

Control of Macadamia flower caterpillar and Macadamia nutborer.

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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 this publication.

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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 when the publication was prepared. Persons wishing to use a chemical 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 before and during use.

Image acknowledgements

Cover image: harvesting the amendment trial at the Centre for Tropical Horticulture, Alstonville.

Unless otherwise stated, the images in this guide have been sourced from the NSW DPIRD.

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Printing

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Contents

About this guide

This 11th edition of the *NSW Macadamia plant protection guide* aims to provide commercial macadamia growers with up-to-date information on all aspects of protecting an orchard from pests and diseases.

Distribution

The guide is available free to macadamia growers and is distributed to all macadamia processors in Australia. Copies can be collected from the NSW Department of Primary Industries and Regional Development (DPIRD) office at Wollongbar, processors, the Australian Macadamia Society, and selected rural retail stores. Every effort is made to have all macadamia growers obtain a copy of this publication.

The guide can also be downloaded from the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-protection-guide).

Pesticides

We do not list every pesticide that is registered for a specific use, but rather guide growers in their choice of chemicals. Our policy is to use common chemical names or active ingredients, not trade names, when referring to pesticides, crop regulation compounds and nutrient sprays. 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 pesticide 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 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.

Acknowledgements

Special thanks to Dr Jay Anderson, Senior Research Fellow at Southern Cross University, for reviewing the diseases section and to Aphrika Gregson, Farm Chemicals Officer, NSW DPIRD, for reviewing the pesticide recommendations.

Feedback please

NSW DPIRD wants to make sure the information we are providing is what you need to help your business grow. We welcome suggestions, comments and ideas from growers and technical people that might improve the usefulness and relevance of the guide. Please contact me with your suggestions.

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What's new?

Feature article

This year's feature article focuses on the lessons learned from the flood in 2022, tropical cyclone Alfred and other recent extreme wet weather. Research led by Dr Suzy Rogiers, a physiology expert with NSW DPIRD, has provided valuable insights into how macadamia trees respond to submergence and the following prolonged wet conditions. Her findings have highlighted management practices that might contribute to tree survival during these challenging events.

From this research, practical strategies have been identified to help the macadamia industry better prepare for future wet weather. These recommendations aim to support growers in building more resilient orchards that can withstand not only floods, but a wide range of climatic extremes.

This article complements our previous feature on drought resilience, reinforcing our broader goal: to strengthen the industry's capacity to adapt and thrive under all environmental conditions. Encouragingly, many of the approaches to managing drought and flood resilience share common ground, offering a unified path for growers.

New publications

Horticulture Innovation Australia contracted NSW DPIRD to review and update the 2004 *Macadamia grower's guide* (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/macadamia-growers-guide2). The contract was to develop 6 online modules within 3 years. This has been achieved and the project is now complete. The modules developed included:

1. *Nutrition and soil health – part 1 – the foundations*
2. *Nutrition and soil health – part 2 – the next level*
3. *New orchards*
4. *Cultivars*
5. *Managing young trees*
6. *Bearing trees*.

The *Macadamia integrated orchard management guide: drainage* (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management) has also been updated to include sub-surface drainage.

Growers can access these and much more information on macadamia at the NSW DPIRD website. Alternatively, scan the QR code to the NSW DPIRD nut webpage (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts).

Chemical changes

Diazinon

The APVMA has published its final decision on the reconsideration of diazinon, an insecticide and acaricide. Horticulture uses, except nursery plants, have been withdrawn. A one-year phase-out period authorising possession, custody, use and supply of diazinon products is in force until September 10 2025. For details, refer to the APVMA's public chemical registration information system search (https://portal.apvma.gov.au/pubcris) and the diazinon summary of uses report (https://www.apvma.gov.au/sites/default/files/2024-09/Diazinon%20uses%20%E2%80%93%20summary%20of%20assessment%20outcomes%20in%20final%20regulatory%20decision.pdf).

New Group 30 Insecticide registered for macadamia

A new insecticide with a novel mode of action (Group 30) has been registered for use in macadamia orchards to control key pests, including fruit spotting bug and macadamia seed weevil. The product, Vertento® Plinazolin, contains the active ingredient isocycloseram.

Important usage note: Vertento® Plinazolin should not be applied during flowering or when bees are actively foraging.

AUSTRALIAN MACADAMIA SOCIETY

Get involved in the National Macadamia Tree Crop Map Project

The global macadamia industry is booming – production is tipped to grow by **10% every year until 2029**. With that growth comes opportunity, but also the need for better planning and data.

That's where Australian macadamia growers come in.

The **National Macadamia Tree Crop Map** already shows around **45,000 ha** of commercial orchards across Australia. Now, AMS is working with researchers to **take the map to the next level** – capturing **block-level details** to give us a clearer picture of how and where we grow.

We started in **Bundaberg**, where 50% of farms are already mapped. Your input is key to completing the picture – and expanding the project nationwide.

Watch the video now to hear why FNC Plantations got involved and why you should too.

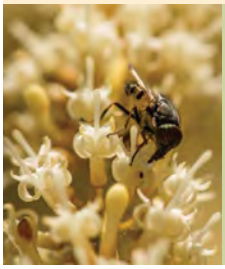
Scan here to watch

Why get involved?

By sharing your orchard details, you'll help the industry:

- ✓ Respond faster to **pest outbreaks** and **natural disasters**
- ✓ Improve **yield forecasting** and **market planning**
- ✓ Unlock new **export and sustainability opportunities**
- ✓ Support smarter decisions around **infrastructure, water, and research**
- ✓ Strengthen **industry advocacy.**

And the data is secure – only accessible by AMS.



It's simple to get involved.

We just need a few details such as **orchard location**, **planting year**, **cultivars**, and **irrigation source**.

This is your chance to help futureproof our industry — one orchard at a time.

Let's grow smarter, together.

Two easy ways to share:

Scan for survey

1. ONLINE:

Visit **australianmacadamias.org/industry** and follow the link to the survey on the home page OR scan the QR code on this page to go straight to the survey.

2. CONTACT YOUR AMS REP:

Share a KML file from your farm mapping app:

NSW: Leoni Kojetin
leoni.kojetin@macadamias.org
0433 007 925

QLD/WA: Emily Grieve
emily.grieve@macadamias.org
0438 772 757

AARSC Applied Agricultural Remote Sensing Centre · une University of New England · Hort Innovation · Future Food Systems

This project is a collaborative piece of work co-funded by the Future Food Systems CRC, Hort Innovation, University of New England, Australian Macadamia Society and other tree crop industries to continue the development, trial and extension of technology-based cropping and monitoring tools.

Merivon®

Merivon® (250 g/L pyraclostrobin + 250 g/L fluxapyroxad; Group 7 + 11) is currently registered for macadamia husk spot and has now been registered for the control of flower blight complex (dry flower, raceme blight) including but not limited to: *Pestalotiopsis* spp., *Neopestalotiopsis* spp., *Botrytis cinerea*, and *Cladosporium* spp. in macadamia.

New advice regarding Luna® Experience

Bayer has advised that the registered Group 3 + 7 fungicide (fluopyram and tebuconazole, Luna® Experience 400 SC) should not be used in export macadamia crops until a use pattern is identified that will ensure nuts meet the maximum residue limit (MRL) requirements of all overseas markets.

Sivanto® Prime residue issues

Advice from Bayer regarding Sivanto® Prime (flupyradifurone), which is currently registered for the control of macadamia lace bug, scirtothrips and fruit spotting bug, has no export limitations applied for the upcoming season to macadamia nuts.

Varroa mite transition to management

The *Varroa destructor* mite is now considered established in New South Wales. Varroa mite is a notifiable pest under the Biosecurity Act 2015 and Biosecurity Regulation 2017, so beekeepers are required to monitor and report its presence. For information on managing varroa mite, refer to the NSW DPIRD Varroa mite transition to management webpage (https://www.dpi.nsw.gov.au/emergencies/biosecurity/current-situation/varroa-mite-emergency-response).

Pesticide management on-farm

Last year's feature article *Pesticide management on-farm: sensitive areas, buffer zones, chemical storage and disposal* has been transitioned into a Primefact and is available for easy access on the NSW DPIRD nut webpage (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/1566803/Pesticide-management-on-farm-web.pdf).

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Lessons learnt from the flood in 2022 and a cyclone in 2025

Jeremy Bright and Kevin Quinlan, NSW DPIRD

Building resilience to withstand climate challenges

Climate change brings with it an increased frequency of extreme weather. While the unpredictability of this limits some of the preventative measures we can take within the orchard, it does not diminish our broader strategy: building resilience into our orchards to withstand and recover from all types of climatic challenges.

This feature article discusses recent extreme weather, most notably the flood in 2022 and the tropical cyclone in 2025, and the lessons we have learned from them. Drawing on first-hand experience and scientific evaluation, we examine how these events have shaped our understanding and approach to managing macadamia trees before, during and after these conditions.

The main question to answer is: How can we better manage our orchards to mitigate the effects of such events and adapt to an increasingly unpredictable climate?

How extreme rainfall affects macadamias

The position within the landscape strongly influences the types of flood-related damage that occurs. For example, submergence is more likely on floodplains, slopes are prone to washouts and inundation and washouts are more common on plateaus.

Submergence

The entire plant, including the canopy, is fully submerged under water. This can severely affect plant survival due to:

- lack of light for photosynthesis
- prolonged oxygen deprivation
- increased susceptibility to pests and diseases
- tree death
- structural damage.

Submergence can also lead to loss of nut production and harvestable nuts (if on the orchard floor).

Washouts and flash flooding

With intense rainfall in a short period, washouts and flash flooding can occur, mostly affecting plants on moderate to steep slopes (Figure 1). While plants might not be fully submerged, significant damage can still occur. Common problems include:

- soil erosion and loss
- root exposure
- increased pest and disease risk
- increased susceptibility of plants being uprooted
- loss of harvestable nuts.

Inundation and waterlogging

Plant roots can be submerged for extended periods while the canopy remains above water (Figure 2). Prolonged waterlogging can lead to:

- oxygen deprivation in roots
- reduced nutrient uptake
- increased susceptibility to pests and diseases
- loss of harvestable nuts.

Figure 1. Roots exposed in a washout caused by intense rainfall.

Figure 2. Waterlogged macadamia.

Cyclones

Cyclones combine extreme rainfall and high wind speed. Either or both of these can cause:

- plants to be uprooted (Figure 3)
- stems and branches to break
- saltwater intrusion (in coastal areas)
- soil erosion and loss
- root exposure
- compounded stress from both water and wind damage
- increased susceptibility to pests and diseases
- loss of harvestable nuts.

Cyclones and east coast lows often coincide with the macadamia harvest season, creating a high-risk period for growers. Extreme winds during these can lead to premature nut drop and cause tree limbs and branches to fall. The resulting clean-up efforts divert labour and resources away from harvesting, potentially affecting yield and efficiency.

Figure 3. A young tree that was uprooted due to saturated soil and high winds.

How cyclones affect macadamias

Cyclones and East Coast Lows can cause significant damage to macadamia trees as they combine the effects of intense rainfall and strong winds. The main problems are branches breaking, leaf stripping, and intense rainfall, which can cause challenges at harvest.

Branch breakage

Strong winds from cyclones can cause considerable branch breakage. Often with cyclones, the wind direction will change, causing branches to get twisted around (Figure 4). The strong winds can cause branches to snap off, leaves and nuts to drop (potential premature nut drop), and twigs to drop. There is also increased potential for pests and diseases, such as bark beetles and Botryosphaeria. Where branches have been snapped off, the damaged section that remains on the tree is a point for disease entry.

Figure 4. Wind changes during cyclones often twist and break branches.

Prevention strategy

Ensure damaged sections of broken branches are cut cleanly to prevent infection, but do not do this while the tree branches are wet and sap flow is reduced, as it will increase the risk of Botryosphaeria disease entry.

The best strategy to reduce wind damage is to prune trees, especially when they are young, to set a strong structure, particularly low in the tree. Ensuring branches have strong crotch angles is important to reduce weak points. When training young trees, ensure there are no branches for at least 300 mm above the graft union so if a strong wind causes branches to break, it should be above this point, allowing the trees to be pruned and regrowth to occur. If branches are too close to the graft union, the split might extend below it, making it impossible to cut off the damage and regrow from the scion.

In mature trees, pruning to remove poor crotch angle branches and reduce competition is important to help reduce wind damage. A long branch with a large amount of leaf material on the end is more susceptible to breakage than short branches with evenly distributed leaves because the leverage force is reduced. Pruning also promotes new growth, and if this is done to open the tree up, it will help sustain leaf and twig growth within the trees. Having less dead wood in a tree reduces the amount of material that can be dropped onto the orchard floor during strong winds.

Leaf stripping

Cyclonic winds can strip leaves from trees. This stripping and damage to leaves reduces energy production within the tree. The damaged parts also increase the potential for diseases to enter the tree. If the leaf stripping coincides with harvest, it will create additional challenges, and mowing might be required before running a harvester to reduce clogging of finger wheels and augers.

Prevention strategy

Preventing leaves from being stripped from the tree is not possible. However, ensuring the tree is healthy is critical, as having strong sap flow so the tree can seal off wounds left from leaf stripping is important to minimise the potential for disease entry into the plant.

Intense rainfall

The intense rainfall during a cyclone can cause soil erosion and organic matter to be moved from under the trees. The timing of the rainfall (both within the season and the life of the orchard) will determine what management strategies will be required.

In the short term, soil profiling (outside of harvest) can help cover tree roots and direct water flow away from tree rows. However, this on its own has limited value; longer-term solutions must be put in place to reduce future damage.

Longer term, having a strong drainage network, including sound diversion banks, is essential. Maintaining living ground cover in the inter-rows is critical to minimise soil erosion (refer to *Integrated orchard management guide 2016*). Having non-living ground cover under the trees promotes strong feeder root development and improves soil health. Non-living ground cover that promotes fungi growth and the polysaccharide mucilage they excrete within the mulch helps bind it together, making the orchard floor more resilient.

Prevention strategy

As the orchard develops, the drainage network will be affected by shading of water courses, movement of soil and efficiencies of previously installed diversion banks. Monitor and amend the drainage networks through the orchard regularly so it is as effective as possible during heavy rainfall and inundation. Undertake canopy management and/or orchard management practices that balance production and maintain living ground cover in the inter-row.

Harvesting and dehusking

Cyclonic winds pose a significant challenge to macadamia harvesting and dehusking operations. These conditions often result in heavy leaf litter, fallen branches, twigs, and excessive nut drop, complicating ground conditions and machinery performance. Additionally, the displacement of soil and mulch from beneath trees further hinders efficient harvesting.

Management strategies

To manage these challenges, several practical strategies can be employed, such as:

- Harvesting up to fallen branches, then removing them to clear the area.
- Mowing before harvesting to break up leaf litter and expose nuts.
- Harvesting the centre of rows first, followed by smaller, controlled passes ('taking small bites') to maintain travel speed and reduce finger wheel stalling.
- Avoid overloading harvester augers to prevent blockages.
- Using harrows post-harvest to recover nuts that might have been buried.

When dehusking, systems must be capable of handling increased levels of debris and moisture. To help with this:

- Use leaf blowers at the receival hopper to remove light debris such as leaves.
- Incorporate pre-cleaners to reduce contamination.
- Rapidly remove husks to preserve nut quality, especially when the husk is wet.

Regularly maintaining and adjusting the dehusking equipment is essential to ensure reliable performance under these demanding conditions.

How flooding affects macadamias

The flood in 2022, which led to the Richmond River having the highest recorded flood level at 14.44 m, devastated many sectors of the Northern Rivers. Very few were spared in many industries. Young macadamia trees (0–4 years) were severely affected, particularly on the floodplains (Figure 5). NSW DPIRD, in conjunction with the Australian Macadamia Society[1], established a research project to learn from this disaster and to use these learning outcomes to help the industry be better prepared for future flooding.

With input from growers, a trial was established to replicate flood conditions (Figure 6). The aim was to see how macadamia coped with flooding. Treatments included:

- Control (no flood)
- 1 week of flood
- 2 weeks of flood
- 2 floods, one month apart.

Figure 5. The 2022 floods resulted in macadamia trees being submerged on farms, and depending on the duration of submergence, tree death.

Figure 6. A flood simulation study with macadamia.

[1] These trials were funded by the Early Needs Recovery Program. The Early Needs Recovery Program is part of the $150 million Primary Industries Support Package co-funded by the Australian and NSW government agencies.

What happens to completely submerged young trees in a flood?

Tree mortality was influenced by both the duration and frequency of submersion (Figure 7). For instance, 2 floods one month apart had a greater effect than one isolated flood. If the trees were only submerged once for one week, the levels of loss would likely have been lower. The compounded stress and huge draw on the young trees' stored carbohydrates from 2 successive floods created a much more challenging environment, greatly reducing the trees' chances of recovery.

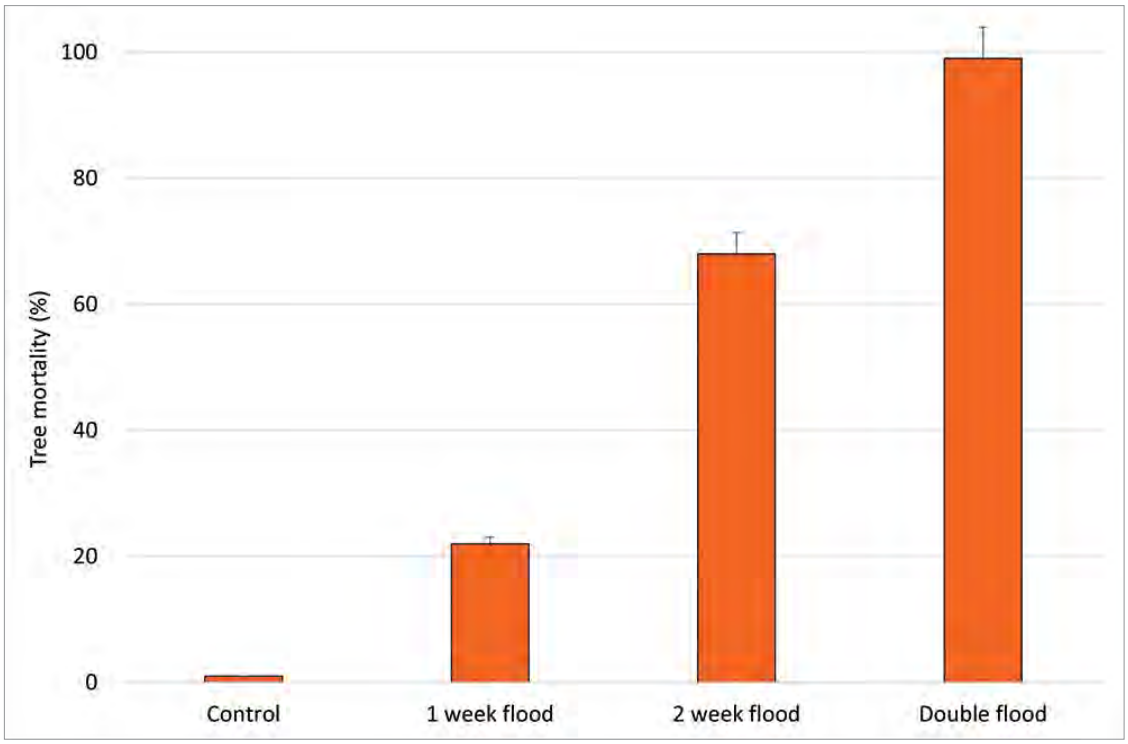

Figure 7. Macadamia mortality (%) from flood simulation with different submergence duration and frequency.

Effects of flooding on the macadamia plant – why and how do the trees die?

Root hypoxia

Prolonged submergence, where the tree roots remain fully saturated, leads to hypoxia, a condition where water replaces the oxygen that was previously held in the soil air pockets (pores). Oxygen shortage leads to poor root respiration, reduced energy production and eventually cell death. This can happen to fully submerged trees and those with canopies above flood levels, especially in areas with poor drainage or inadequate 'freeboard', i.e. when planting mounds are too low (Figure 8). Refer to *Considerations for developing and managing macadamia on floodplain soil* (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/considerations-for-developing-and-managing-macadamia-on-floodplain-soils) for more information.

Carbohydrate status

During periods of low photosynthesis caused by stress such as drought or waterlogging, stored carbohydrates help sustain critical functions until conditions improve. This can be effective after a one-week flood, but a young plant's resources can be exhausted if a second flood occurs one month later. After the first flood, the tree uses its reserves to push new growth/flush in an attempt to restore photosynthesis and, therefore, the ability to generate energy again (Figure 9). Producing new growth takes a lot of energy from the plant. If this new growth is then submerged in a second flood before it is fully extended and photosynthesising, the plant loses both its energy production (the leaves) and a portion of its stored energy (within the trunk). Following the second flood, the tree is often left depleted and unable to recover, i.e. exhausted.

Figure 8. Dr Suzy Rogiers destructively samples flood-affected plants for root hypoxia.

Figure 9. New flush emerging from a young tree that was fully submerged in a flood.

Rootstock–scion combinations

There were no differences between rootstock–scion combinations for surviving waterlogging or a flood. In replicated flooding trials, macadamia trees were moderately resilient to short-term flooding, but prolonged submersion significantly increased mortality. When fully submerged for one week, approximately 22% of trees died within 4 to 5 months. A 2-week submersion led to 68% mortality, while 99% died after the double flood (Figure 7).

Key points

Rootstock–scion combination

The trial did not reveal a clear rootstock–scion combination more suited to higher survival rates than any others. Instead, the survival rate was based on individual plant size and overall health.

This has important agronomic implications as it highlights the critical need to prioritise early growth and plant health from the time of planting. Developing a well-balanced canopy and root system, along with strong trunk structure, will provide better chances of survival from extreme weather.

Once young plants are fully submerged, photosynthesis rates begin to decline as water exposure causes irreversible damage. The longer the leaves remain submerged, the more severe the damage becomes. Even when leaves re-emerged as green and appeared relatively healthy, their photosynthetic capacity was halved compared to the trees that were not submerged.

Strategy: while it might be tempting to prune old or damaged leaves immediately after a flood, we recommend waiting a few weeks before doing any canopy intervention. Allow the plant time to stabilise and begin its natural recovery process. Research and field observations have shown that after a flood, whether the plant was submerged for one or 2 weeks, it will begin to restore its energy reserves by producing new leaves. These new leaves can achieve full photosynthetic capacity, helping the plant recover more effectively. If no subsequent flooding occurs, the plant will continue to rebuild its energy reserves.

The roots

Roots could tolerate a 1-week flood, provided it was an isolated occurrence. After short-term flooding, the roots continued to grow and form new clusters. However, 2 weeks of flooding and the double flood had clear negative effects on the roots, reducing overall growth.

Strategy: ensuring adequate freeboard is essential to help plants escape saturated soil conditions as quickly as possible. To reduce the risk of prolonged waterlogging and help plant survival, build mounds and ridges to at least 600 mm and plant in areas above 1.5 m AHD (Australian height datum). For more information, refer to *Considerations for developing and managing macadamia on floodplain soil*.

Phytophthora

Phytophthora, a soil-borne pathogen, thrives in waterlogged soil but still requires oxygen for certain stages of its life cycle. Therefore, while the plant is underwater and suffering from hypoxia, phytophthora will also be affected. Applying phosphonic acid or potassium phosphite immediately after a flood as a rescue spray is not effective. Instead, wait until the plants start showing signs of new growth, indicating the soil is becoming less saturated and oxygen levels are increasing. Monitor the trees and consider applying a preventative spray once leaves have hardened up (turned dark green).

Building flood resilience

Maximise light interception by the canopy

Plants rely on sunlight for photosynthesis, so maximising the amount of canopy above the water level can improve survival rates. In new plantings, targeted pruning can encourage rapid elongation to increase plant height. However, this must be balanced with the development of a strong, supportive root system to anchor the plant during strong wind. Overly tall, young trees with underdeveloped root systems are more susceptible to wind damage. In such cases, staking might be necessary. Taller, mature trees are generally less affected by complete canopy submersion.

Strategy: review annual pruning practices; try to balance the canopy to root growth.

Ensure well-aerated soil with high organic matter

Waterlogged soil can lead to oxygen deprivation, which harms root health and soil microbiology. Improving soil structure with organic matter, such as compost or mulch, enhances aeration and drainage. This improves the soil's capacity to withstand periods of high moisture and increases the plant's tolerance to waterlogged conditions.

Strategy: annual application of organic amendments, such as manure, double ground mulch and husk, will gradually increase soil organic matter and cation exchange capacity (CEC); note, when applying organic amendments, do not apply while soil is saturated or waterlogged.

Build plant carbohydrate reserve levels

Plant carbohydrates are an important energy store during stressful times when photosynthesis is sub-optimal. Higher carbohydrate reserves will give the plant a better chance of surviving. These reserves build up when the canopy has good light exposure and when the plant receives adequate nutrition (available carbohydrate is greater than required carbohydrate), both of which are essential for optimal photosynthesis.

Strategy: conducting annual soil and leaf analyses will help you to plan and implement a suitable soil health and nutrition program.

Optimise plant size and minimise growth stress

Plants are most vulnerable to submersion and flooding in their first year. New plantings should be at an optimal size, as smaller plants have low carbohydrate levels and are unable to photosynthesise if completely submerged. Minimising issues, such as nutrient deficiencies and poor soil quality, supports healthy growth and better flood resilience.

Strategy: promote plant growth through a sound soil health and nutrition program.

Delay pruning after flooding

Flooding can severely damage leaves and reduce canopy size. While pruning encourages new growth by mobilising carbohydrate reserves, it is energy intensive. For young plants, this can deplete energy stores and increase vulnerability to a second flood. It is generally recommended that young trees be observed but not pruned for at least 2 to 3 months following a flood. However, dead limbs infected with *Botryosphaeria* spp. fungi should be removed.

Strategy: identify and remove dead branches, check by thumb-nailing back the cambium layer: green = living and brown = dead (Figure 10). Prune dead material before new canopy growth after a flood, although this will vary depending on the severity and duration of the flood.

Note: avoid pruning during wet weather, when the soil is waterlogged and when the sap flow is likely to be reduced, as the risk of Botryosphaeria infection will be increased (refer to Branch dieback on page 111).

Avoid planting during high flood-risk periods

Planting when there is a high risk of prolonged flooding, such as in La Niña years or at the start of the wet season, can expose young trees to waterlogged soil, leading to oxygen deprivation and reduced nutrient uptake. Avoiding planting during these times will reduce the risk of flood-related damage and give plants a better chance to establish and thrive. However, this decision should also include the potential trade-off with drought risk.

Strategy: do not plant in La Niña years. Ensure adequate water is available, including watering after planting, if necessary (Figure 11).

Figure 10. Dr Suzy Rogiers checking for tree survival by thumb-nailing back the cambium layer.

Figure 11. A water cart used to provide plants with water during the 2019 drought. Photo: Tony Flick.

Monitor for stress, pests and diseases

Regular inspection helps detect early signs of stress, pest infestations or diseases. Symptoms such as yellowing leaves or wilting can signal underlying issues. Early detection allows for prompt intervention, preventing small problems from becoming major issues that could damage or kill plants.

Strategy: during recovery, flag unusual symptoms and have these followed up with a crop consultant to assist with identification and treatment plans. Burn all dead and removed material, as it provides an ideal breeding site for bark beetles.

Support for young trees

If the site is prone to direct effects from east coast lows, cyclones, or is located on the coastal floodplains, it is essential to stake each tree on both sides (Figure 12). While this creates an added cost, the benefits will far outweigh the expense if the farm receives severe wind. Even for orchards situated further inland, such as on the plateau, staking young trees remains a recommended best practice to help trees establish and ensure orchard resilience.

Strategy: support trees to maintain a good growing structure and encourage a strong root system to develop.

Figure 12. Trees should be staked for early support, especially on a floodplain.

Maintain consistent soil moisture

Plants require a steady supply of moisture for optimal growth. Fluctuating moisture levels, particularly during dry periods, can lead to drought stress, stunted growth, and even plant death. Maintaining consistently moist (but not waterlogged) soil is vital to support plant health throughout the year.

Strategy: improve soil moisture holding capacity through applying organic amendments. Create living ground cover around the plant rows to reduce the effects of radiant heat and evaporation.

Understand the constraints of the land before planting

Land that is lower than the recommended elevation for planting might not be suitable for macadamia, especially during wet years. Check the height above sea level (1.5 m AHD) and flood history before deciding whether to plant macadamias. Drainage constraints and mounding also need to be considered. Soil acidity and acid sulfate soil, common in low-lying areas, can be harmful to macadamias, fish and the aquatic habitat downstream. Low-lying areas of a property might be better suited to natural habitat buffer zones to improve farm biodiversity. On the plateau, have sound drainage that diverts the excessive water away from the tree roots and over grassed water courses designated for large volumes. Ensure drainage systems are maintained as the orchard evolves. Also, consider decommissioning blocks with slopes of greater than 31%. Refer to *Considerations for developing and managing macadamia on floodplain soil* (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/considerations-for-developing-and-managing-macadamia-on-floodplain-soils).

By implementing these strategies, growers can foster a favourable environment for plant growth, maximising soil and tree health and minimising the risks posed by environmental stressors such as flooding, east coast lows, cyclones and even droughts. For more information, consult the updated *Macadamia grower's guide* (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/macadamia-growers-guide2).

In general, healthy vigorous plants have a better chance of survival.

Summary

The key strategies for building an orchard with resilience against extreme weather, such as flooding and cyclones, include:

Prioritise early plant health

- Healthy, vigorous, young plants have a higher survival rate.
- Focus on developing a balanced canopy and root system from the start.
- Undertake canopy management and/or orchard management practices that balance production and maintaining living ground cover in the inter-row.
- Ensure drainage networks are in place and maintained to protect the orchard and the environment.

Understand and prepare for flood damage

- Understand your orchard's landscape position, whether it is on a floodplain, slope, or plateau.
- Be aware of the associated risks from heavy, persistent rainfall, such as washouts, inundation, and submergence.

Learn from research

- No rootstock–scion combination proved superior; plant health was the key factor for survival.
- Repeated flooding significantly increases mortality, especially in young trees.

Manage carbohydrate reserves

- Stored carbohydrates are vital for recovery after a flood.
- Avoid stressing plants further; do not prune when reserves are low.

Prune strategically

- Delay pruning after the flood to allow plant recovery.
- Only remove dead material.
- Avoid pruning during wet weather, when the soil is waterlogged or when sap flow is low.
- Prune trees, especially when young, to develop a strong structure and minimise breakage.
- In older trees, continue pruning to ensure poor crotch angles are minimised.
- Prune to ensure living ground cover in the inter-rows is maintained.
- Ensure pruning cuts are clean and are on an angle to ensure water sheds.

Improve soil health

- Conduct a soil analysis, as waterlogging is likely to have depleted essential nutrients from the soil.
- Use organic amendments to enhance aeration and drainage.
- Maintain high organic matter to support healthy roots.

Protect against disease

- Delay phosphonic acid or potassium phosphite application until new growth appears after a flood.

Race to get the canopy above the potential flood level

- Encourage canopy growth above flood levels.
- Balance the canopy and root system to reduce wind damage.
- Stake the trees in wind-prone areas.

Organic matter and high cation exchange capacity

- Reduce extremes of soil moisture.

Know your land's limitations

- Avoid planting in low-lying, flood-prone areas.
- Avoid planting in steep areas (>22% slope) to avoid washouts.
- Decommission blocks with a slope of >31%.

Refer to the *Managing subtropical horticulture in extreme wet weather* guide for more information (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/1587433/Managing-subtropical-horticulture-in-extreme-wet-weather.pdf).

Macadamia season summary 2024

Jeremy Bright[1], Shane Mulo[2], Grant Bignell[2] and Kevin Quinlan[1]

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By documenting conditions over time, we can build up an information bank detailing the events and potential causes of fluctuations in production, saleable kernel and quality.

The 2025 season summary will feature in next year's *Macadamia plant protection guide*.

2024 season review

The price

The price offered for nut-in-shell at 10% moisture content increased from approximately $1.80 in 2023 to around $3.40 in 2024. While significant penalties remained for high levels of reject kernel, the increase in price paid for saleable kernel (especially premium grade) outweighed these penalties. As a result, growers were motivated to invest more in inputs and management practices than the previous year.

Growing conditions

The 2024 macadamia season started well in all growing regions, with robust flowering and minimal nut drop during the nut sizing phase. In New South Wales (NSW), a condensed flowering window combined with favourable weather contributed to low lace bug pressure, although precise and timely spray applications were required. Premature nut drop was delayed until around the New Year.

In South East Queensland (SEQ), early dry conditions during flowering and nut sizing helped suppress early husk spot pressure. However, high humidity later in the season led to elevated germination rates and subsequent damage from kernel grub.

Central Queensland (CQ) had 3 distinct flowering periods, resulting in nuts at different development stages throughout the growing season. While early dry conditions limited macadamia nut borer (MNB) and *Trichogrammatoidea cryptophlebiae* wasp populations, a late-season surge in MNB (outpacing wasp population recovery) caused significant damage. Frequent rainfall and high humidity contributed to brown centres and increased insect pressure, with reject levels reaching 7–8% in some cases. The season was shorter than expected due to early nut maturity, and wet conditions during harvest hampered nut drying and led to reduced quality.

Persistent wet weather in the Northern Rivers and Mid North Coast restricted spray opportunities for fruit spotting bug and also led to a rise in rat populations and associated damage. Monolepta beetle outbreaks were widespread and persistent in NSW and SEQ, while bark beetle activity was seen on young flush. Late-season high humidity and overcast conditions contributed to mould, brown centres, and kernel grub infestation. Frequent rainfall, rather than total rainfall, was the primary challenge, complicating drying and reducing nut quality. These conditions also led to limited windows of opportunity to harvest. When harvesting was possible, substantial volumes were harvested (in short timeframes), placing significant pressure on processors' receival and storage capacity.

Production limiting factors

The macadamia industry benchmarking team has collected seasonal production and quality data since 2009 and cost data since 2013. This benchmark sample represented approximately 54% of the national production in 2024. Benchmarking participants indicated wet weather and pests were the main factors limiting productivity (Figure 13).

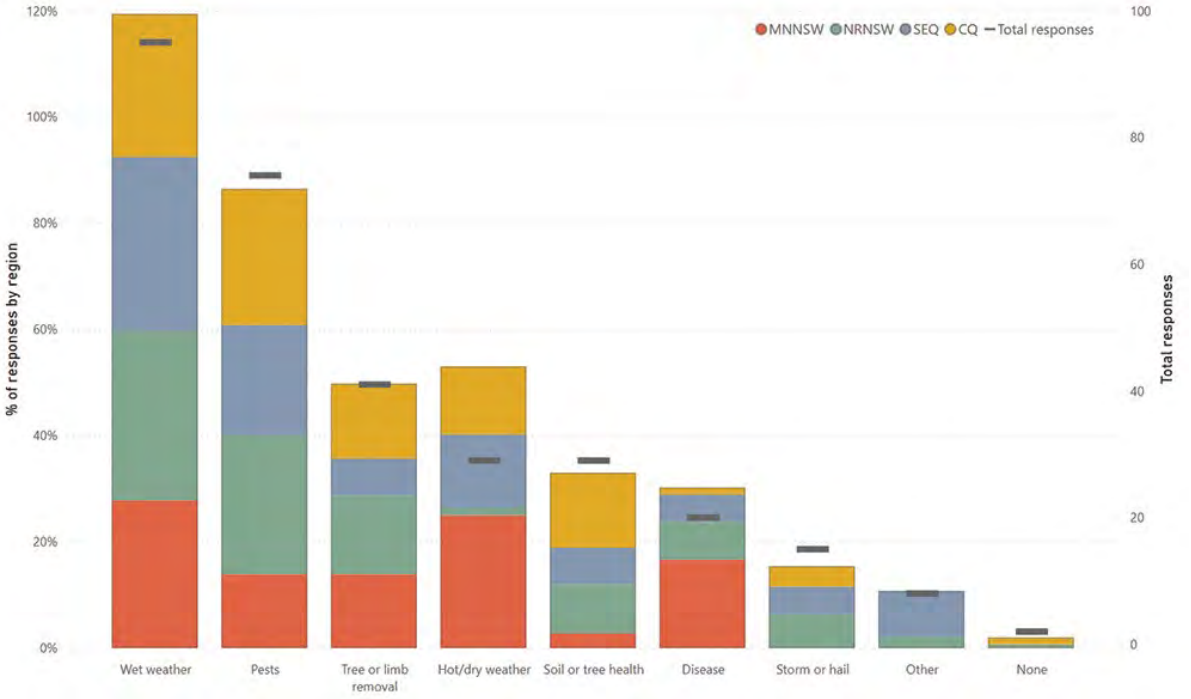


Figure 13. Seasonal limitations by region in 2024.

Pests limiting production

Pests included fruit spotting bugs and banana spotting bugs, with rats being a major issue in many regions (Figure 14). Consultants in all growing regions reported that late-season wet weather created ideal conditions for fruit spotting bug to thrive. Continuous rainfall disrupted pest management schedules, leading to delayed or poorly timed control measures.

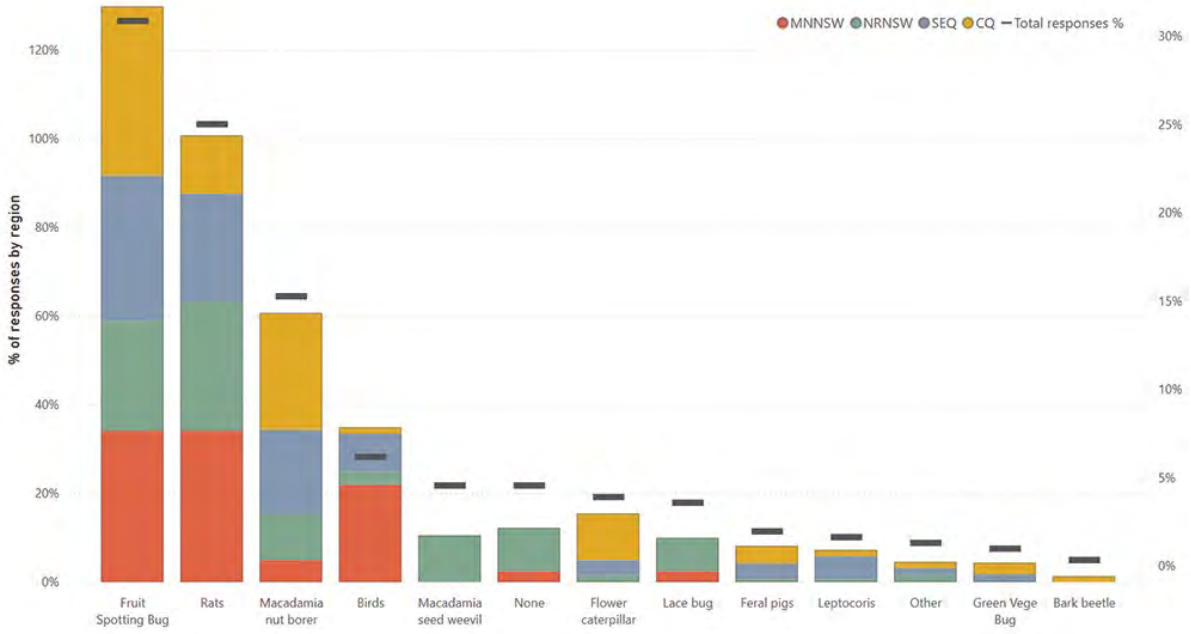


Figure 14. Limiting pests by region in 2024.

Diseases limiting production

Phytophthora and husk spot were commonly reported in all regions (Figure 15). Around harvest, hot, humid, and moist conditions further contributed to quality issues, with some nuts developing brown centres and mould.

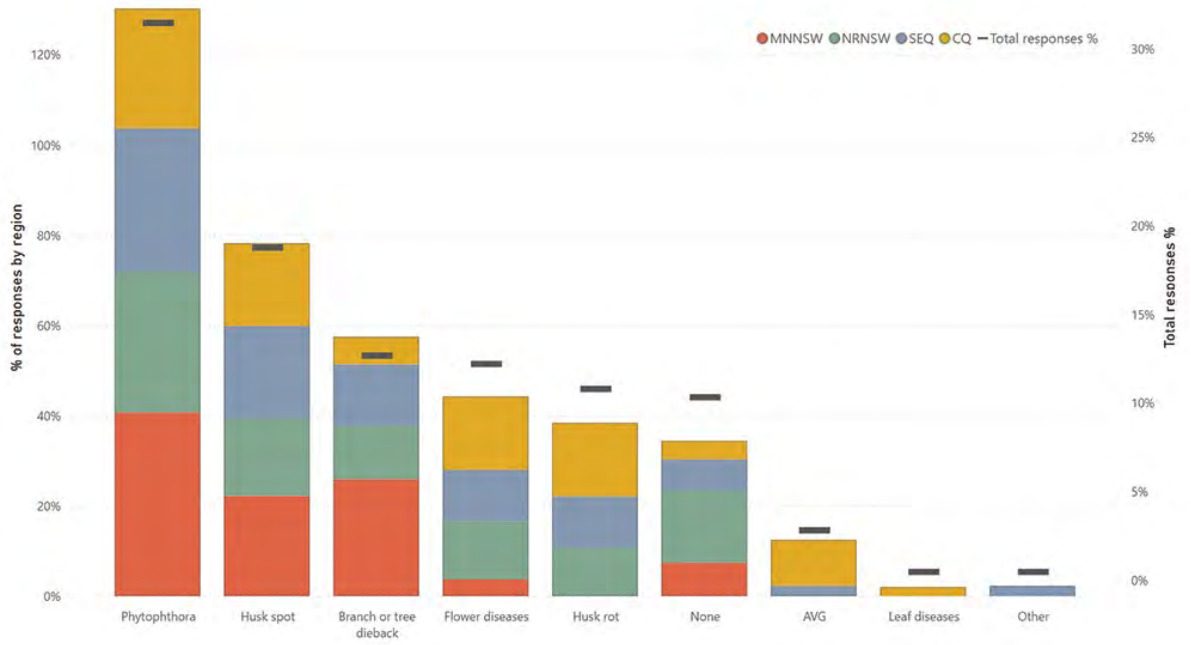


Figure 15. Limiting diseases by region in 2024.

Production

The 2024 crop produced 57,850 tonnes in-shell at 10% moisture, which was a notable improvement from 51,900 tonnes in 2023. This increase is attributed to several factors, with many consultants suggesting the improved nut-in-shell (NIS) price enabled growers to resume standard orchard management practices that were scaled back in the previous season due to economic constraints. With business operations returning to normal, the climate once again became the primary influence on yield variability.

Average NIS and saleable kernel (SK) yields for the benchmark sample and for each major production region are shown in Figure 16 and Figure 17. In 2024, average productivity was improved in several growing regions compared to 2023. Recovery was strong in Central Queensland, with yields for mature farms (10 years or older) increasing from 2.90 tonnes per hectare (NIS) in 2023 to 3.40 t/ha in 2024. The Northern Rivers region of NSW also had an excellent year, achieving its highest productivity since 2016 with 2.70 t/ha for mature farms. There was a slight improvement in the Mid North Coast of NSW, where yield increased from 2.10 t/ha in 2023 to 2.20 t/ha in 2024. Productivity declined in SEQ, dropping from 3.50 t/ha in 2023 to 2.30 t/ha in 2024. This reduction was most likely due to persistent wet weather during harvest, which created conditions conducive to high germination rates and increased kernel grub damage, ultimately affecting both yield and quality.

The 2024 season reminded the industry of the significant influence weather has on productivity. While favourable conditions early in the season helped establish the crop for strong potential yields, persistent wet weather later in the season disrupted standard orchard practices, particularly pest and disease control. In many cases, rainfall prevented timely interventions, allowing pest and disease pressures to escalate. Although the season began well in all regions, the continuous wet conditions that followed created substantial challenges. These difficulties are reflected in the variability of yields between regions, as shown in the seasonal nut-in-shell and saleable kernel productivity trends.

Figure 16. Productivity by season.

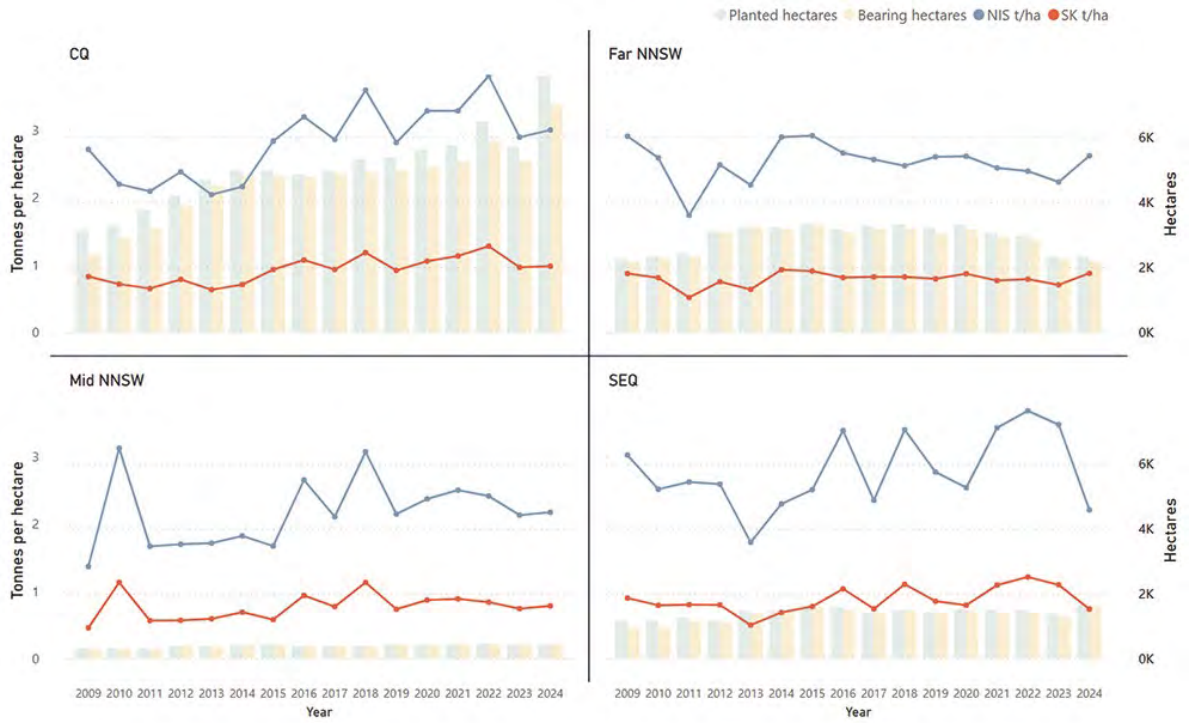


Figure 17. Seasonal productivity by region from 2009 to 2024.

Kernel recovery

The weighted average kernel recovery trends for each major production region are shown in Figure 18. The average saleable kernel recovery in the CQ region was reduced from 35.6% in 2023 to 34.9% in 2024. All other regions had increased saleable kernel recovery from the 2023 season.

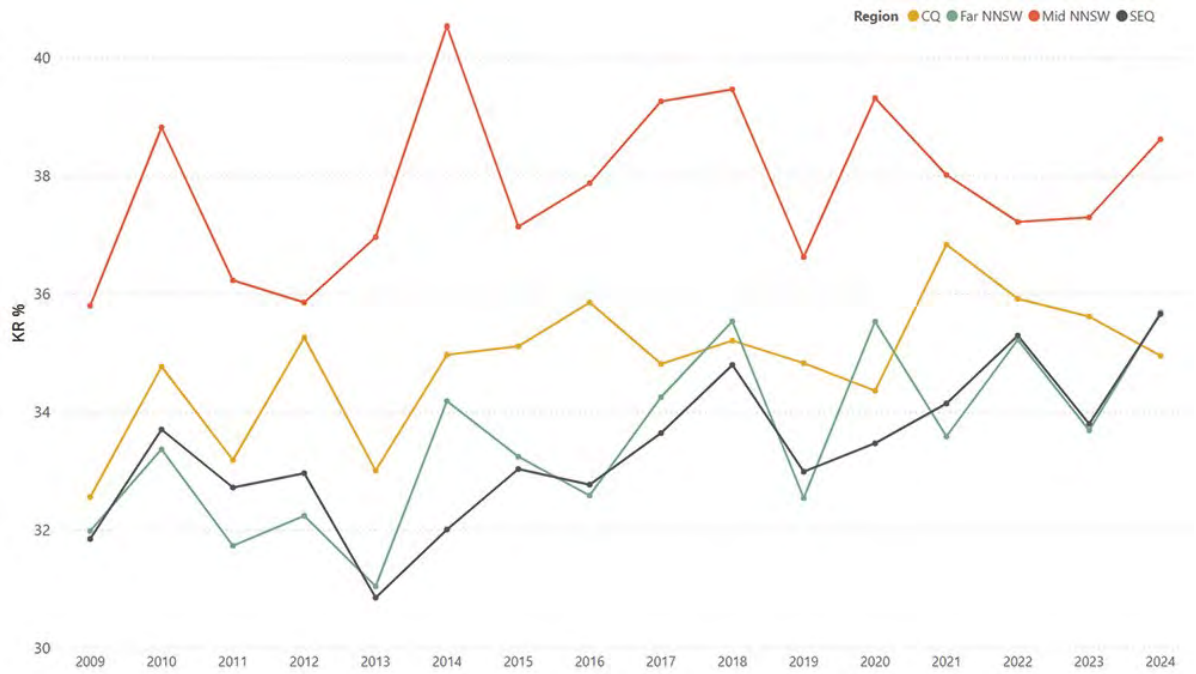


Figure 18. Saleable kernel recovery trends by region from 2009 to 2024.

Factory rejects

Insect damage was the leading cause of factory rejects, at 1.2% reject kernel recovery (RKR); the highest level recorded since benchmarking began in 2009. Brown centres followed closely, contributing 0.9% RKR. All reject categories were increased from the 2023 season, elevating the overall factory reject rate from the record low of 1.9% RKR in 2023 to 3.3% RKR in 2024 (Figure 19).

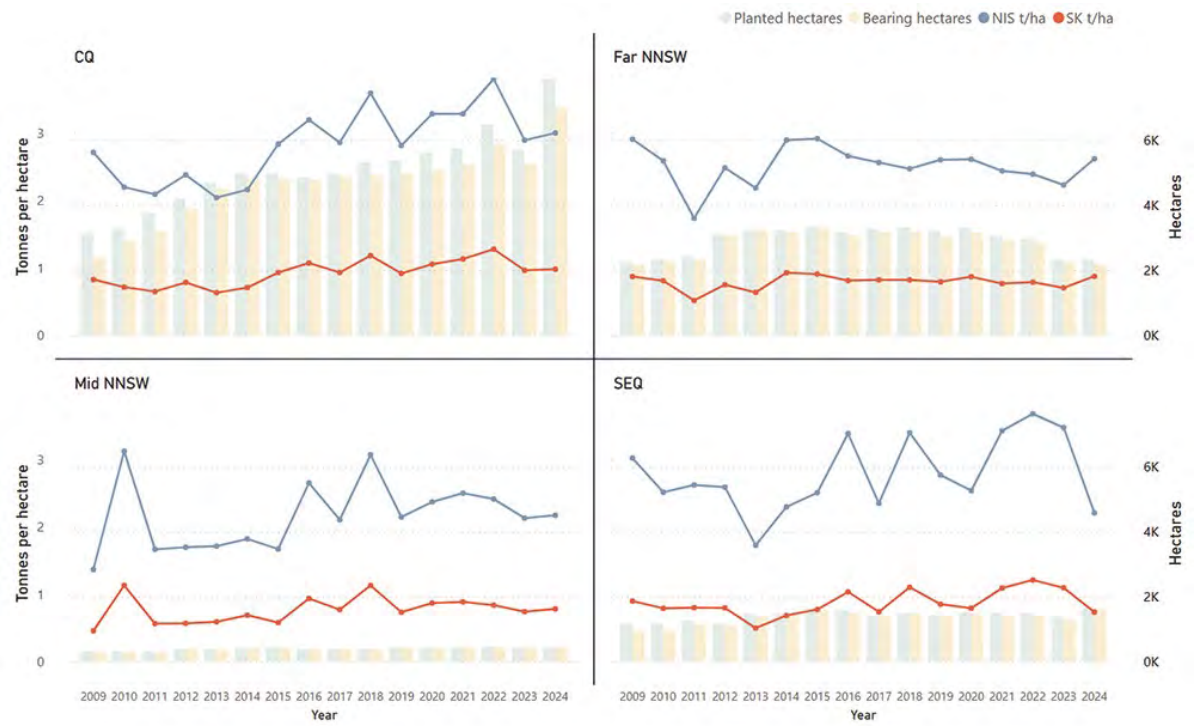


Figure 19. Factory kernel recovery reject trends from 2009 to 2024.

Factory reject categories by region are shown in Figure 20. Insect damage increased in all regions except Far Northern NSW, with CQ showing the most substantial rise, not only in insect damage but also in brown centres and mould. All reject categories in CQ were up compared to the 2023 season.

The Mid North Coast of NSW had a substantial increase in insect damage, being the second-highest level since benchmarking began in 2009. This spike was largely attributed to weather conditions that hindered timely pest control applications.

Far Northern NSW had a relatively average season for reject levels, with no major deviations from historical norms. Meanwhile, SEQ had increased insect damage, brown centres, and mould compared to the previous year, all of which could be attributed to late-season continuous wet weather.

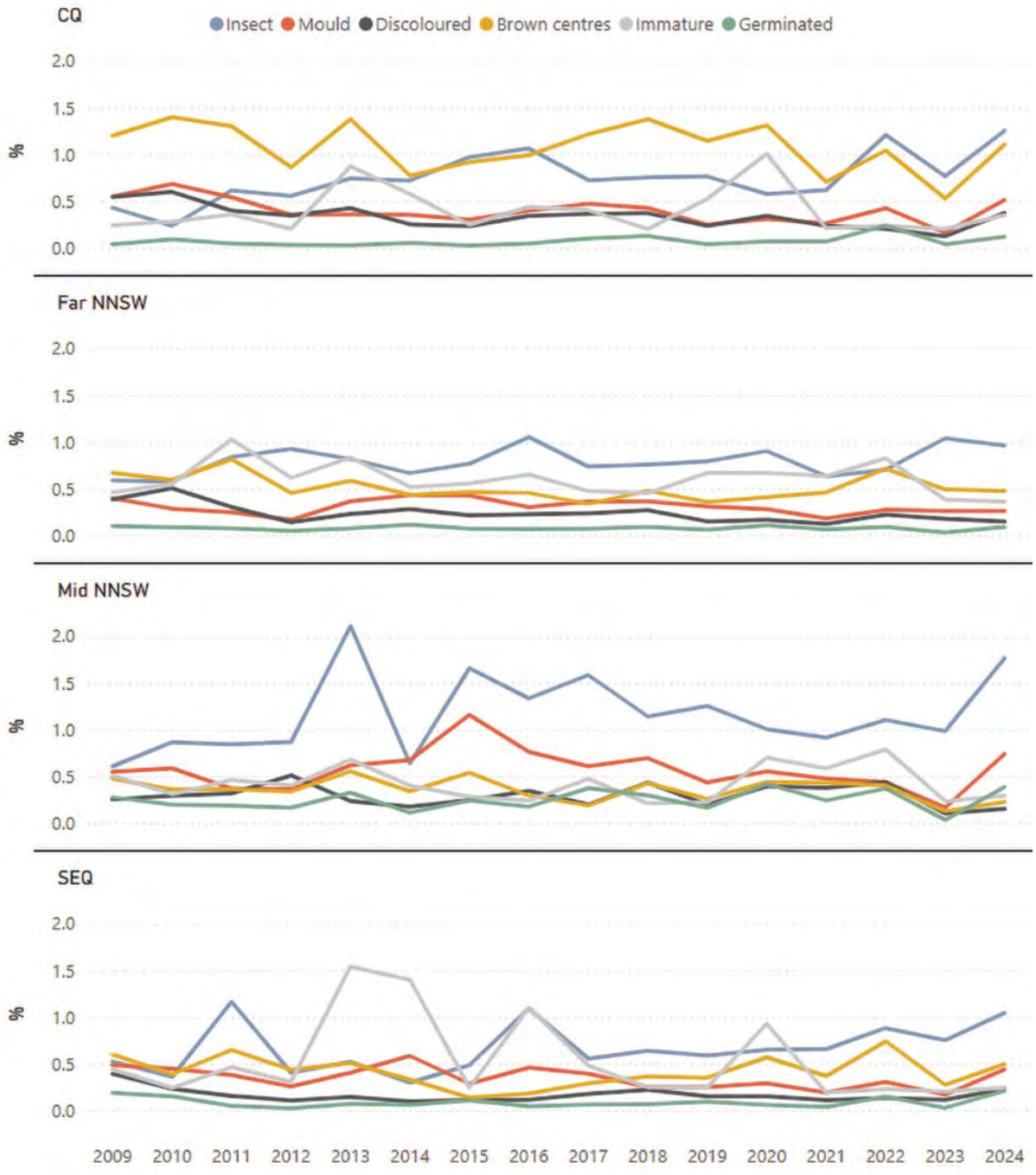


Figure 20. Reject kernel recovery trends for regions from 2009 to 2024.

Growing season pest and disease summary

Disease

Growers participating in the benchmarking project overwhelmingly identified phytophthora as the most limiting disease affecting productivity. This suggests the climate from flowering to nut set was generally favourable for crop development. Husk spot was also mentioned as a constraint, possibly due to the late-season rainfall. However, since husk spot typically infects nuts at the match head stage, the extended dry conditions earlier in the season could have limited its effect beyond that point. Nut immaturity in the reject kernel recovery in the regions might have been triggered by macadamia nut borer and kernel grub rather than by husk spot.

In CQ, the 3 distinct flowering periods presented additional challenges for pest and disease management. The staggered flowering possibly complicated the timing of control measures. Additionally, some flower diseases might have emerged where climatic conditions were conducive to their development.

Fruit spotting bug

The seasonal conditions during the 2024 growing season (August 2023–March 2024), with persistent rainfall late in the season, favoured FSB population development. The weather in all regions made timely application of control sprays difficult for this pest. This is most likely why the late insect reject kernel recovery is at an all-time high since benchmarking began in 2009. Bundaberg had the highest ever late insect damage for 2024.

Macadamia nut borer

Populations of macadamia nut borer (MNB) and its biological control, *Trichogramma cryptophlebiae*, were low early in the 2024 season. However, MNB numbers increased substantially later in the season, potentially contributing to the high incidence of immature nuts observed in several regions. The industry has a well-established and coordinated approach to managing MNB through the area-wide distribution of MacTrix cards, which release the predatory wasp. To effectively prevent MNB-related issues, such as immaturity, timely and coordinated MacTrix wasp releases are strongly recommended. For detailed guidance on implementing this control strategy, refer to Macadamia nut borer on page 89.

Final remarks

Northern Rivers and Mid North Coast (NSW)

Growing conditions: fairly typical year overall. High rainfall in May led to warmer minimums and lower radiation. Soil water remained high for most of the year, although summer rainfall was below average.

Challenges: wet weather from March to May restricted efficient harvest opportunities.

Main pests: fruit spotting bug, rats, monolepta beetle, and bark beetle.

Major diseases: phytophthora (most limiting), husk spot (notable but less limiting due to early dry conditions).

Productivity: Northern Rivers had its best year since 2016, with mature farms averaging 2.70 t/ha. Mid North Coast had a slight improvement to 2.20 t/ha.

Factory rejects: insect damage was the leading cause, reaching 1.2% RKR, the highest since 2009 in the Northern Rivers. Brown centres contributed 0.9% RKR. The overall reject rate rose to 3.3% RKR from 1.9% in 2023.

South East Queensland (SEQ)

Growing conditions: a dry early season helped suppress husk spot; however, conditions later in the year might have caused husk spot infestation. High humidity later led to kernel grub damage and elevated germination rates.

Challenges: husk spot was difficult to control. Late-season wet weather increased insect damage, brown centres, and mould.

Productivity: greatly reduced from 3.50 t/ha in 2023 to 2.30 t/ha in 2024.

Central Queensland (CQ)

Growing conditions: 3 distinct flowering periods extended the season.

Challenges: a late-season surge in macadamia nut borer (MNB) outpaced wasp recovery. High humidity caused brown centres and increased insect pressure. Reject levels reached 7–8% in some cases. Wet conditions hampered drying and quality.

Productivity: recovery was strong, with mature farms increasing from 2.90 t/ha in 2023 to 3.40 t/ha in 2024.

Kernel recovery: decreased from 2023 levels.

Acknowledgements

The Macadamia benchmarking and sustainability insights project (MC22000) has been funded by Hort Innovation, using the macadamia research and development levy and contributions from the Australian Government. The Queensland Government has also co-funded the project through the Department of Agriculture and Fisheries. For more information on the fund and strategic levy investment, visit horticulture.com.au

Hort Innovation | The University Of Queensland Australia | NSW Department of Primary Industries and Regional Development | University of Southern Queensland | Queensland Government

Hort Innovation 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

Macadamia climate summary for the 2024–2025 season

Kim Broadfoot and Kel Langfield, Seasonal Conditions Coordinators, NSW DPIRD

Climate analysis for the 2025 season provides a comprehensive regional overview of conditions in the phenological stages of macadamias in NSW and Qld. Climate data for the analysis are derived from 2 sources:

1. **ANUClimate 2.0**. This dataset is a 1 km² grid of daily and monthly climatic elements in Australia from 1970 to the current year. It is an invaluable resource for understanding long-term climate patterns and their influence on agriculture. The data for NSW can be accessed through the ANU Climate 2.0 portal (https://geonetwork.nci.org.au/geonetwork/srv/eng/catalog.search#/metadata/f2576_7854_4065_1457).
2. **SILO**. As a repository of historical climate records dating back to 1889, the SILO Patched Point Dataset (PPD) provides quality assured daily meteorological data for approximately 8,000 climate stations. This encompasses the broader range of climate variables needed and formatted for immediate application in biophysical models, academic research, and various climate-related analyses. These climate datasets are available via the SILO database (https://www.longpaddock.qld.gov.au/silo/).

These datasets are instrumental in informing the agricultural sector, particularly in the strategic planning and management of macadamia production, by offering insights into prevailing climate conditions and trends.

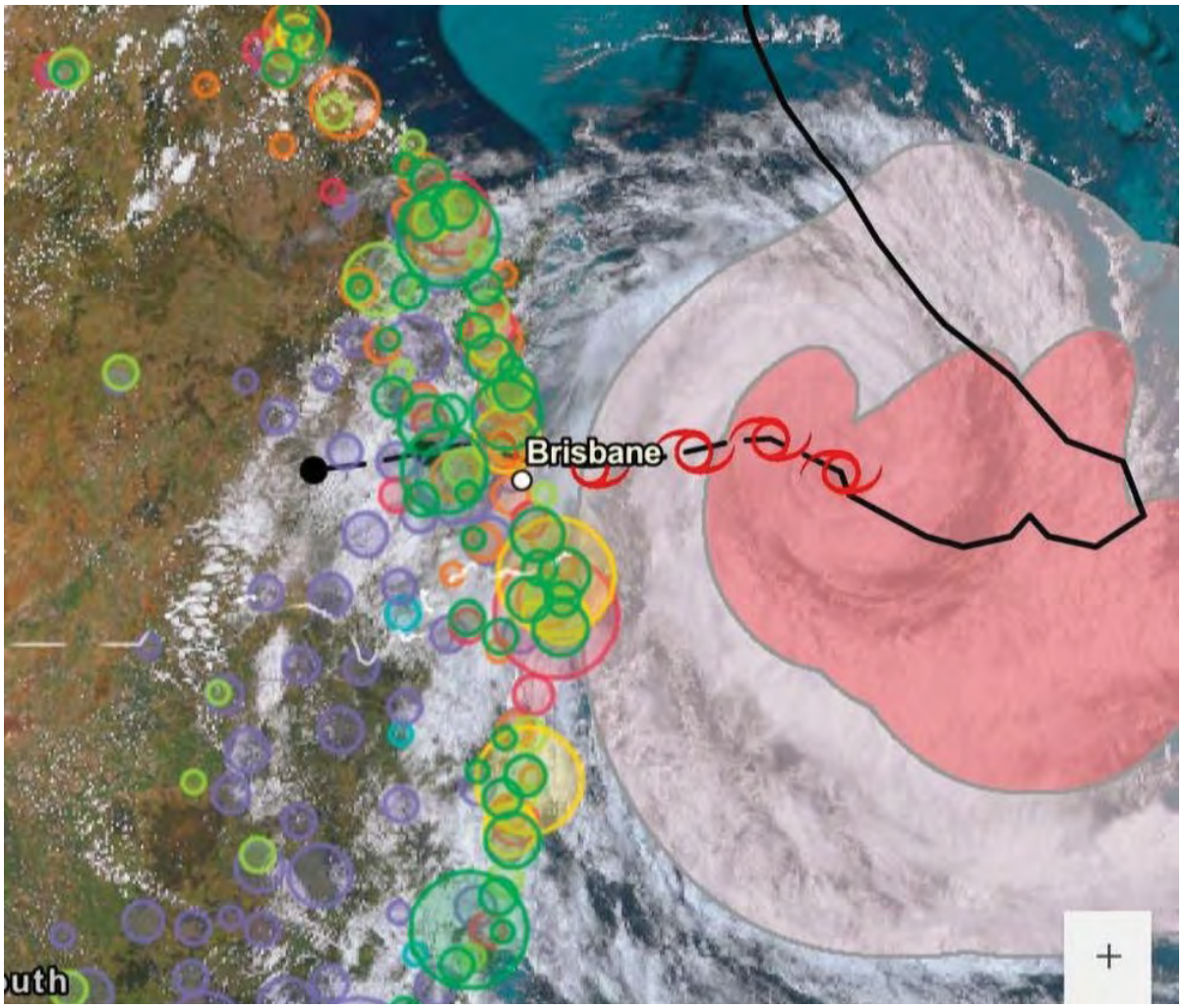


Figure 21. Tropical Cyclone Alfred approaching the east coast of Australia in March 2025.

New South Wales

Ballina Region

Temperatures were highly variable during the 2024–2025 season (Table 1). Minimum temperatures were near or slightly above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 22). The maximum temperatures were average to above average.

Above average rain fell in August and September 2024, as well as in March (Figure 21) and April 2025. Rainfall was above the long-term average in all phenological stages.

Table 1. Temperature and rainfall for the Ballina region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	13.0 ± 2.6	11.6	23.3 ± 3.7	22.1	460.6	130.8
Nut set and development (September– December)	16.8 ± 3.4	16.1	25.7 ± 3.1	25.2	624.8	445.8
Oil accumulation (January–April)	19.1 ± 1.9	18.8	27.2 ± 2.3	26.8	907.7	753.8
Harvest (April)	16.9 ± 1.4	16.4	24.9 ± 1.5	24.8	244.9	198.0

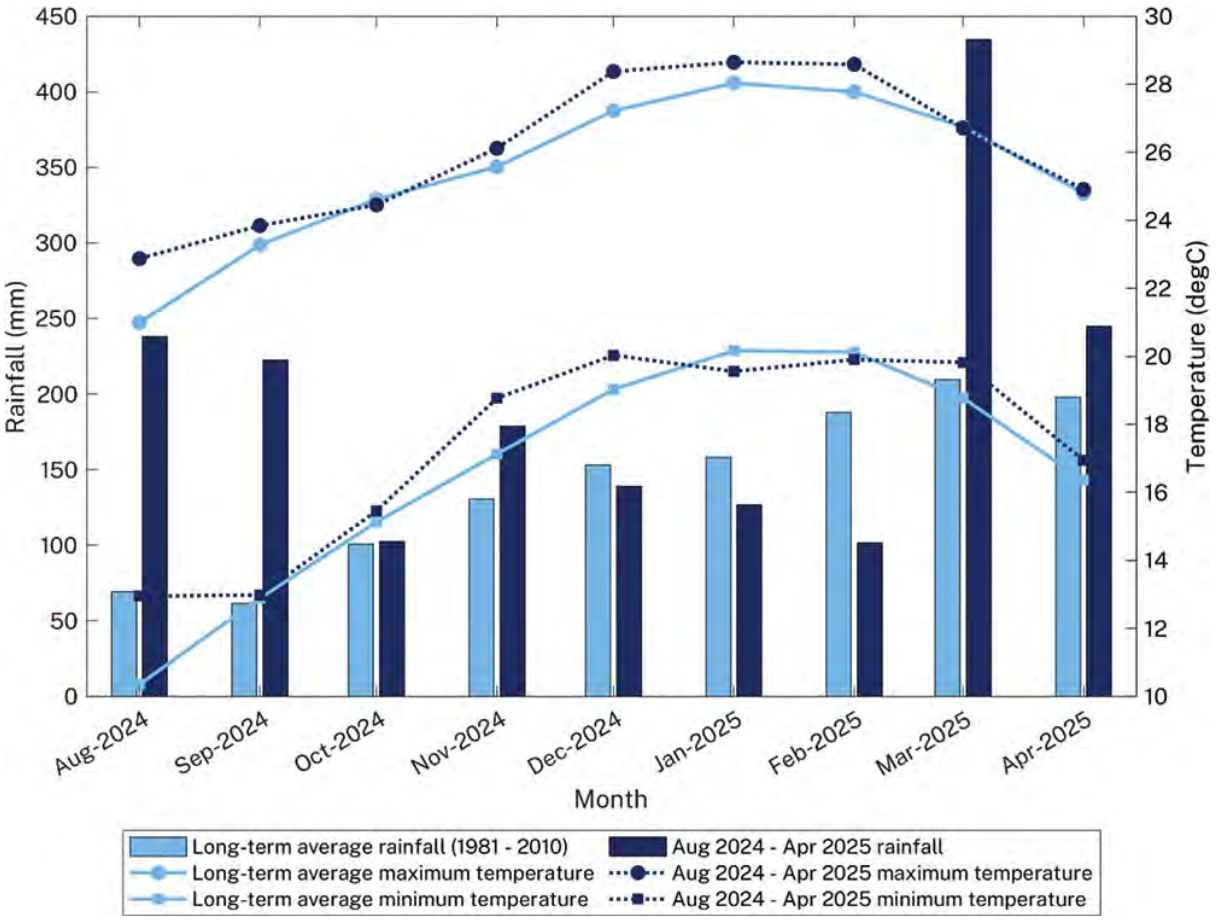


Figure 22. Climograph of the average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Ballina. Source: ANUClimate, Australian National University.

Dunoon Region

Temperatures were highly variable for the 2024–2025 season (Table 2). Minimum and maximum temperatures were near or slightly above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 23).

Rainfall was variable, with above average falls in August and September 2024, and in March and April 2025. Rainfall was above the long-term average in all phenological stages.

Table 2. Temperature and rainfall for the Dunoon region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	11.0 ± 2.8	9.6	23.9 ± 3.9	22.5	432.7	103.5
Nut set and development (September– December)	15.3 ± 3.7	14.5	26.6 ± 3.3	26.1	751.2	425.9
Oil accumulation (January–April)	17.5 ± 2.0	17.4	27.1 ± 2.6	27.0	1117.3	728.0
Harvest (April)	15.3 ± 1.6	14.7	24.7 ± 1.7	24.6	221.2	173.8

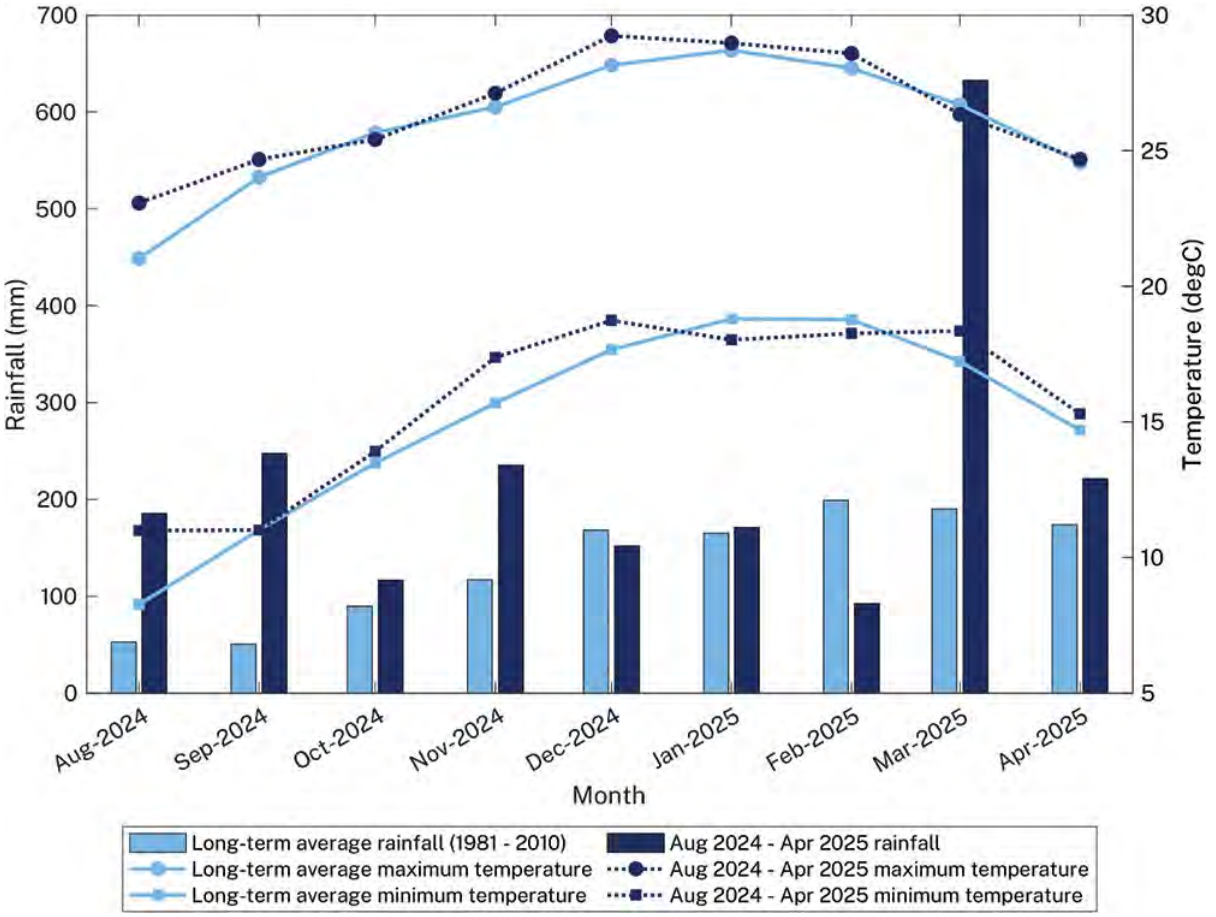


Figure 23. Climograph of the average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Dunoon. Source: ANUClimate, Australian National University.

Maclean Region

Temperatures were highly variable for the 2024–2025 season (Table 3). Minimum and maximum temperatures were near to above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 24).

Rainfall was variable, with above average falls in August and September 2024, and March and April 2025. Rainfall was above the long-term average in all phenological stages.

Table 3. Temperature and rainfall for the Maclean region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	10.9 ± 2.9	9.5	24.1 ± 4.1	22.9	304.7	89.1
Nut set and development (September– December)	15.4 ± 3.8	14.7	26.9 ± 3.6	26.3	442.7	338.1
Oil accumulation (January–April)	18.0 ± 2.2	17.8	27.7 ± 2.6	27.4	760.9	591.2
Harvest (April)	15.4 ± 1.6	14.9	25.3 ± 1.8	25.2	231.2	136.2

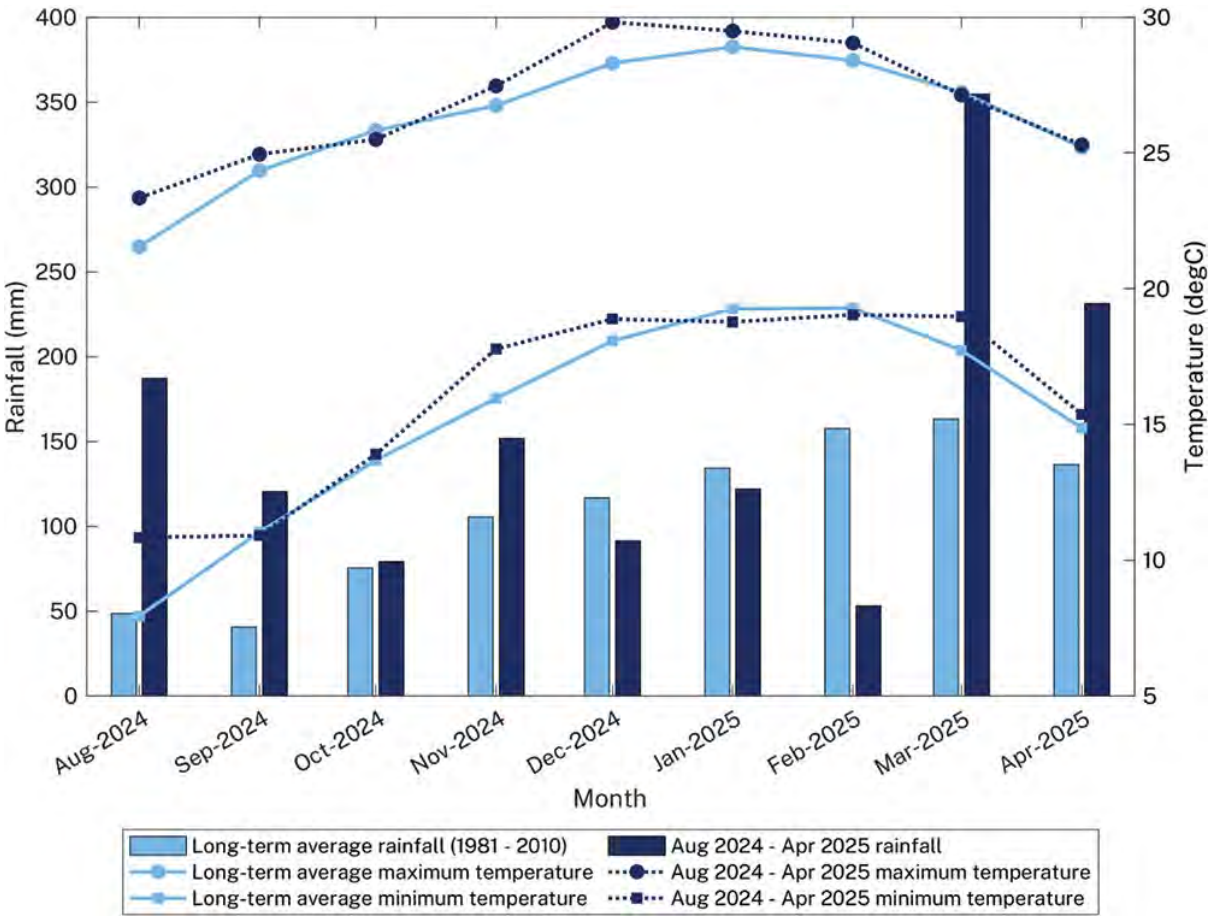


Figure 24. Climograph of average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Maclean. Source: ANUClimate, Australian National University.

Yarrahappini Region

Temperatures were highly variable for the 2024–2025 season (Table 4). Minimum and maximum temperatures were near or above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 25).

Rainfall was variable, with above average falls in August and September 2024, and March and April 2025. Rainfall was near to above the long-term average in all phenological stages.

Table 4. Temperature and rainfall for the Yarrahappini region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	10.3 ± 3.0	9.2	23.1 ± 3.8	22.3	197.9	101.0
Nut set and development (September– December)	14.8 ± 4.2	14.1	25.7 ± 3.6	25.5	379.3	384.7
Oil accumulation (January–April)	17.6 ± 2.3	17.3	26.8 ± 2.4	27.2	824.0	634.3
Harvest (April)	14.9 ± 1.8	14.5	24.6 ± 2.0	25.0	208.5	153.8

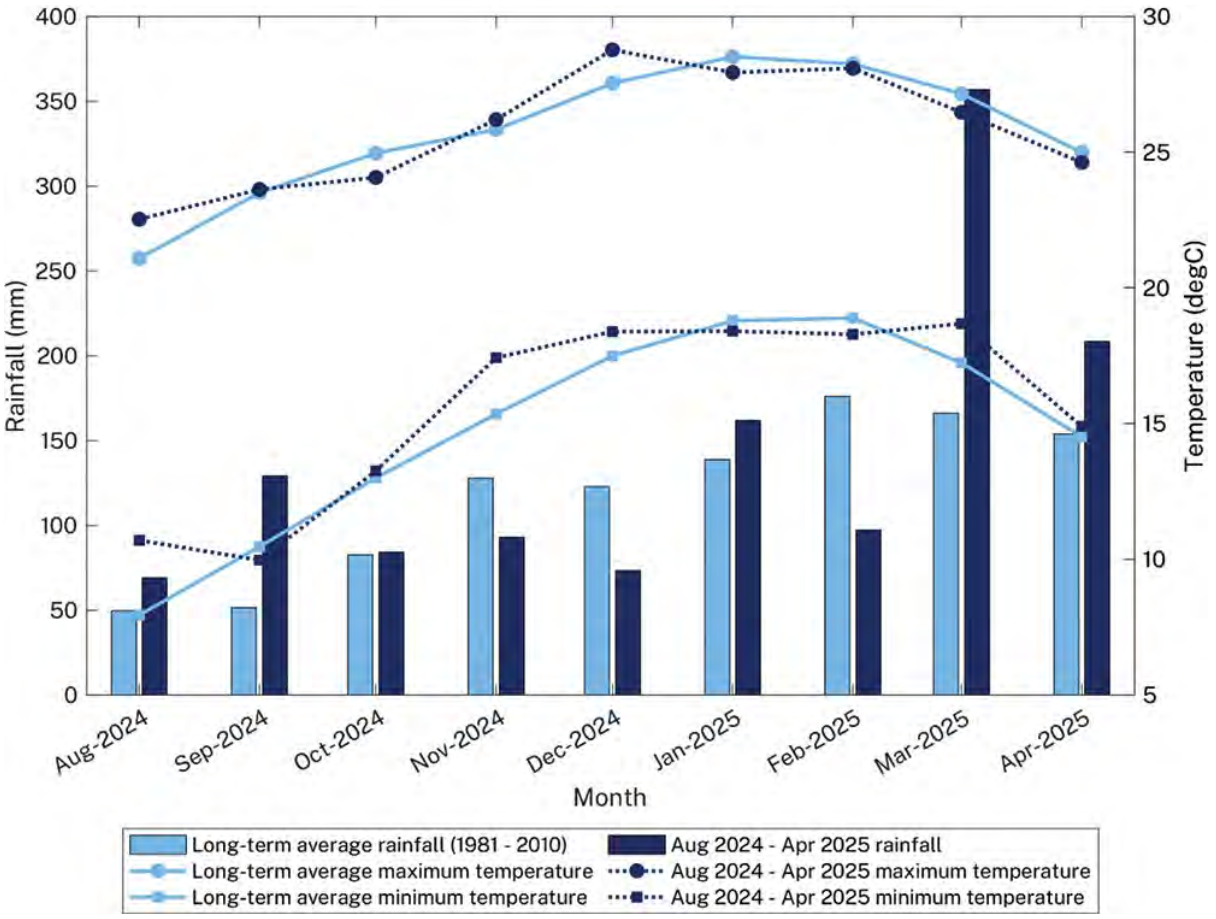


Figure 25. Climograph of average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Yarrahapinni. Source: ANUClimate, Australian National University.

Queensland

Bundaberg Region

Temperatures were highly variable for the 2024–2025 season (Table 5). Minimum and maximum temperatures were near or above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 26).

Above average rain fell in August and December 2024, and in March and April 2025. Rainfall totals were near to above the long-term average for all the phenological stages.

Table 5. Temperature and rainfall for the Bundaberg region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	14.6 ± 2.8	13.2	25.9 ± 2.0	24.6	87.4	77.1
Nut set and development (September– December)	19.1 ± 3.2	18.2	29.0 ± 2.0	27.8	323.3	330.3
Oil accumulation (January–April)	21.2 ± 2.2	20.7	30.3 ± 1.9	29.6	555.0	444.3
Harvest (April)	18.7 ± 1.9	18.3	28.5 ± 1.0	27.7	123.3	70.2

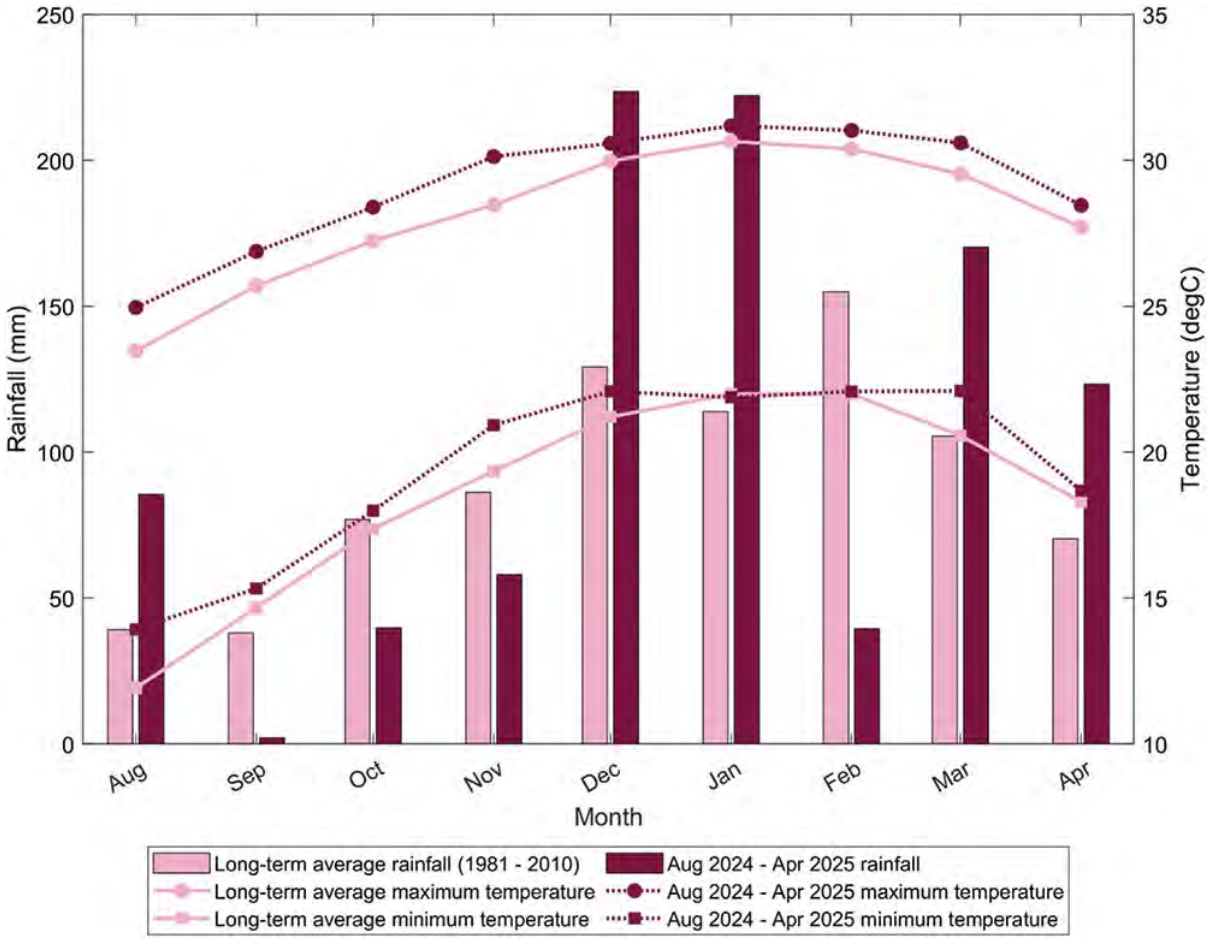


Figure 26. Climograph of average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Bundaberg. Source: SILO (Scientific Information for Land Owners) Patched Point Data, Queensland Government.

Glasshouse Region

Temperatures were highly variable for the 2024–2025 season (Table 6). Minimum and maximum temperatures were near or above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 27).

Above average rain fell in August, November and December 2024 and in March 2025. Rainfall totals were above the long-term average for all the phenological stages.

Table 6. Temperature and rainfall for the Glasshouse region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	13.2 ± 3.5	11.0	25.5 ± 3.5	23.4	153.1	97.5
Nut set and development (September– December)	17.7 ± 3.6	16.0	27.9 ± 3.6	26.9	642.4	420.2
Oil accumulation (January–April)	19.9 ± 2.1	19.0	28.5 ± 2.3	28.0	926.6	722.4
Harvest (April)	17.6 ± 2.0	16.2	26.5 ± 1.5	25.8	210.6	148.4

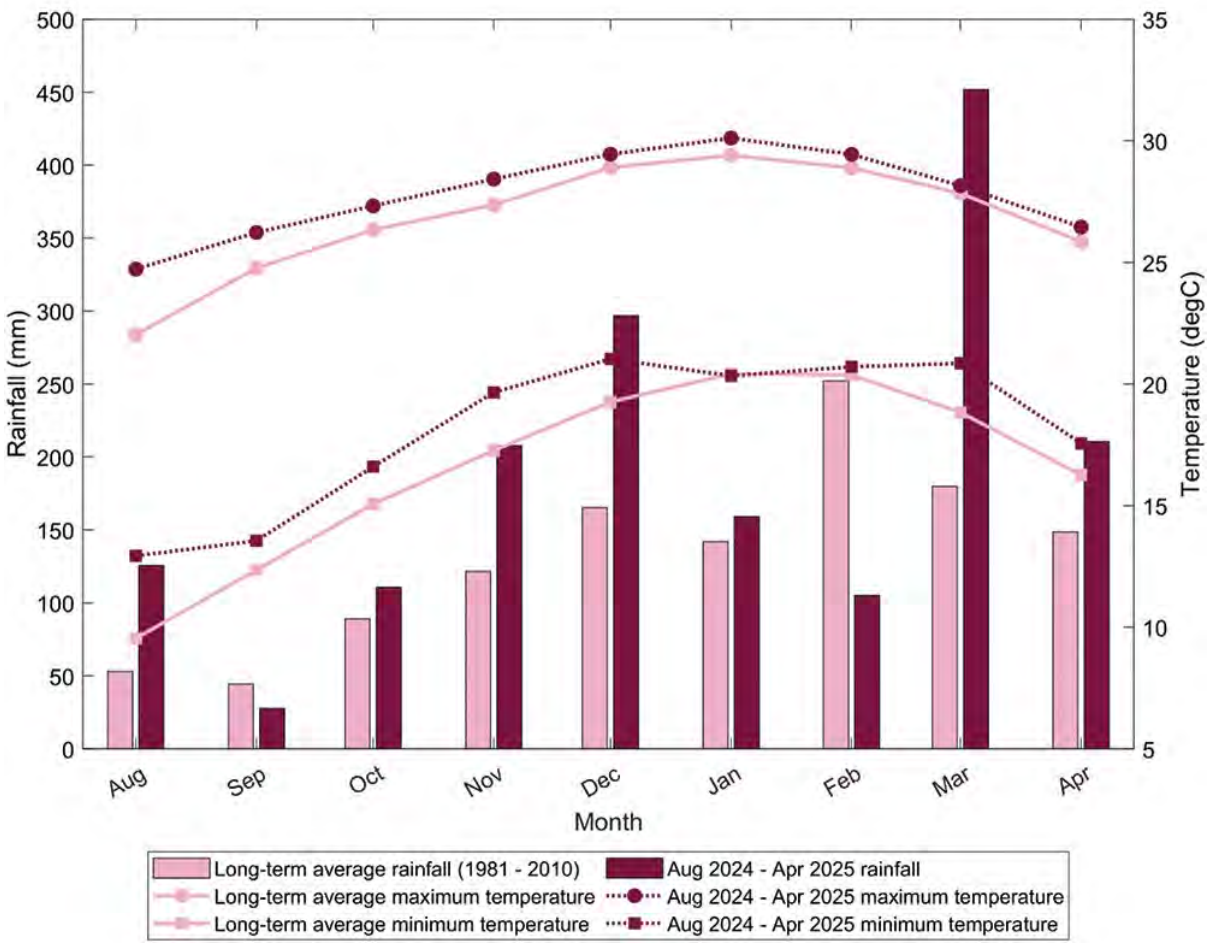


Figure 27. Climograph of average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Glasshouse. Source: SILO (Scientific Information for Land Owners) Patched Point Data, Queensland Government.

Gympie Region

Temperatures were highly variable for the 2024–2025 season (Table 7). Minimum temperatures were near or slightly above the long-term monthly average (1981–2010) between August 2024 and April 2025 (Figure 28). The maximum temperatures were above average across the season.

Above average rain fell in November and December 2024, and in March and April 2025. Rainfall totals were above the long-term average for all the phenological stages.

Table 7. Temperature and rainfall for the Gympie region from August 2024 to April 2025.

Phenological stage	Temperature (°C)				Rainfall (mm)	
	Average monthly minimum	Long-term average minimum	Average monthly maximum	Long-term average maximum	Average rainfall received	Long-term average
Flowering (August– September)	12.0 ± 3.5	9.7	26.1 ± 3.1	24.6	98.0	83.4
Nut set and development (September– December)	17.1 ± 3.9	15.4	28.9 ± 3.9	28.5	585.0	359.6
Oil accumulation (January–April)	19.4 ± 2.5	18.5	29.3 ± 2.5	29.2	740.0	487.1
Harvest (April)	16.7 ± 2.7	15.6	27.1 ± 1.4	26.8	145.2	87.2

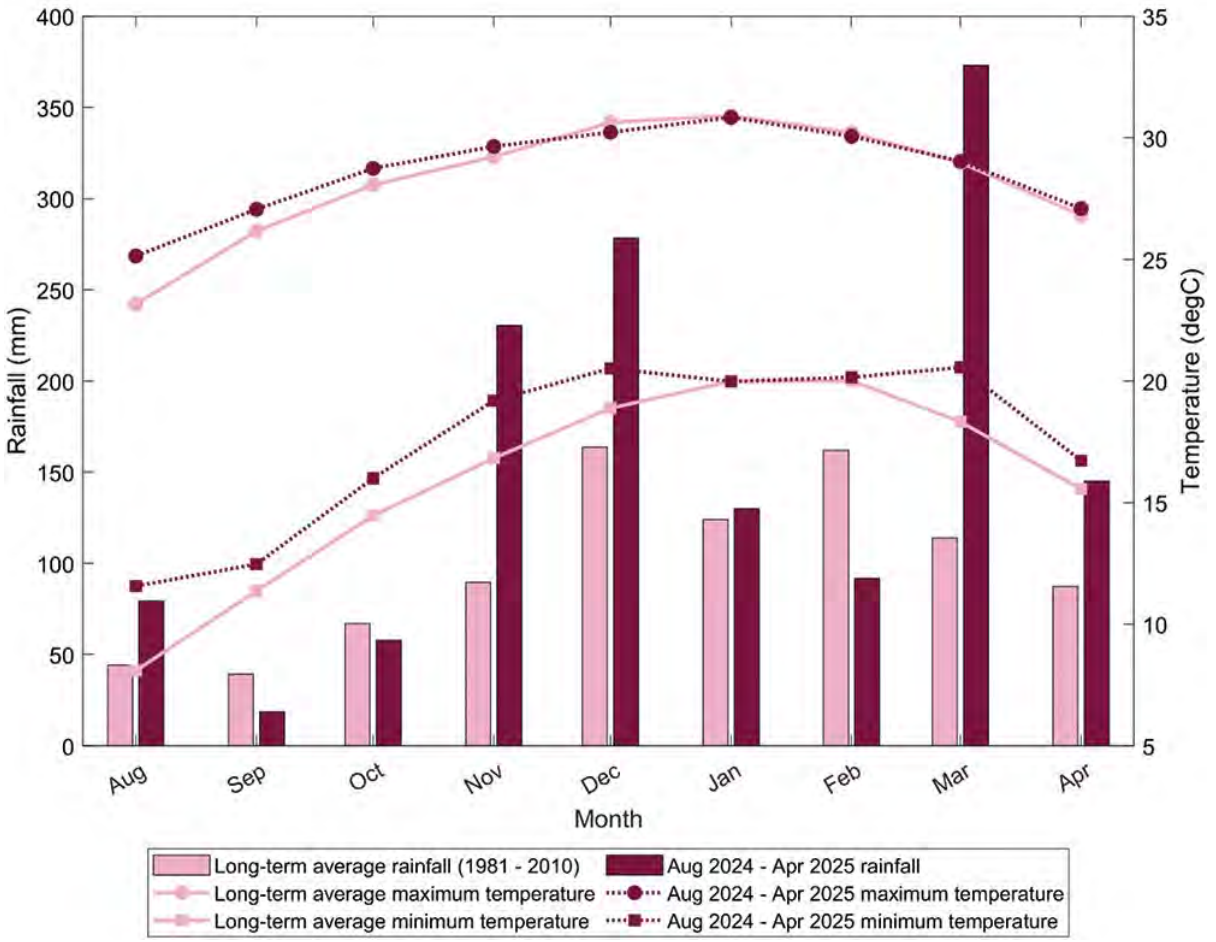


Figure 28. Climograph of average monthly minimum and maximum temperatures, total monthly rainfall from August 2024 to April 2025, and long-term averages (1981–2010 baseline period) at Gympie. Source: SILO (Scientific Information for Land Owners) Patched Point Data, Queensland Government.

Growing macadamias in NSW: preparing for a changing climate

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

Methodology and data

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

The Vulnerability Assessment Project is intended to highlight potential industry-or regional-level changes. Intermediate and high emissions scenarios were used in the assessments (RCP4.5 and RCP8.5), but these are not the only scenarios possible. The inclusion of climate variables important to the commodities was based on published research, expert knowledge and data quality and availability.

Macadamias in NSW

Macadamias are a significant Australian horticultural export and the first Australian native plant to have been developed as an international food crop. During the 2021–22 season, the NSW macadamia harvest produced over 22,000 tonnes of nuts valued at $135 million (Source: NSW DPIRD). In NSW, macadamias are predominantly grown in the Northern Rivers and Mid-North Coast regions (Figure 29). Macadamias in NSW are not irrigated, except in Dareton in southwest NSW.

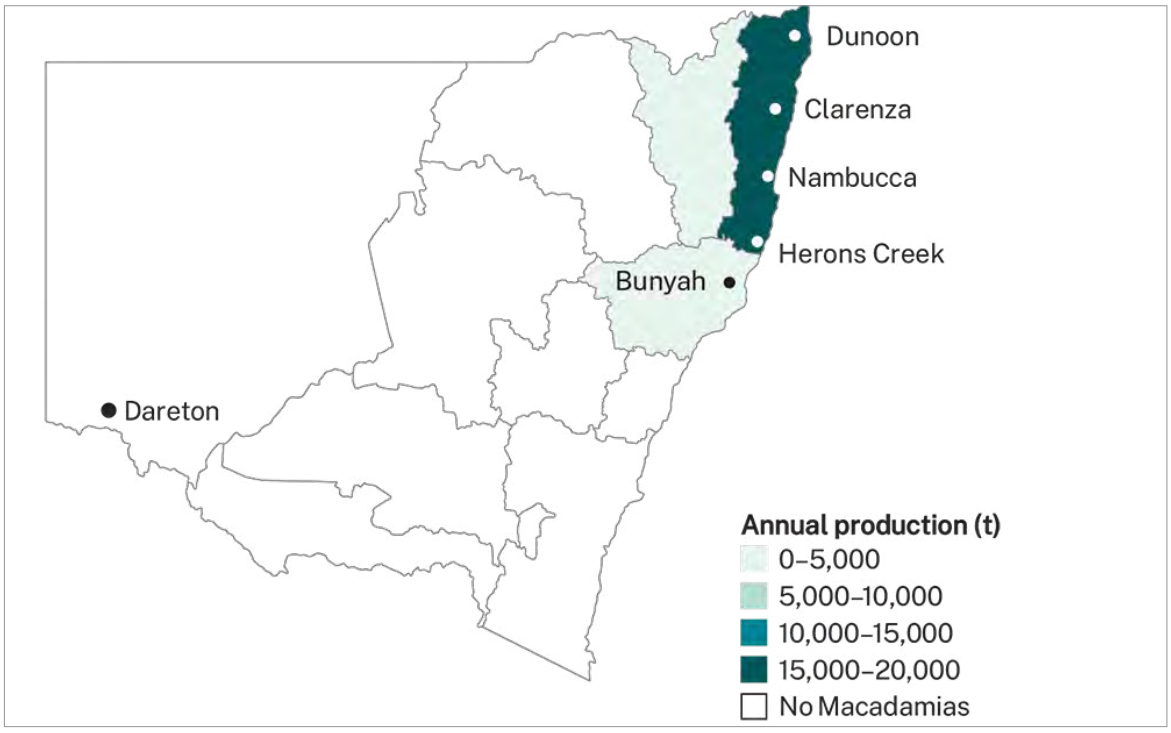


Figure 29. Macadamia growing regions in NSW. Darker colours represent higher nut production.

Climate and macadamia growing regions

Macadamia growing regions in NSW are expected to continue having high to very high climate suitability by 2050 under a changing climate.

Extreme heat: increased temperatures and a high frequency of hot days might affect nut set and sizing (Table 8), flowering and quality.

Rainfall: seasonal rainfall for current growing sites is likely to remain similar to what it has been (moderate confidence).

Frost: fewer days below 0 °C will possibly decrease frost damage at flowering.

Nut quality: climate suitability is expected to remain very high for all growing regions under a warmer climate.

Table 8. The projected effects of climate change on macadamia growth stages.

Growth stage	Change in climate suitability
Flower bud initiation	Remain very high all North Coast growing regions (high confidence). Dareton is projected to maintain high climate suitability (high confidence).
Flowering	Remain very high (high confidence) and might be protected from frost damage under a warmer climate.
Nut set and size	Could decrease due to an increase in days with temperatures above 35 °C and 40 °C (moderate to high confidence). Could increase due to fewer days with temperatures below 10 °C, with the potential to expand growing regions further south (moderate to high confidence).
Oil accumulation	Remain very high in the North Coast growing regions (moderate to high confidence). Decrease in Dareton due to increased high heat days (moderate to high confidence).
Harvest (maturity)	Remain high to very high at all sites (moderate confidence). Decrease in Dareton due to more extreme heat (moderate confidence).

Potential adaptation strategies

- Increased high heat days are expected to affect nut set and size and increase water demand. Implementing supplementary irrigation systems and increasing soil organic matter by regularly applying compost and mulch might help to alleviate the effects during drier periods.
- A transition to growing macadamias as an irrigated crop in NSW could be considered.
- A changing climate might bring opportunities for expanding the NSW macadamia growing region in the south of the state.

For more information, please email vulnerability.assessment@dpird.nsw.gov.au

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

A peek behind macadamia disease forecasting tools: MacDisease

Theophilus Mensah, Dr Vivian Rincon-Florez, and Professor Femi Akinsanmi, Queensland Alliance for Agriculture and Food Innovation, the University of Queensland

Fungal diseases in macadamia

Fungal diseases are a major threat to macadamia production, affecting all parts of the tree at different growth stages. These diseases can cause significant economic losses, with yields dropping by as much as 40% in severe cases.

Flower infections are a particular concern, leading to flower blight, which includes several types of diseases. Dry flower disease is caused by different species of *Neopestalotiopsis* and *Pestalotiopsis*. Grey mould is caused by *Botrytis cinerea* and *B. macadamiae*, while *Cladosporium* species cause green mould.

Macadamia fruit can also get fungal infections. This can lead to husk spots from *Pseudocercospora macadamiae*, as well as husk rot, which includes several types: phomopsis husk rot (*Diaporthe* species), anthracnose husk rot (*Colletotrichum species*), and calonectria husk rot (*Calonectria* species). Fungal pathogens can damage macadamia wood, affecting various genera in the Botryosphaeriaceae family and causing symptoms of BOT disease (Botryosphaeria branch dieback). *Nectria pseudotrichia* is linked to gall canker.

Disease forecasting tool

Disease forecasting tools such as RIMpro (https://rimpro.eu/) and NEWA (https://newa.cornell.edu/) are increasingly used in cropping systems such as almonds, apples, and pears. These tools provide early warnings about disease outbreaks and have been shown to reduce fungicide spray applications by 30% to 100%, cutting production costs and improving yields compared to traditional calendar spraying. For instance, apple growers in the USA using RIMpro saved nearly US$1 million managing a 5,000-hectare orchard.

With climate change influencing infection dynamics, the importance of these forecasting tools is growing. They are becoming more sophisticated in predicting early-season risks and optimising fungicide timing. This article discusses their development and application in the Australian macadamia industry.

The MacDisease dashboard has been developed to predict disease risks in macadamias, including grey mould, green mould, dry flower disease, husk rot, and Botryosphaeria branch dieback. It uses data from weather stations and pathogen life cycles to provide real-time forecasts for 2 to 4 weeks, helping to inform management decisions and reduce uncertainty about disease risks.

Components of disease forecasting tools

Disease forecasting tools are grounded in the 3 components of the disease triangle (Figure 30). Data from these components are used to develop predictive models, forming the foundation for simulating disease development.

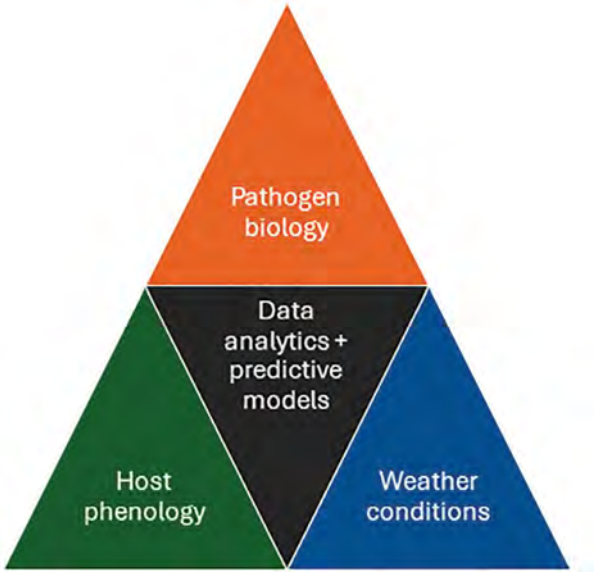
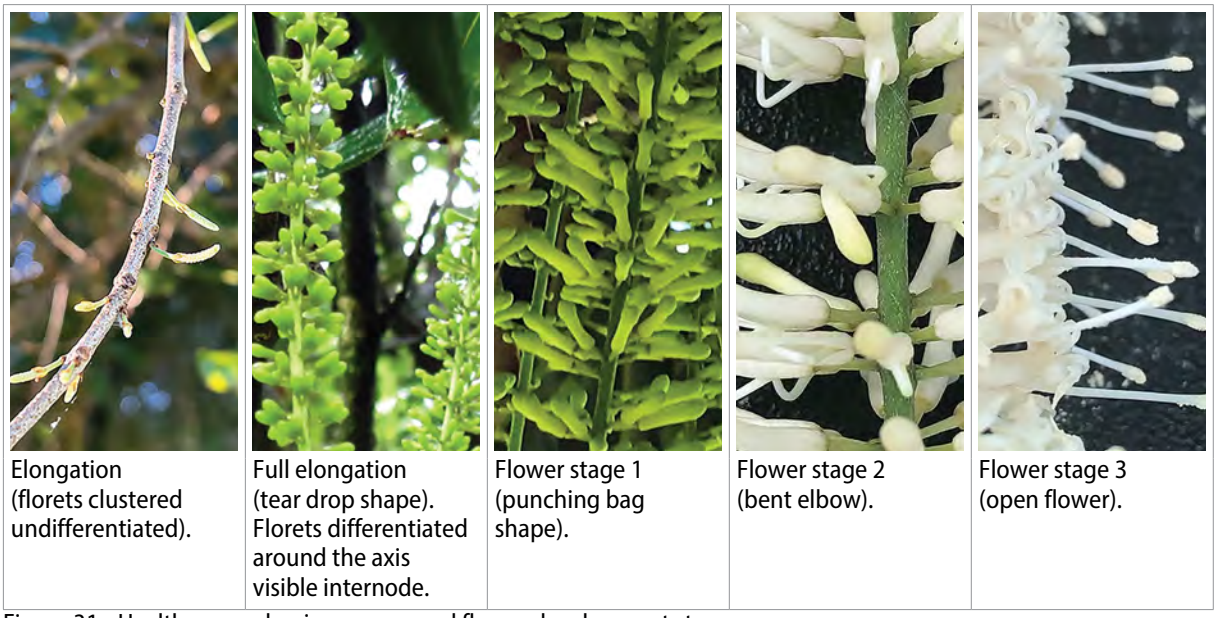


Figure 30. Key components for developing predictive disease and infection risk models.

1. Distinct host phenology stages

The occurrence of flower and fruit diseases in macadamia is closely associated with specific phenological stages of tree development. Phenological data are a critical component of disease forecasting tools. They help define the start and end points of the forecasting window, ensuring that forecasts align with periods of host susceptibility. The susceptibility of flowers to dry flower disease, grey mould and green mould depends on the flower phenology (Figure 31). Fruit infected by the husk spot pathogen at match head and pea-size stages are at risk of premature nut drop, while husk rot pathogens become destructive at the shell hardening and oil accumulation immature fruit stages.



Elongation (florets clustered undifferentiated).

Full elongation (tear drop shape). Florets differentiated around the axis visible internode.

Flower stage 1 (punching bag shape).

Flower stage 2 (bent elbow).

Flower stage 3 (open flower).

Figure 31. Healthy macadamia racemes and flower development stages.

2. Pathogen life cycle data

Understanding the life cycle of pathogens is vital for effectively predicting and managing disease outbreaks in macadamia trees. Spores are the primary infectious agents released from infected plant tissues. Once released, these spores can be dispersed by rain or wind, travelling significant distances before landing on vulnerable healthy flowers, fruit, or wounds on the trees. Upon landing, the spores cling tightly to these tissues, and, under the right weather conditions, they germinate, penetrate, and invade the plant. Spore traps are used to monitor spore abundance and peak dispersal periods. The data are integrated into forecasting.

3. Weather data

Certain weather conditions help fungal pathogens grow on macadamia trees (Figure 32). For example, the dry flower pathogens *Neopestalotiopsis macadamiae* and *Pestalotiopsis macadamiae* prefer high temperatures around 25 °C and moderate humidity at 75%. The grey mould pathogen, *Botrytis cinerea*, grows best in cooler temperatures around 18 °C and high humidity (80% or more).

Green mould, caused by *Cladosporium cladosporioides*, also needs high humidity (80% or more) but does better in warm conditions at 25 °C. *Pseudocercospora macadamiae*, which leads to husk spot, thrives at 26 °C and humidity of 90% or higher. *Diaporthe* spp., responsible for husk rot, grows best at about 25 °C.

The pathogens *Lasiodiplodia theobromae* and *Neofusicoccum luteum*, which cause Botryosphaeria branch dieback, can start growing with just 0.2 mm of rain, especially when temperatures are between 28 °C and 30 °C and humidity is above 70%.

Recent studies show that factors like maximum dew point temperature, accumulated degree days, and leaf wetness duration are important for the severity of husk rot. Daily moisture and changes in temperature also greatly affect the amount of *Lasiodiplodia* and *Neofusicoccum* spores in orchards.

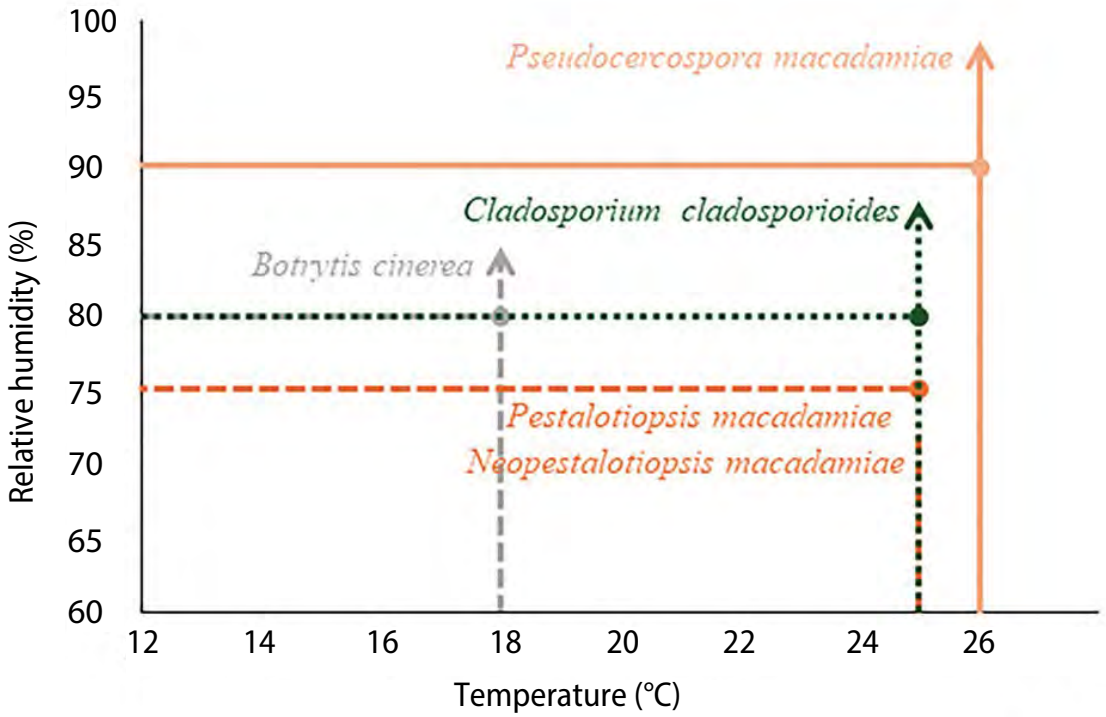


Figure 32. Optimal temperature (°C) and relative humidity (%) for growth of *Botrytis cinerea*, *Cladosporium cladosporioides*, *Pestalotiopsis macadamiae*, *Neopestalotiopsis macadamiae* and *Pseudocercospora macadamiae*.

Weather data used in disease forecasting tools are primarily obtained from:

- On-site weather stations (e.g. in-canopy and on-farm stations such as those provided by WeatherLink).
- Regional weather stations (e.g. the Bureau of Meteorology (BOM), Australian Government) and gridded weather datasets (e.g. the Scientific Information for Landowners (SILO), Queensland Government).

Predictive models use historical data on spore abundance, disease incidence, and associated weather variables to assess infection risks at specific stages of the host's development.

Infection risk index models combine factors like temperature, rainfall, humidity, and leaf wetness to generate a risk score categorised as low, moderate, or high. These models are more robust and widely used in disease forecasting than degree-day and rule-based models. They employ statistical methods such as generalised linear models and newer AI techniques, including machine learning and deep learning models such as support vector machines and artificial neural networks.

The development of these models followed 6 key steps:

1. **Data splitting**: historical datasets are divided into training and test sets, typically in an 80:20 ratio.
2. **Cross-validation**: multiple models are cross-validated on the training set to determine the best performer.
3. **Model training**: the selected model is trained on the complete training set to establish predictive relationships.
4. **Model evaluation**: predictions are made on the test set, and metrics such as precision and accuracy are assessed.
5. **Model validation**: risk thresholds (low, moderate, high) are defined based on various criteria, and the model's classification accuracy is validated.
6. **On-farm validation and cost-benefit analysis**: the model is tested in real orchard settings to compare yields and costs with traditional methods. A cost-benefit analysis helps determine its economic value, with feedback incorporated for further refinement.

MacDisease tool: a web-based decision support system

Validated infection risk models are typically deployed as computerised forecasting tools, commonly referred to as a decision support system (DSS), to guide fungicide application decisions based on predicted infection or disease risk.

The system integrates a Geographic Information System (GIS) and mapping panel, linked to a real-time weather data source, alongside dedicated panels for macadamia phenology, disease selection and risk chart. This system was developed using historical data on disease severity and pathogen inoculum levels collected from orchards in Central Queensland (CQ), Southeast Queensland (SEQ) and the Northern Rivers (NR) region of New South Wales, since 2000. The system predicts infection or disease risk by integrating real-time weather data with validated machine learning and deep learning models. Current performance metrics indicate prediction accuracies exceeding 90%, with error rates below 10%.

The macadamia web-based DSS (Figure 33) is an easy-to-use platform that helps growers make informed decisions. It automatically collects weather data from different sources for real-time forecasting. The platform supports grey mould, green mould, dry flower disease, husk rot and Botryosphaeria branch dieback.

Enter the location of your orchard to get important information about environmental conditions and assess the risk of infection or disease. The platform can be accessed through web browsers or mobile apps, as long as you have internet connectivity.

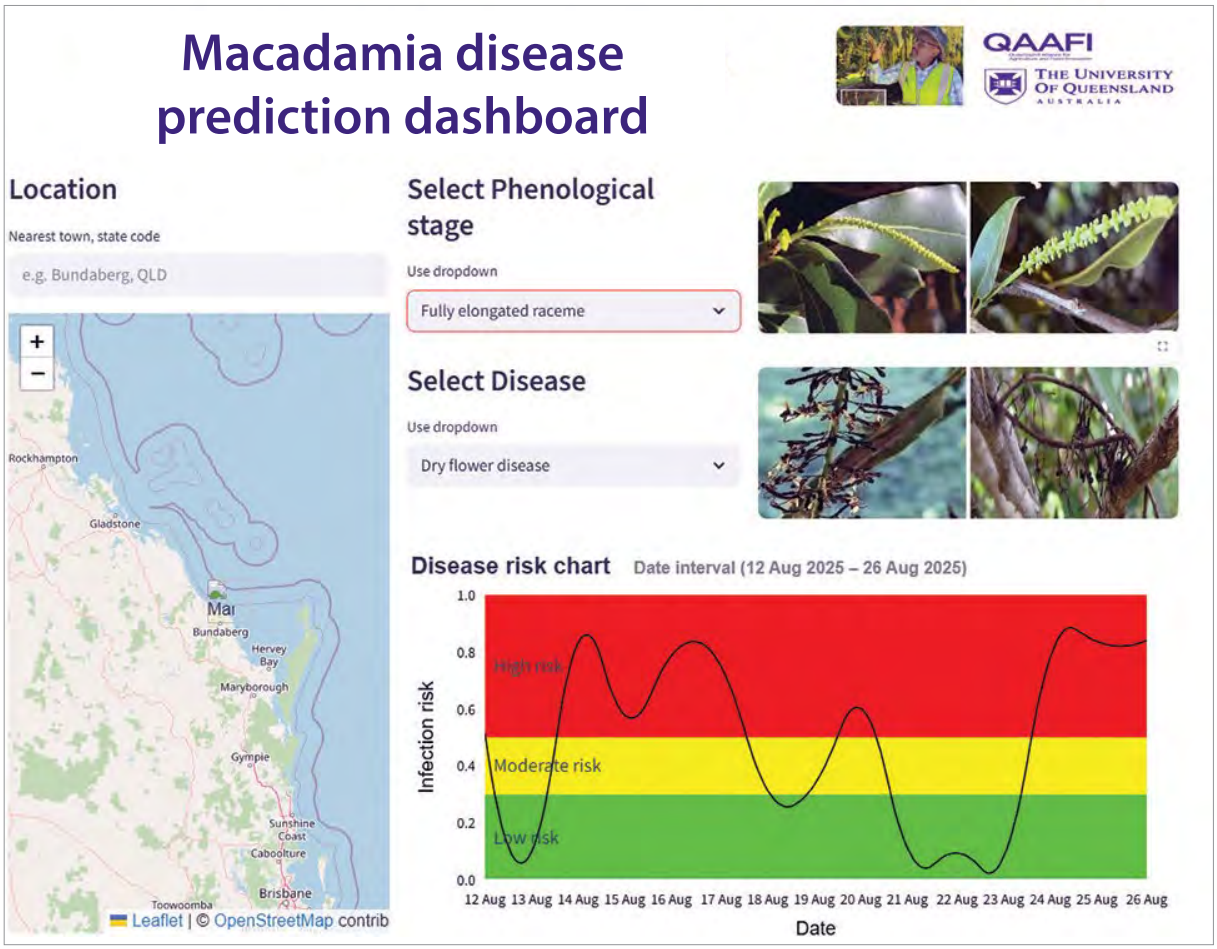


Figure 33. A web-based forecasting system for managing macadamia diseases in Australia.

The DSS can generate risk forecasts for multiple timeframes including daily, weekly, fortnightly, monthly or seasonal, depending on the availability of reliable forecast data. The output is visualised as a line chart overlaid on a traffic light-style background, where:

Red indicates high risk (action, such as fungicide spraying, required).

Yellow indicates moderate risk (monitoring required).

Green indicates low or no risk (no action needed).

How the system works

1. Enter the name of the town and state of the orchard of interest.
2. Select the phenological stage.
3. Select the diseases of interest.
4. The system automatically pulls the weather data of the orchard and generates a 16-day risk forecast.
5. The forecast is presented as a line chart on a traffic-light background, indicating infection or disease management thresholds.

Challenges behind the scenes

- Data scarcity and integrity: especially for cultivars, trees of different canopy densities and disease history.
- Pathogen complexity: the life cycles of some of the pathogens have not been fully characterised.
- Climate variability: increasing unpredictability in weather patterns challenges long-term forecasting accuracy.
- Integration with management practices: forecasts are only useful if they support actionable decisions.

Next steps

This web-based system will undergo field validation during the 2025–2026 production season in orchards throughout CQ, SEQ and NR. Feedback from growers and industry partners will be used to refine the system, ensuring its optimisation for practical, real-world use. Once validated, it will be deployed to the macadamia industry to support the timely management of diseases.

Acknowledgement

This project, 'An integrated disease management approach for the Australian macadamia industry' (MC21001) has been funded by Hort Innovation, using the macadamia research and development levy and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

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bagMUSTER rollout expands Agsafe's stewardship network to tackle soft plastic waste on farms

Anita Jay, Marketing and Communications Manager, Agsafe

Agsafe's newest product stewardship initiative, bagMUSTER, began rolling out in early 2025, providing a collection and recycling program for single-use agricultural plastic bags. Designed to complement and expand Agsafe's existing waste disposal services, drumMUSTER and ChemClear, bagMUSTER offers Australian growers a sustainable solution for managing plastic waste.

Each year, Australian farms generate thousands of tonnes of soft plastic packaging waste from products such as fertilisers, seed, grain, stock feed and pet food. Without an appropriate disposal pathway, this waste often ends up buried, burnt or stockpiled, posing environmental and safety risks. bagMUSTER fills this gap by providing a responsible and coordinated collection program to recycle these plastics into new products.

'The addition of bagMUSTER to Agsafe's suite of stewardship programs marks a pivotal step in closing the loop on agricultural packaging waste,' said Alicia Garden, General Manager of Agsafe (Figure 34). 'We have taken the time to run trials and carefully phase the rollout so we can launch in areas with the right infrastructure, ensuring all collected bags are recycled. By integrating this initiative with drumMUSTER and ChemClear, we are not only simplifying waste management for growers, but we are also helping the entire industry take meaningful action toward circular economy goals and meet rising sustainability and compliance expectations.'

Integrated waste stewardship across the supply chain:

- drumMUSTER has been Australia's trusted chemical container recycling program for over 25 years, collecting and recycling more than 45 million drums to date.
- ChemClear provides a safe disposal route for unwanted or deregistered AgVet chemicals, helping to keep farms and the environment free from hazardous legacy stock.
- bagMUSTER now completes the offering, giving farmers and retailers a way to dispose of soft plastic packaging through approved collection sites across rural regions.

Figure 34. Left to right; Alicia Garden (GM Agsafe), Matthew Cossey (CEO CropLife Australia), Katherine Delbridge (CEO ASF), and Tim March (President ASF Board).

Figure 35. bagMUSTER current collection sites.

The initial rollout of bagMUSTER began in western Victoria in early 2025 (Figure 35), with a phased national expansion planned (Figure 36). The program is supported by agricultural retailers and chemical manufacturers, with 100% of collected bags recycled in Australia, avoiding landfill and incineration.

The launch of bagMUSTER comes at a critical time for the agricultural sector, as government expectations around packaging waste and recycling intensify. Under the National Environment Protection (used packaging materials) Measure (NEPM) and the Australian Packaging Covenant (APC), manufacturers, importers and retailers are increasingly required to demonstrate how they reduce packaging waste, ensure recyclability, and recover packaging materials after use.

bagMUSTER enables participating businesses to meet these requirements by offering a credible, transparent, and nationally coordinated pathway for collecting and recycling used plastic packaging. This not only strengthens sustainability credentials but also provides the reporting evidence needed to satisfy APC signatory obligations and avoid regulatory risk.

The program supports compliance with quality assurance (QA) programs, which often require proof of responsible chemical and packaging disposal. bagMUSTER helps growers meet these standards by providing access to approved collection sites and documentation that supports on-farm environmental management systems.

Participation in bagMUSTER is simple. Growers drop off eligible bags (Figure 37), which are shaken out, empty, and free of residues, at participating bagMUSTER sites, which are co-located with drumMUSTER sites. This co-location uses existing infrastructure, making it easy and efficient for growers to manage waste at a single site by dropping off drums and bags at the same time.

For more information, visit www.bagmuster.org.au or contact Agsafe on (02) 6206 6888.

About Agsafe: Agsafe is a not-for-profit industry organisation committed to the safe handling, storage, and transport of agricultural and veterinary chemicals through its Member Services program. Through stewardship initiatives such as drumMUSTER, ChemClear and bagMUSTER, Agsafe supports sustainable waste management and environmentally responsible practices across the agricultural supply chain.

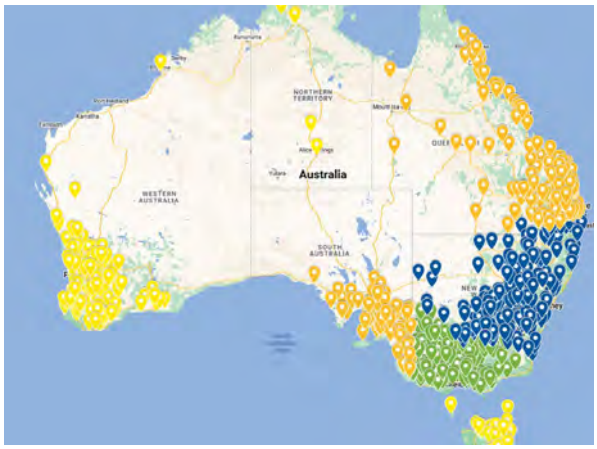

Figure 36. bagMUSTER phased launch map (proposed locations).

Figure 37. bagMUSTER trial day in Gatton, QLD.

Farm biosecurity for the macadamia industry: managing the risks

Dr Zac Hemmings, Plant Biosecurity and Product Integrity, NSW DPIRD

What is biosecurity and why is it important?

Biosecurity is a set of measures to protect crops and property from the negative effects of pests, diseases, and weeds. Australia is free from many major pests and diseases present elsewhere in the world. This pest-free status provides several benefits, including reduced cost of agricultural production, increased agricultural productivity, and access to international markets. A pest's effect is not limited to economic damage; it can also have negative effects on society, human health, and the environment.

Biosecurity risks can be managed by:

- preventing the entry of pests and diseases
- finding, detecting, and eradicating pests
- minimising the effect of those pests that cannot be eradicated.

These principles apply to government departments managing biosecurity (national or state) and growers who wish to prevent the spread of pests, diseases and weeds on their property. Biosecurity is a shared responsibility; everyone has a role in protecting our economy, environment, and community from biosecurity threats.

How can I protect my farm?

The best defence against pests, diseases, and weeds is to implement sound biosecurity practices. It is more cost-effective to prevent pests, diseases, and weeds from entering your farm than it is to eradicate or manage them once they are there. Anything that involves moving people, plant material, or other items that can carry pests, diseases, and weeds is a biosecurity risk.

People

Visitors can bring pests, diseases, and weeds to your property on clothing, footwear, and tools. Visitors who have recently travelled overseas and those who visit multiple properties, such as casual workers, tourists, and contractors, are particularly high risk. Measures to mitigate the risks associated with people movement include:

- Maintaining a visitor log and requiring all visitors to sign in. This can be achieved with a logbook in the farm office or digitally using QR codes.
- Establishing biosecurity zones to help manage where people move on and around the property. Fences or barriers can be used to minimise the movement of people and vehicles between zones, and signs can be used to direct visitors and staff.
- Ensuring that everyone understands their biosecurity obligations and what is expected of them. Conduct site inductions with visitors, provide training to employees, and place signs at key locations (e.g. footbath stations).
- Clothing can transmit diseases such as fungal spores, weeds, and pests such as lace bugs and cobbler's peg. All visitors should thoroughly wash their hands on arrival. Travellers from overseas should shower and wash their clothing before entering the property. Workers and contractors should use clean gloves when in production areas.
- Everyone entering the property should ensure their footwear is clean and free from soil and plant material. There are several ways to achieve this. For instance, you could provide disinfecting footbaths that visitors and employees are required to use. Alternatively, you could require them to exchange their footwear for footwear provided by you, which is to be worn only in certain areas of the farm.
- Consider purchasing a sturdy plastic tub to use as a footbath or make your own from on-farm materials, such as leftover intermediate bulk containers (IBCs).

- Disinfectants cannot penetrate dirt and mud. Stiff brushes, screwdrivers, hoof picks, or high-pressure hoses can be used to remove all soil and plant material before using the footbath.
- Footbaths should have a hard surface or tarp at the entry and exit to reduce the amount of soil going into them.
- The footbath solution should be changed regularly to prevent it from becoming excessively dirty. The dirty water should be disposed of safely and away from crops.
- Footbaths should be undercover or have a lid to prevent them from filling or overflowing during rain.
- A variety of disinfectants is available for use in footbaths and to clean equipment. Bleach is readily available and effective against a wide range of pests and pathogens. When used in a footbath, bleach should be diluted to 1% active sodium hypochlorite (the active ingredient in bleach). If you are concerned about more resilient pathogens, consider disinfectants such as Virkon S, Powerquat, or F10SC. Note that some disinfectants are caustic and might damage clothing and equipment. Always use products as directed on the label.

Vehicles, equipment, and machinery

Vehicles pose a significant biosecurity risk, as they can transport soil and plant material that can carry pests, diseases, and weeds. There are several ways to minimise the risk of vehicles introducing pests to your property, such as:

- Arrange for visitors' vehicles to be inspected before they enter the farm. If the vehicle is contaminated, send it away to be cleaned.
- Always practice '**come clean, go clean**'. All vehicles and machinery entering and exiting production and packing areas should be free from mud, dirt, and plant material. When cleaning vehicles:
  - park the vehicle on a hard surface
  - use high-pressure water to remove gross matter: target areas frequently exposed to dirt and plant material, such as wheel arches, tyres, side steps, and the underbody of the vehicle
  - apply a suitable disinfectant to the outside of the vehicles and any interior parts exposed to dirt, such as floor mats and footwells
  - rinse the disinfectant from all surfaces
  - passengers should disinfect their footwear in a footbath.
- Have designated parking areas for visitors' vehicles and ensure they only travel along marked roads. A vehicle should only enter a production area if it is necessary.
- Transfer passengers to dedicated farm vehicles that only operate within production areas.
- Use signs to inform visitors about property access points and parking areas.
- Request that any contractor vehicles or earth-moving equipment be cleaned, and inspect them before they enter your property to ensure they are free from soil, mud, and other plant material.
- If your operation requires frequent movement of off-farm vehicles into production areas, consider establishing dedicated vehicle wash-down facilities at entrances and exits. Wash-down facilities should be on a hard surface and have disinfectant. Wastewater should be contained in the sump or collection area.

Tools and equipment are a common vector for plant diseases, posing a significant biosecurity risk. Tools that come into contact with the plant, such as pruning equipment, can transmit plant diseases.

- If contractors or workers bring their own tools or machinery, ensure they are disinfected before being used on your property, especially if they have previously been on other farms. Inspect them after cleaning.
- If possible, keep tools on the farm rather than having them move off-site. Depending on the scale and nature of the business, it might be possible to provide workers with dedicated, clean, on-farm tools.
- Ensure that tools are regularly cleaned and disinfected.

Farm inputs

Plant and propagation material can introduce pests, diseases and weeds to your farm. To reduce this risk:

- Maintain planting records, including how many plants of each variety were purchased, the supplier, purchase date, planting date, and where on the farm they were planted.
- Only purchase propagation material from reputable sources and check the plants before they are delivered. Use clean planting material that has been tested for pathogens. Ask the supplier for information on any pathogen testing or other plant health documentation that might be required. The supplier should have a biosecurity management plan in place to manage biosecurity risks on their property.

Always ensure any plant material is from a reputable nursery and check the plants before delivery.

- Propagation material should be inspected for pests and diseases before bringing it into production areas. Many diseases cannot be detected until symptoms appear, so new plants should be kept separate from established plants and regularly monitored for signs of pests or diseases.
- Have a quarantine area where farm inputs are isolated from production areas. This includes materials such as pallets and packaging, which could contain endemic and exotic pests. Regularly monitor this area for pests, diseases and weeds.
- Ensure fertilisers and growing media are free from pests and comply with relevant standards and certifications.
- Bees can act as vectors for pests and diseases. The hives themselves can carry mud and plant material that might spread disease and weeds. Ask where hives have been before coming onto your property. Bees themselves are at risk from pests and diseases.
- Water can transmit diseases. Treat water to reduce the risk of spreading diseases. Only use new irrigation equipment. Run-off can transfer disease into your irrigation source. Divert run-off from production areas away from dams.
- Ensure that water in designated parking and visitors' areas does not run into production areas.

This is not an exhaustive list of plant biosecurity practices. Biosecurity is not a one-size-fits-all approach; what is suitable for one property might not be appropriate for another. The best approach is to assess the specific biosecurity risks associated with your operation and determine how you can feasibly manage these risks. Remember, there might be multiple ways to manage risks; consider what works for your property.

Biosecurity management plans

A biosecurity management plan is a document that outlines the measures taken to mitigate the risks of pests, diseases and weeds on a property. It is a tool to help you manage the biosecurity risks associated with your operations. Biosecurity management plans are enforceable under NSW law, and people entering areas where a plan applies must comply with the measures outlined in the plan.

Biosecurity management plans apply to a property, not a business. If your business operates on multiple properties, you will need a plan for each. A plan does not need to apply to an entire property; it might only apply to specific areas on a property where production, processing, or movement of biosecurity material takes place.

Biosecurity management plans are:

- **Not a compliance tool for the government**. They are not audited, and there is no legal requirement for a property to have a biosecurity management plan in place. However, some industry certification and accreditation schemes might require participants to have a plan to acquire or maintain accreditation.
- **Not a tool to restrict access** by police, emergency services, authorised inspectors, or utility service providers. However, they should follow the measures outlined in the biosecurity management plan where practical.

What does a biosecurity management plan look like?

NSW legislation does not require biosecurity management plans to follow a specific structure or format; it can be as simple or complex as required. A biosecurity plan that outlines a few basic biosecurity practices might be a few pages with dot points, while a large business might have a plan that spans many pages. While biosecurity management plans can take many forms, they should include:

- a map of the property, with any zoning clearly marked
- identification of biosecurity risks and the specific actions to mitigate these risks
- any procedures or instructions visitors and staff must follow; this might include step-by-step instructions for washing vehicles or entering production areas.

The only requirements for a biosecurity management plan to be valid under NSW legislation are:

- It contains reasonable measures to prevent, eliminate, or minimise biosecurity risks.
- You must have adopted the plan and followed the requirements set out in it; you cannot expect visitors to follow the plan if you and your staff do not.
- It must be clear where the plan applies; this means there must be a sign at each entrance to the property to which the plan applies. These signs must:
  - advise that a plan is in place
  - outline that it might be an offence under the *NSW Biosecurity Act (2015)* for a person to fail to comply with the measures set out in the plan
  - state how a copy of the plan can be obtained
  - inform visitors how they can contact you; usually, this means having a clear and legible contact number on the sign (Figure 38).

Figure 38. A biosecurity sign with space for the appropriate contact phone number to be displayed.

Biosecurity signs placed around farms are **not** enforceable without a biosecurity plan.

For more information about biosecurity management plans in NSW, including templates for biosecurity signs, visit the NSW DPIRD website (https://www.dpi.nsw.gov.au/biosecurity/your-role-in-biosecurity/primary-producers/biosecurity-management-plan).

Reporting exotic pests

Early detection and reporting are essential for successfully eradicating or minimising the effects of exotic pests. If you suspect that an exotic pest is in your farm or garden, you can report it to NSW DPIRD by:

- Phoning the exotic plant pest hotline on **1800 084 881**. This is a national reporting hotline, and when calling from NSW, you will be directed to NSW DPIRD.
- Emailing report details directly to biosecurity@dpird.nsw.gov.au
- Submitting report details via the online webform on the NSW DPIRD website (https://www.dpi.nsw.gov.au/dpi/biosecurity/report-a-pest-or-disease).

All reports are taken seriously and are treated confidentially. When submitting a report, you will be asked to provide information, including:

- Your name and contact details.
- Location of the pest, disease or weed.
- Name of the affected plant, a description of the pest or disease, and the symptoms and/or the damage caused to the plant.
- Several clear photographs showing:
  - the affected plant and its wider environment
  - a close-up of the symptoms and/or pest, disease or weed.

High-priority exotic pests

Several pests and diseases not currently in Australia have been identified as high-priority threats to the macadamia industry. If these were to enter Australia, they could become established in most macadamia-growing regions, potentially having a significant effect on yields and production costs. Some exotic pests and diseases of macadamia include Tropilaelaps mites (*Tropilaelaps* sp.), tropical nut borer (*Hypothenemus obscurus*), bacterial leaf scorch (*Xylella fastidiosa*), and sudden oak death (*Phytophthora ramorum*).

This is not a comprehensive list of high-priority pests. If you see anything unusual, such as a strange insect causing damage, plants with new symptoms, or familiar symptoms on a new plant or variety, report it to NSW DPIRD via the exotic plant pest hotline on **1800 084 881**.

Tropilaelaps mites

Tropilaelaps is a genus of parasitic mites that threaten bees and the pollination services they provide. Their host range includes most species of bees belonging to the genus *Apis*, including the European honey bee (*Apis mellifera*). They have also been observed infesting carpenter bees in India, indicating they could potentially affect some Australian native bee species.

Their life history is similar to that of *Varroa* spp. mite (Figure 39), with both being external parasites feeding primarily on the brood stages (Figure 40). Feeding by *Tropilaelaps* spp. mites cause physical damage that can kill the brood or result in adult bees emerging with deformities, including distorted abdomens, missing legs, and stubby wings. They can also be a vector for serious pathogens, such as deformed wing virus and American foulbrood. *Tropilaelaps* spp. and *Varroa* spp. mites can coexist in the same hive. *Tropilaelaps* spp. are considered to be more damaging than *Varroa* spp., owing to their much higher reproductive rate, with some sources indicating 25 Tropilaelaps mites for each varroa mite.

Tropilaelaps spp. mites are reddish brown, approximately 1 mm long and 0.5 mm wide, making them large enough to be seen by the naked eye against the white of broods (Figure 40). Symptoms of mite infestation include deformed bees, crawling bees, discarded brood at the hive entrance, and mites on the brood. Unlike varroa mites, Tropilaelaps mites spend most of their time within brood cells and are unlikely to be observed on adult bees.

Figure 39. Varroa mite (left) next to a Tropilaelaps mite (right). Photo: Zachary Huang, cybertree.net.

Figure 40. *Tropilaelaps* sp. mites on European honey bee broods. Photo: Denis Anderson, CSIRO.

Tropical nut borer (*Hypothenemus obscurus*)

The tropical nut borer is an exotic species of bark beetle not known to be in Australia. It is among the most serious pests of macadamia overseas. If it was to become established in Australia, it would threaten our macadamia industry.

Unlike most other bark beetles, which infest the woody tissue of trees, tropical nut borer infests the nut, boring through the husk and shell to feed on the kernel. This renders the nut unmarketable, reducing saleable yield. The mechanical damage caused by the beetles also exposes the nut to secondary infection by fungi. The tropical nut borer has been observed to damage 22% of kernels within 5 weeks of nut drop, with damage potentially exceeding 50–60% of the crop if populations are left unmanaged.

Adult beetles are 1.0–1.5 mm long, dark brown and look similar to other bark beetles (Figure 41). It is unlikely they can be easily distinguished from endemic species outside of a laboratory. The best indicator of tropical nut borer is kernels infested with small bark beetles. Damage first presents as small holes, approximately 0.5 mm in diameter, in the husk. Removing the husk and shell reveals tunnelling throughout the kernel (Figure 42). Green nuts are rarely attacked, with sticktights and fallen nuts being more favourable for reproduction due to the lower water content. The presence of infested nuts alone is insufficient to diagnose tropical nut borer as the endemic species, as *Hypothenemus eruditus* and *H. seriatus* are also known to infest macadamia kernels.

Figure 41. Dorsal (left) and lateral (right) view of tropical nut borer. Photos: Ken Walker, Museums Victoria.

Figure 42. Tropical nut borer damage inside a macadamia nut. Photo: Craig Maddox, NSW DPIRD.

Xylella fastidiosa

Xylella fastidiosa is a bacterial pathogen capable of infecting more than 450 plant species, including macadamia. The bacterium inhabits the host's xylem, which is the vascular system responsible for transporting water and nutrients from the roots to the stems and leaves. It is an extremely destructive plant pathogen; there is no treatment, and many host species will inevitably die once infected.

The build-up of bacteria within the xylem inhibits the movement of water, causing a progression of symptoms. Initially, leaf edges become scorched (Figure 43), giving the disease its name, 'bacterial leaf scorch'. This scorching progresses towards the middle of the leaf (Figure 44), with infected leaves dying and dropping off the tree. In Costa Rica, young macadamia trees infected with *Xylella fastidiosa* had yellow and scorched leaves, shortened internodes, stunted growth, and small inflorescences. It is unclear whether these symptoms were caused solely by *Xylella fastidiosa* or by a combination of infection and poor growing conditions.

Xylella fastidiosa symptoms are similar to those caused by other diseases, nutrient deficiencies, and abiotic stressors, making it challenging to identify the disease in the early stages.

Xylella fastidiosa is spread when infected plant material is grafted onto healthy tissue or by xylem-feeding insects. The most notable insect vectors of *Xylella fastidiosa* are the glassy-winged sharpshooter (*Homalodisca vitripennis;* Figure 45) and the meadow spittlebug (*Philaenus spumarius*; Figure 46), both of which are exotic and not currently found in Australia.

Figure 43. A young macadamia plant with mild symptoms of *Xylella fastidiosa* infection. Photos: Lisela Moreira Carmona, CIBCM, Universidad de Costa Rica.

Figure 44. Leaf scorching in a shingle oak caused by *Xylella fastidiosa*. Photo: John Hartman, University of Kentucky, Bugwood.org.

Figure 45. Glassy-winged sharpshooter. Photo: Johnny N Dell, Auburn University, Bugwood.org.

Figure 46. Meadow spittlebug. Photo: Ryan Hodnett, inaturalist.org/observations/7838025.

Sudden oak death (*Phytophthora ramorum*)

Phytophthora ramorum is an exotic species of *Phytophthora* not currently found in Australia. Globally it has caused serious damage to the nursery and forestry industries, as well as the natural environment. It is known to infect over 135 plant species, including wild, commercial, and amenity trees and shrubs. If it was to reach Australia, it could have a significant effect on our horticultural and nursery industries, as well as the natural and urban environment.

There are several endemic species of *Phytophthora* already in Australia, including *P. cinnamomi*, which causes Phytophthora root rot and is an ongoing issue for macadamia growers. *Phytophthora ramorum* differs from many other *Phytophthora* species because it is an aerial pathogen that is readily spread by wind, water, and mechanically on clothes and soil. There is no cure for the diseases it causes and no effective chemical treatments. Common fungicides will prevent symptoms from showing but will not destroy the pathogen; once treatment stops, symptoms will return. Infection with *P. ramorum* makes the host susceptible to secondary infection by other pests, such as ambrosia and bark beetles.

Hosts of *P. ramorum* can be categorised into 2 types: trunk hosts and foliar hosts. Trunk hosts get infections in the bark, causing the disease sudden oak death, which is often fatal. Foliar hosts get infection in the leaves (Figure 47), causing the disease ramorum blight, which is rarely fatal. Symptoms of *P. ramorum* are host-specific but can include:

- Branch dieback (Figure 48).
- Brown or black discoloured bark that oozes a red sap on the trunk (Figure 49) from the root crown to the top of the tree (up to 20 m above the ground), but not on the roots. Removing the outer layer of bark reveals mottled areas of necrotic inner bark tissue delimited by thin dark lines (Figure 50).
- Stem lesions
- Localised necrotic leaf spots and leaf blight.

Symptoms of *P. ramorum* are similar to those caused by other species of *Phytophthora*, and confirming *P. ramorum* requires samples to be sent to a laboratory for testing.

Figure 47. Foliar symptoms of *Phytophthora ramorum* in Rhododendron (left) and California laurel (right). Photos: Joseph O'Brien, USDA Forest Service.

Figure 48. Severe *Phytophthora ramorum* symptoms in coast live oak. Photo: Joseph O'Brien, USDA Forest Service.

Figure 49. Bleeding and discolouration on the outer bark of an oak. Photo: Bruce Moltzan, USDA Forest Service.

Figure 50. Necrotic lesions on the inner bark of coast live oak. Photo: Joseph O'Brien, USDA Forest Service.

Macadamia development stages

This section shows the macadamia growth stages referred to in this guide. The growth stage is determined by when most of the plant is in a specific stage of development. These are:

Bud break: includes early small bud emergence until the green raceme is fully extended (Figure 51 and Figure 52).

Pre-flowering: includes fully extended, elongated, green racemes. Buds and perianth tubes along the raceme are up to the full elongation stage. Previously referred to as stage 1 flowering (Figure 53 and Figure 54).

Early flowering: some bud/perianth tubes from pre-flowering have started to open, generally starting from the top of the raceme to the bottom. Flowers will still have some buds/perianth tubes that have not yet fully opened (Figure 55 and Figure 56).

Peak flowering: most of the tree has fully extended and opened flowers. This was formerly described as stage 2–3 flower development (Figure 57 and Figure 58).

Nut set: the pollinated nut is up to and including match head size. The ovary at the base of the style is starting to swell to the size of a match head. This was formerly described as stage 4 flowering (Figure 59 and Figure 60).

Pea-size nut and spring flush: the nut expands from match head size up to pea size (8–10 mm diameter; Figure 61).

Shell hardening and oil accumulation: nut sizing has ceased and the nut is now accumulating oil for maturity and harvest (Figure 62).

Bud break

Figure 51. Bud break. Photo: Chris Fuller, Nutworks.

Figure 52. Bud break close up. Photo: Chris Fuller, Nutworks.

Pre-flowering

Figure 53. Pre-flowering.

Figure 54. Pre-flowering.

Early flowering

Figure 55. Early flowering.

Figure 56. Early flowering. Note, the top of the raceme is at 'open flower', the middle raceme is at 'bent elbow', and the bottom raceme is at 'punching bag' stage.

Peak flowering

Figure 57. Peak flowering.

Figure 58. Peak flowering.

Nut set

Figure 59. Nut set.

Figure 60. Nut set (match head size).

Pea-size nut and spring flush

Figure 61. Pea-size nut and spring flush.

Shell hardening

Figure 62. Shell hardening.

Controlling pests and diseases in macadamia

This section provides an overview of the main pests and diseases of macadamia in NSW and Qld and gives options for control based on research and grower experiences. 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, targeted 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 (Figure 63), botrytis and other fungal problems. It can also stimulate fruit spotting bug (FSB) breeding, thus creating higher pressure from this pest. High temperatures within and around the orchard can increase the speed at which insect pests develop through their life cycles.

Maintaining an open canopy, or selecting varieties that accommodate an open canopy, helps control pests and diseases. Darker canopies have higher pest pressure. Opening up an orchard by appropriately managing the canopy can substantially reduce pest numbers.

Reducing canopy height and maintaining it at or below the row width helps with pest control, as it is harder to achieve thorough coverage with crop protective sprays in higher canopies. Sticktights (old nut husks that do not fall) can be 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 and increasing within the area. A good example of this is macadamia nut borer (MNB) parasitism; by monitoring moth flights across the region, the industry can 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, suitable soil pH, maintaining high levels of organic matter to cover exposed roots, and ensuring adequate nutrients are available to the trees.

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 64) and breeding patterns. For information on controlling vertebrate pests in macadamia, refer to the NSW DPIRD nuts webpage (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts).

Figure 63. Husk spot can be triggered by wet weather.

Figure 64. Rats are known to like macadamia nuts.

Table 9. The peak risk periods for pests in macadamia orchards.

Pest	Bud break	Pre-flowering	Early flowering	Peak flowering	Nut set	Pea-size nut and spring flush	Shell hardening to harvest	Harvest to bud break	Page number
Beetles (various)									Page 63
Fall armyworm									Page 68
Macadamia felted coccid									Page 78
Macadamia leaf miner									Page 86
Macadamia twig girdler									Page 96
Macadamia seed weevil									Page 92
Tea mosquito bug									Page 106
Black citrus aphid									Page 67
Macadamia flower caterpillar									Page 80
Macadamia lace bug									Page 84
Flower looper									Page 70
Banana fruit caterpillar									Page 61
Mites									Page 98
Red-shouldered leaf beetle									Page 100
Australian plague locust									Page 60
Fruit spotting bug									Page 71
Green vegetable bug									Page 75
Leptocoris species									Page 84
Scale insects									Page 101
Scarab beetles									Page 104
Thrips									Page 104
Macadamia nut borer									Page 89
Macadamia kernel grub									Page 76

Table 10. The peak risk periods for macadamia diseases.

Disease	Bud break	Pre-flowering	Early flowering	Peak flowering	Nut set	Pea-size nut and spring flush	Shell hardening to harvest	Harvest to bud break	Page number
Branch dieback	■	■	■	■	■	■	■	■	Page 111
Phytophthora									Page 117
Dry flower disease	■	■	■	■					Page 113
Green mould									Page 114
Macadamia husk spot	■	■	■	■	■				Page 116
Botrytis blight (grey mould)									Page 110
Husk rot and canker					■	■	■		Page 115

Insect pests in macadamia

Australian plague locust

Australian plague locusts (*Chortoicetes terminifera*) usually prefer to feed on grasses and cereal crops such as wheat. However, they will attack a wide range of plants including horticulture crops. When locusts are in large swarms, all crops are at risk.

Risk period

Table 11. The peak risk period for Australian plague locusts is from peak flowering to bud break.

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

Pest identification

Australian plague locusts can be green or brown (Figure 65), have a dark spot on the end of their wings and a dark 'X' mark on top of their thorax. When numbers are high, Australian plague locusts will form swarms.

Damage

Australian plague locust swarms can severely damage crops; a large swarm can cause up to 100% crop loss. Often the swarm will land overnight and will have eaten out a crop by the following morning. In orchards, the foliage will receive more damage than fruit as the locusts will feed on green material first.

Figure 65. Adult Australian plague locust.

Monitoring

Australian plague locusts usually begin hatching in late August and early September and will be flying by November. Both the hopper stage and the flying adult locusts feed on green plant material. Monitoring paddocks adjacent to orchard areas for hopper emergence and observing trees for infestation and/or damage will give early indications of Australian plague locust activity.

Management

Cultural and physical

Australian plague locust eggs can be reduced by cultivating egg beds, however this is generally ineffective in orchards as locust swarms are transient. Management should focus on regular monitoring and applying sprays when locusts are in a concentrated band.

Chemical

The chemical option for controlling Australian plague locusts is in Table 12.

Table 12. Chemical control option for Australian plague locusts in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Malathion PER13642, expires 30.4.30	S6	1B	0 when used as directed	High (10)	Do not apply to the orchard floor between the beginning of nut fall and the end of the harvest period.

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 Qld coast. The mature banana fruit caterpillar (BFC) was featured on a Norfolk Island stamp (Figure 66). In macadamia it appears to be a serious pest in Emerald, Rockhampton, Baffle Creek, Bundaberg, and sometimes Gympie. The pest has a large host range and appears to be in greater numbers where there is inkweed (*Phytolacca octandra*).

Figure 66. The 1976 Norfolk Island stamp featured the banana fruit caterpillar adult.

Risk period

Table 13. The peak risk period for the banana fruit caterpillar is from early flowering to shell hardening.

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

Pest identification

Adults are medium to large moths (Figure 67), 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 68) have 2 pairs of black marks on the top of the body and grow to about 60 mm (Figure 69). The life cycle takes approximately 6 weeks.

Figure 67. Banana fruit caterpillar adult.

Figure 68. Banana fruit caterpillar larvae.

The caterpillars will hide under leaf litter during 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 caterpillars feed during nut set, so monitoring should start at flowering. Look for chew marks on developing nuts up to 20 mm diameter (Figure 70). 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 lights (Figure 71).

Figure 69. Banana fruit caterpillar. Photo: Chris Searle, MacAvo Consulting.

Figure 70. Banana fruit caterpillar damage to macadamia. Photo: Chris Searle, MacAvo Consulting.

Figure 71. Banana caterpillars 'abseiling' from the tree to the ground on a silken thread, glistening in the light. Photo: Chris Searle, MacAvo Consulting.

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. Pest thresholds can change yearly, so discuss them with a pest scout to get the most current information.

Cultural and physical

The BFC is vulnerable within the mulched leaves at the base of the tree. Growers have had success by sweeping the leaf litter out from under the trees and mulching it 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. 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 14.

Table 14. Chemical control option for banana fruit caterpillar in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Methomyl (Lannate® L) PER90592, Qld only, expires 30.4.26	S7	1A	0	High (10)	Ground surface spray only. Blow out leaf litter before spraying.

Beetles (various)

Scolytid beetles (Figure 72) have recently become more prevalent in the macadamia industry. This situation becomes more complicated because scolytid beetles represent a family of beetles with many species that attack different parts of the macadamia plant. This section describes the scolytids 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 DPIRD 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 72. *Cryphalus subcompactus*, scolytid adult.

Risk period

Table 15. Beetles can be in macadamia orchards all year.

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

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 beetle taxonomy. The ecological niche of these beetles is breaking down lignin and they have different modes of action to do this.

Pinhole borers

Hypothenemus eruditus (predominantly in NSW) and *H. seriatus* (predominantly in Bundaberg) are beetles that infest the nuts in shells (Figure 73). 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 Qld also have *H. birmanus*, which feeds on avocado trunks as well as macadamia. The Bundaberg region now has the auger beetle (Figure 74), which will cause similar issues.

Figure 73. Pinhole beetle (*Hypothenemus seriatus)* damage, Bundaberg, Qld.

Figure 74. Auger beetle (*Xylopsocus gibbicollis,* left) and *Euwallacea* spp. (right).

Ambrosia beetle

Ambrosia beetles *(Xyleborus* spp.; Figure 75) burrow into trees. 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.

In 2016–17, the NSW DPIRD entomology team found several trees that were destroyed by lightning strikes. *Xylosandrus crassiusculus* (Figure 76) and *Cnestus solidus* were subsequently found in the damaged trees. *Cnestus solidus* drills into the hardwood and forms spaghetti-like sawdust masses (Figure 77). A clear sign of ambrosia boring damage is the sap exudation (Figure 78) and waste matter at the base of the trunk (Figure 79).

Figure 75. *Xyleborus* spp. damaging macadamia.

Figure 76. A 2 mm long scolytid (*Xylosandrus crassiusculus*) found in a dead tree in Qld.

Figure 77. The spaghetti-like sawdust masses caused by ambrosia beetles.

Figure 78. Sap holes in the trunk of an infected tree.

Classic bark beetle

The classic bark beetle, *Cryphalus subcompactus*, feeds on the cambium layer and can potentially ringbark branches (Figure 80), causing significant dieback (Figure 81 and Figure 82). As the female ring barks the tree, she is continually laying eggs under the cambium.

Figure 79. The sap collection caused by ambrosia beetles at the base of a tree.

Figure 80. Ringbarking caused by *Cryphalus subcompactus.*

Longicorn beetle

Longicorn beetles (Cerambycidae; Figure 83) lay eggs in the bark crevices. The larvae burrow into the hardwood, 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 (*Carpophilus hemipterus*, Figure 84) inhabits nuts in shells 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 beetles in other crops.

Figure 81. *Cryphalus subcompactus* exit holes in a dead branch.

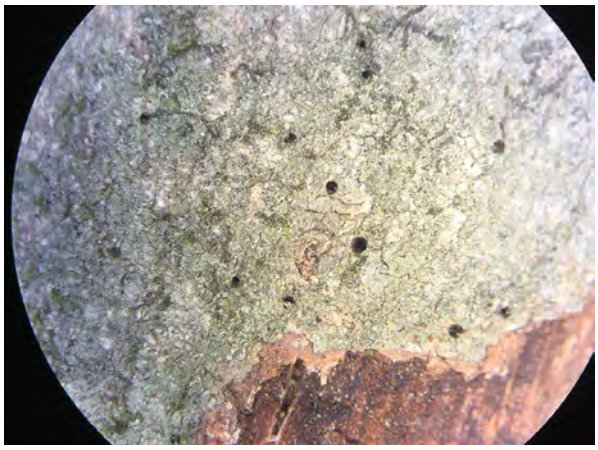

Figure 82. A close-up of the *Cryphalus subcompactus* exit holes.

Figure 83. A longicorn beetle (*Urocanthus* spp.) found on a young macadamia tree.

Figure 84. Adult carpophilus beetle (left) and larvae (right and above).

Management

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

Traps (Figure 85) 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 by the regular spray program. 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 nearby trees because when beetles leave an infested tree, they usually move onto other adjacent trees.

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 the orchard.

Postharvest sorting and hygiene will help to remove any nuts infested with carpophilus and *Hypothenemus* spp. It is easier to prevent the pests from establishing in the orchards 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 86), as this could indicate that *Botryosphaeria ribis* has also infested the branch (refer to Branch dieback on page 111). Keep cutting the branch lower until the cross-section is clear.

All infested material should be burnt as soon as possible. Do not make a burn pile that will sit in 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. This can then be incorporated into a composting pile where temperatures range between 50 and 65 °C before turning (refer to NSW DPIRD Primefact *How to compost on farm*). These temperatures will kill the bark beetle within the chip.

Another non-burning option is to expose the chips to heat. 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.

Figure 85. A trap for monitoring bark beetle numbers.

Figure 86. A discoloured cross-section potentially indicating that *Botryosphaeriaceae ribis* has also infested the branch.

Do not leave burn piles anywhere in the orchard for extended periods.

Biological

The NSW DPIRD entomology team has noticed some bark beetles have been infested by *Metarhyzium* or *Beauvaria* fungi. Research could continue to see if this might become an effective control method.

Chemical

There are no products with label registration or permits for any of the scolytids.

Black citrus aphid

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

Risk period

Table 16. The peak risk period for the black citrus aphid is from bud break to nut set.

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

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 87). Black sooty mould often accompanies this. Infestations are most common in the cooler months of winter and early spring.

Figure 87. Black aphids and ants on macadamia flowers. Photo: Chris Fuller, Nutworks.

Management

Monitoring should start around winter and spring so the aphids can be identified early, i.e. before flowering. Also look for ants as they are likely to be with the citrus aphid.

Biological control

There are several natural predators of the black citrus aphid, including parasites and pathogens. The most common are lady beetles (adults and larvae), syrphid fly (hoverfly) larvae, lacewing larvae, and tiny parasitoid wasps that lay their eggs in the adult aphids. These populations should be encouraged by growing refuge corridors.

Chemical

There is no registered chemical available for use on black citrus aphid in macadamia.

Fall armyworm

Fall armyworm (FAW) is the common name for the larval stage of the *Spodoptera frugiperda* moth. This insect pest is a serious threat to many horticultural industries. The moths are strong flyers and will travel hundreds of kilometres on storm fronts. The larvae can also be spread in cut flower, fruit and vegetable consignments. Fall armyworm has been found throughout Australia.

Risk period

Table 17. Fall armyworm could appear in the orchard throughout the year.

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

Identification and damage

FAW can complete its life cycle within 23–27 days (from egg laying to moth emergence) when suitable temperatures and host plants are present.

Female moths lay most of their eggs within 4–5 days of mating but can continue laying for up to 14 days. As FAW does not diapause (suspend development) during the pupal stage, populations are unlikely to establish in areas where temperatures fall below 12 °C.

Eggs are pale yellow and usually laid on the underside of leaves in masses of 100–200, covered with a felt-like layer of scales.

Small FAW larvae are usually light green to brown, with a dark head capsule. Larvae grow to 30–40 mm, becoming darker as they mature, with pale white stripes along the body. The caterpillars have a pale inverted Y shape between the eyes. They also have dark spots with dark spines on each body segment on the upper body surface, with 4 black spots in a square on the last abdominal segment.

Moths have a 30–40 mm wingspan and a white hindwing with a dark-brown margin. Males are more patterned with distinct triangular white spots at the tip and near each forewing centre.

Young larvae feed on the leaf surface, leaving an opaque layer of cuticle referred to as a 'window', which is usually more evident than the presence of larvae. Foliage symptoms will be similar to those caused by other caterpillars and chewing insects.

Management

Cultural and physical

Ensure biosecurity best practice actions to prevent pests and diseases from entering, establishing and spreading.

Biological

Natural predators and parasitoids could be why FAW incidence is not consistent. General predators include spiders, beetles, ants and predatory wasps. Two wasps known to parasitise Lepidoptera include *Cotesia* spp., which has been seen to parasitise FAW larvae and *Trichogramma* spp., which is known to parasitise FAW eggs.

Chemical

The control option for FAW is listed in Table 18.

Further information

NSW DPIRD fall armyworm webpage (https://www.dpi.nsw.gov.au/biosecurity/plant/insect-pests-and-plant-diseases/fall-armyworm).

Table 18. The control option for fall armyworm in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Bacillus thuringiensis (Bt; Bacchus® WG)	0	11C	0	Low (1)	Apply Bt at the first sign of activity. Bt is best used in a routine program; it is not suitable for emergency treatment.

NSW GOVERNMENT

Identifying fall armyworm

(Spodoptera frugiperda)

What to look for

- Larvae – dark head with an upside down pale Y-shaped marking *(above)*
- Larvae – 4 black dots aligned in a square on the last segment of the body near the back are clearly visible (left)
- Moth – brown or grey forewing and white hindwing
- Eggs – pale yellow and form a mass on foliage. Covered with a layer of silk-like furry substance.

www.dpi.nsw.gov.au/fall-armyworm

It can easily be mistaken for other species, so if you suspect fall armyworm, call the Exotic Plant Pest Hotline.

EXOTIC PLANT PEST HOTLINE
1800 084 881

Flower looper

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

Risk period

Table 19. The peak risk period for the flower looper is from pre-flowering to nut set.

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

Identification and damage

Flower looper larvae are up to 15 mm long and light green with brown spots running along the body (Figure 88). The larvae feed on flower buds, mainly at the bulbous ends.

The adult moth has brown and green areas on the wings (Figure 89).

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

The control option for flower looper is listed in Table 20.

Figure 88. A flower looper. Photo: Chris Fuller, Nutworks.

Figure 89. An adult flower looper on a raceme.

Table 20. The control option for flower looper in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Bacillus thuringiensis (Bt; Bacchus® WG)	0	11C	0	Low (1)	Apply Bt at the first sign of activity. Bt is best used in a routine program; it is not suitable for emergency treatment.

Fruit spotting bugs

The fruit spotting bug (FSB, *Amblypelta nitida*) and the banana spotting bug (BSB, *A. lutescens lutescens*) are the most important pests of macadamia. Both feed on macadamia fruit and flowers and have multiple host plant species. *Amblypelta nitida* is in Northern NSW and South East Qld. Recently *A. lutescens lutescens* was found in NSW. Its range extends through to Cape York in Qld.

Risk period

Table 21. The peak risk period for fruit spotting bugs is from peak flowering to harvest.

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

Pest identification

Both FSB and BSB have 7 life stages including an egg stage, 5 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 nymphs have reddish–black legs and antennae and an orange–brown abdomen (Figure 90). Banana spotting bug nymphs are pinkish-red and white and have a distinctive light red stippling surrounding the pair of large black spots on the abdomen (Figure 91). 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.

Figure 90. Fruit spotting bug (*Ambypelta nitida)* nymph.

Figure 91. Banana spotting bug (*Amblypelta lutescens lutescens)* nymph.

Damage

The first indication of FSB 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 darken and sink as the nuts develop.

Kernel damage appears as a translucent brown water-soaked spot. In many cases, this might 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 normal in macadamia. However, about 2 months after the initial set (usually from October to December), if there is a noticeably higher nut drop, it could be attributed to FSB. As the nuts develop further, they are less likely to drop after being stung.

Management

Fallen nutlet counts from October to November are the key monitoring tool used to inform spray recommendations; the spray threshold is damage to 3% of fallen nuts. 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, depending on the overall thickness of the combined husk and shell; if >10 mm, damage to the kernel is less likely. Damage is visible as dark, slightly sunken spots on the husk, collapsed testa while it is soft, and misshapen, brown and shrivelled translucent kernels. Secondary disease from organisms spread by FSB can cause further damage.

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 92)
  - identify other insect damage, e.g. MNB and MSW (Figure 93)
  - repeat fortnightly until nut drop stops in December
  - late damage is difficult to detect as the nuts remain in trees.

Figure 92. Checking for sting lesions in husk and shell.

Figure 93. Common causes of nut drop include macadamia seed weevil (top left), macadamia nut borer (top right) and fruit spotting bug feeding (bottom).

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 thinner shelled varieties (e.g. A4 and 849), is hard to detect from the ground and can be very costly if unchecked.

When monitoring nut drop in spring, it is important to recognise and distinguish the common causes of nut drop, including tea mosquito bug, green vegetable bug, *Leptocoris*, macadamia seed weevil (MSW), macadamia nut borer (MNB) and FSB feeding (Figure 93).

Using a trap crop

Trap crop hedges are being used commercially for FSB and BSB monitoring. A trap crop is one that is planted next to the macadamia crop that also attracts FSB and BSB. One of the best trap crop species is *Murraya paniculata* (mock orange). Other proven species include *Macadamia ternifolia* and *Dimocarpus longan* (longan).

Trap crop monitoring helps 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.

ADAMA

Trivor®

It's the beauty on the inside that counts.

Trivor insecticide protects kernel quality and marketable yield by providing premium protection against a range of key stinging and sucking pests.

- Knockdown and residual control of Fruit Spotting Bug and other key pests in macadamias*
- Combines two unique modes of action (Group 4A/7C) for resistance management
- Highly compatible with other crop protection and nutrition inputs
- Proven solution providing premium kernel recovery for growers

Scan here for more information

INSECTICIDE

ADAMA.COM

*Refer to registered label. ®Registered trademarks of an ADAMA Agricultural Solutions Company. ADA25152

During spring, FSB 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 populations of fifth 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 fifth instar nymph stage. This is the optimal time to spray. The hedge should be continually monitored for further generations to emerge.

Cultural controls

To reduce the risk and damage from FSB:

- select appropriate macadamia varieties (consider avoiding thin-shelled varieties)
- reduce tree height to improve spray coverage and allow ease of monitoring
- 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 host vegetation.

Biological controls

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

- egg parasitoids
  - *Anastatus* spp. (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 ants (*Oecophylla smaragdina*) and big head ants (*Pheidole* spp.)
  - predatory bugs, e.g. assassin bugs (*Pristhesancus papuensis*) and lacewings, e.g. brown lacewing (*Micromus tasmaniae*).

Chemical control

Timing is critical for FSB control. Spraying a week early will not be effective; therefore, monitoring is essential. *Murraya paniculata* trap crops are good FSB indicators and can help determine pressure levels. Monitor orchard boundaries, particularly if backing onto host species. Use previous incidence to help predict incursions. The chemical control options for FSB are listed in Table 22.

Table 22. Chemical control options for fruit spotting bug in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acephate (Lancer® 970)	S6	1B	0	High (10)	Do not spray when bees are foraging.
Acetamiprid + pyriproxyfen (Trivor®)	S6	4A + 7C	14	Medium (5)	Do not spray when bees are foraging.
Beta-cyfluthrin (Bulldock® 25 EC)	S6	3A	7	High (10)	Do not use more than 2 sprays per season to avoid resistance. Dangerous to bees.
Beta-cyfluthrin + piperonyl butoxide (Cyborg® Plus)	S6	3A	7	High (10)	Do not spray when bees are active.
Isocycloseram (Vertento® Plinazolin)	S6	30	14	High (10)	Do not spray while pollinators are foraging as it is harmful to beneficial arthropods.
Sulfoxaflor (Transform® Isoclast®)	S5	4C	0	Medium (5)	Do not use more than 2 sprays per season. Do not spray when bees are foraging.
Trichlorfon (Tyranex® 500 SL) PER13689, expires 28.2.27	S6	1B	2	High (10)	Apply when premature nut fall is evident. Toxic to bees.

Green vegetable bug

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

Risk period

Table 23. The peak risk period for green vegetable bugs is from peak flowering to harvest.

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

Pest identification

The adult GVB is 15 mm long, green and shield-shaped (Figure 94). The nymphal stage looks similar to the adult but with a range of green, yellow and black markings. Females lay clusters of 40–80 pale yellow eggs that become pink, then hatch after about 1 week. The nymphs develop through 5 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.

Figure 94. Adult green vegetable bug.

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 71). Most damage occurs from early shell-hardening onwards. Lack of external damage requires pest scouts to crack open the nuts to assess them.

Management

Green vegetable bugs do 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 do not include host species and close monitoring will be essential, both within the inter-row and the adjoining macadamia crop. Options for managing pests in inter-row plantings should be refined in the next stage of the IPM program for the macadamia industry.

Biological

Green vegetable bug 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 24.

Table 24. Chemical control option for green vegetable bug in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Trichlorfon (Tyranex® 500 SL) PER13689, expires 28.2.27	S6	1B	2	High (10)	Apply when premature nut fall is evident. Toxic to bees.

Leptocoris

Leptocoris species (commonly called soapberry bugs, family Rhopalidiae) are widely distributed throughout NSW and Qld. They will leave their native host and attack cultivated plants such as macadamia. There are most likely 2 species: *L. rufomarginatus*, found in Northern NSW and *L. tagalicus*, found in the Amamoor region, Gympie. Both species will feed on macadamia.

Risk period

Table 25. The peak risk period for *Leptocoris* spp. is from nut set to harvest.

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

Pest identification

The adult *Leptocoris* spp. has a narrow body, is reddish–brown, winged and about 12 mm long (Figure 95). 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 and a brown–black head (Figure 96).

Figure 95. *Leptocoris* spp. adult.

Figure 96. *Leptocoris* spp. nymph.

Ideally the native host plants such as the foam bark tree (*Jagera pseudorhus)* and golden rain tree (*Koelreuteria* sp.*)* will carry *Leptocoris* spp. 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, Page 71) and green vegetable bugs (GVB, Page 75) damage but it will be shallower in the kernel (Figure 97). The damage from all of these pests will render the kernel unsaleable.

NSW DPIRD research showed that, during dry weather such as in 2019–2020, FSB pressure was low and *Leptocoris* spp. pressure was high. Once rainfall returned, FSB pressure increased and *Leptocoris* spp. pressure decreased.

Figure 97. Fruit spotting bug feeding damage on the left and *Leptocoris* spp. damage on the right.

In the 2019–20 season, weekly monitoring picked up flights at the Centre for Tropical Horticulture (CTH), Alstonville, into macadamia 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 during drier seasons, as was observed in the Gympie area during the 2014–15 and 2019–20 seasons.

Management

Monitoring is the key to controlling *Leptocoris* spp. Potential pest pressure can be determined by monitoring any surrounding host plants. It is likely that in a dry year, *Leptocoris* spp. pressure will be high. Pest scouts who perform routine FSB checks will also be able to identify *Leptocoris* spp. within the crop (Figure 98). As pest consultants are working within the region your farm is located, they can alert growers to population pressures and will have control strategies.

Cultural and physical

Ensure that tree height is suited to the capacity of the orchard sprayer. Not covering all of the crop will leave opportunities for *Leptocoris* spp. to continue damaging nuts; **coverage is essential**. Ensure adequate plant density and allow good air movement throughout the canopy. Use existing foam bark or golden rain trees as monitoring tools for *Leptocoris* spp. Where there are high numbers of *Leptocoris* spp. in these trees, be aware of the stage of production of the macadamia crop and be prepared to control the infestation.

Biological

A fly parasite, *Gymnoclytia* spp. (Figure 99), has been isolated in the field by NSW DPIRD entomology staff and identified by Ainsley Seago, NSW DPIRD.

Egg parasitoids used for FSB are not effective on the *Leptocoris* spp. eggs. Birds do not usually feed on *Leptocoris* spp.

Chemical

There are currently no products registered for controlling *Leptocoris* spp. in macadamia. Talk to your crop consultant regarding control strategies.

Figure 98. *Leptocoris rufomarginatus* on a macadamia after shell hardening.

Figure 99. The parasitic fly, *Gymnoclytia* spp.

Macadamia felted coccid

Macadamia felted coccid (*Eriococcus ironsidei*) has recently been an issue in nurseries and in-field plantings. Macadamia felted coccid (MFCoccid) is a common nursery pest that can quickly destroy young seedlings and newly planted trees. In established trees, high macadamia felted coccid numbers on flowers will cause flower death. Growers need to implement good quarantine protocols, especially when receiving nursery material on their farms. Disinfesting this material and cuttings will help reduce MFC incursion onto farms.

Risk period

Table 26. Macadamia felted coccid can be in macadamia orchards all year.

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

Pest identification

MFCoccid looks similar to mealybugs. The name comes from the adult female's felt-like appearance and the males' pupal case. Adult females will moult twice and then become immobile and look like scale insects. Adult males moult once before developing wings and spend their adult lives looking for females to mate. Once mated, females develop a felted sac covering where they deposit eggs (Figure 100). There can be up to 6 generations a year with the life cycle taking about 40 days.

Signs of damage

MFCoccid can damage all above-ground parts of the tree, including the macadamia husk (Figure 101 and Figure 102). Young leaves will be distorted and stunted as the individual coccids insert their needle-like mouthparts into the plant tissue and remove sap (Figure 103). 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 drop might be delayed and nut yields can be reduced.

Figure 100. Felted sacs where the female macadamia felted coccid will lay eggs. Photo: Chris Fuller, Nutworks.

Figure 101. Macadamia nuts covered with macadamia felted coccid. Photo: Ryan Finnerty, International Tropical Fruit Network.

Figure 102. Macadamia felted coccid on a nut husk. Photo: Chris Fuller, Nutworks.

Figure 103. A macadamia leaf damaged by macadamia felted coccid. Photo: Chris Fuller, Nutworks.

Management

MFCoccid travels on infested material such as budwood, cuttings and potted nursery trees. This is how MFCoccid moves between farms, regions and even countries. Growers should ensure any new plant material coming onto their orchards is thoroughly disinfested to ensure limited opportunity for MFCoccid to enter. Introducing MFCoccid 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.

Cultural and physical

Inspecting incoming materials and disinfesting are the best prevention strategies.

Biological

Natural MFCoccid predators include:

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

These can maintain adequate control, but initially MFCoccid populations increase quickly and cause severe damage. Be aware that these natural predators will only thrive where they have a refuge from certain chemical applications.

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 27.

Table 27. Chemical control options for macadamia felted coccid. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Petroleum oil (Summer spray oil) PER11635, expires 30.4.30	S5	Unspecified	0	Low (1)	Do not apply petroleum oil when temperatures exceed 32 °C or when soil is dry and trees are suffering from moisture stress.
Sulfoxaflor (Transform® Isoclast®)	S5	4C	0	Medium (5)	Do not spray when bees are foraging.

Macadamia flower caterpillar

Macadamia flower caterpillar (MFC, *Cryptoblabes hemigypsa*) 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 flowering cultivars are affected most. Unchecked MFC can damage up to 100% of orchards.

Risk period

Table 28. The peak risk period for macadamia flower caterpillar is from bud break to nut set.

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

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 104), making them easily confused with immature scale insects. There are 5 larval stages, which all feed on the flowers or buds. Larvae usually start yellow but will become light green to grey and up to 12 mm long when fully developed. Adult moths are grey, 6–7 mm long with a 14–18 mm wingspan and generally most active at night. Macadamia flower caterpillar (Figure 105) can severely reduce a nut crop if not controlled.

Figure 104. A macadamia flower caterpillar egg on a flower bud. Photo: Chris Fuller, Nutworks.

Figure 105. 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 106), destroyed buds, and webbing (Figure 107) and frass covering the flowers and racemes. As with most pests active at flowering, early flowering cultivars are not as badly affected. Later flowering cultivars and those with prolonged flowering are likely to suffer the most damage from MFC.

Figure 106. Browned-off flowers from macadamia flower caterpillar. Photo: Chris Fuller, Nutworks.

Figure 107. Flowers and racemes covered in webbing. Photo: Chris Fuller, Nutworks.

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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 thoroughly monitor 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.

Management

Cultural and physical management

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

Biological control

Releasing biological control species in surrounding host plants, such as *Grevillea* spp., could manage MFC and protect the biological species when spraying is required. 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 control options for MFC are listed in Table 29.

Table 29. Control options for macadamia flower caterpillar. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acephate (Lancer® 970)	S6	1B	0	High (10)	Do not spray when bees are foraging.
Bacillus thuringiensis (Bt; Bacchus® WG)	0	11C	0	Low (1)	Apply Bt at the first sign of activity. Bt is best used in a routine program; it is not suitable for emergency treatment.
Methoxyfenozide (Prodigy®)	0	18	28	Low (1)	Target eggs and newly hatched larvae.
Spinetoram (Success® Neo)	S5	5	7	Medium (5)	Toxic to bees but dry residue (after 3 hours) is non-toxic. Do not apply more than 4 applications in a season.
Tebufenozide (Ecdypro 700 WP)	S5	18	28	Low (1)	Apply when pest numbers reach economic threshold levels according to field checks.
Trichlorfon (Tyranex® 500 SL)	S6	1B	2	High (10)	Apply when premature nut fall is evident. Good coverage is essential for control. Toxic to bees.

Macadamia kernel grub

The adult 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 30. The peak risk period for macadamia kernel grub is during shell hardening to harvest.

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

Pest identification

Macadamia kernel grub adults (Figure 108) are moths with dark brown forewings, 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 macadamia kernel grub often pupates within the hard nut. The pupae are about 10 mm long.

The macadamia kernel grub is usually recognised by the larvae that gain access to the kernel, either through damage caused by other pests, such as the MNB or FSB, or through an open micropyle. The larvae then consume the entire kernel, replacing it with a webbed mass of insect faeces.

Figure 108. Macadamia kernel grub adult.

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 (Figure 109).

Figure 109. Macadamia kernel grub larvae. Photo: Chris Fuller, Nutworks.

Management

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

Cultural and physical

Management and control of other pests should prevent most macadamia kernel grub damage. Monitoring is the key to controlling this pest. Using egg traps for navel orange worms (*Amyelois transitella*) can be helpful.

Biological

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

Chemical

There are no products registered to control macadamia kernel grub.

Macadamia lace bug

Macadamia lace bug (*Cercotingis decoris,* formerly *Ulonemia decoris*) is native to northern NSW and Atherton, Qld. *Macadamia* species and other similar Proteaceae plants are their native host. There are at least 4 macadamia lace bug (MLB) species, with *C. decoris* being the most damaging. Once established, MLB populations can increase rapidly and become self-sustaining.

Risk period

Table 31. The peak risk period for macadamia lace bug is from bud break to nut set.

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

Pest identification

Macadamia lace bugs are small insects, approximately 3–4 mm long (Figure 110), making them difficult to see, so looking for symptoms will help identify their presence in the orchard. They are named for the intricate lace-type pattern on their hemelytra and thorax. Adults lay eggs in the plant tissue and nymphs emerge within days to begin feeding. The nymphs go through 5 instar stages before becoming adults. The adults can fly well and have been reported to disperse to form other populations up to 20 km away, making it easy for them to recolonise in areas from which they had previously been eradicated.

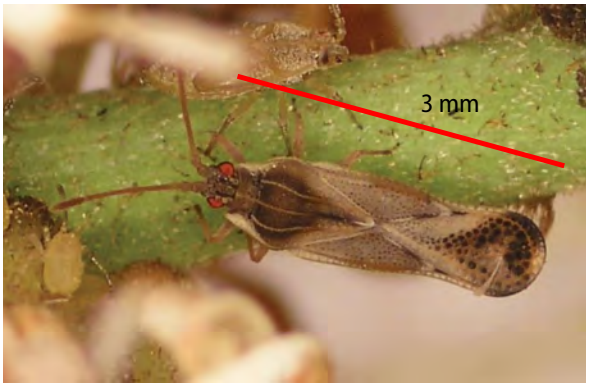

Figure 110. Adult macadamia lace bug (*Cercotingis decoris*) on a raceme. Nymphs are also present (left).

Damage

MLB pierce the plant tissue to feed on sap, damaging the leaves and flowers, starting at the tips, which will appear blackened. Left unchecked, the whole flower blackens and dies (Figure 111). Shaking the head of infested flowers reveals MLB. When MLB is not treated, nut set is prevented, causing >90% production losses in later varieties. These losses can happen quickly, so monitoring the crop early (e.g. at pre-flowering) and consistently is essential. Look for cast lace bug skins (Figure 112) on dead florets and live nymphs on racemes.

Figure 111. Florets damaged by macadamia lace bug.

Management

MLB populations increase in successive seasons as they overwinter on bark. Start monitoring at bud break, especially if MLB was a problem the previous year. Early action will mean less damage later. The 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.

Figure 112. Cast macadamia lace bug skins on dead florets.

Cultural and physical

Generally, what was a hotspot the previous year will probably be a hotspot the next year. NSW DPIRD research found that MLB prefers overcrowded dark orchards, so 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 throughout the orchard.

Biological

Macadamia lace bug has many naturally occurring predators such as predatory bugs, lacewing larvae (Figure 151), lady beetle larvae and spiders. While these might not appear in sufficient numbers to control a rapid increase in MLB populations at flowering, their preservation is an essential part of a long-term sustainable IPM approach.

Figure 151. Lacewing larva (right) versus macadamia lace bug nymph. Note the dead bodies on the lacewing's back. Photo: Chris Fuller, Nutworks.

Chemical

Careful consideration is needed when applying chemical controls during flowering to ensure minimal effect on bees and other insect pollinators. Applying crop protection compounds to 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 on bees. The chemical control options for MLB are listed in Table 32.

Table 32. Chemical control options for macadamia lace bug. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Flupyradifurone (Sivanto® Prime)	S5	4D	20	Medium (5)	**Only apply once per season**. Do not spray when bees are active. **Bee caution**: do not mix with Group 3 (DMI) fungicides when applied during flowering.
Pyrethrin (Pyganic®)	0	3A	1	High (10)	Apply before flower opening. Dangerous to bees.
Sulfoxaflor (Transform® Isoclast®)	S5	4C	0	Medium (5)	Early detection is important for control. Highly toxic to bees. Using early in the fruiting/flowering stages of the crop will conserve beneficials when used as part of an IPM program.
Tau-fluvalinate (Mavrik® Aquaflow)	S5	3A	21	High (10)	Monitor crops from early flowering and apply when local thresholds are reached.
Trichlorfon Tyranex® 500 SL) PER13689, expires 28.2.27	S6	1B	2	High (10)	Monitor crops and apply when local thresholds are reached. Do not apply to plants in flower or while bees are foraging. Toxic to bees.

Macadamia leaf miner

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

Risk period

Table 33. Macadamia leaf miner can be in macadamia orchards all year.

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

Pest identification

The adult moths have dark forewings with 3 white bars across each one (Figure 113). The hindwings are narrow and have an extensive plume of hair along the hind margin. The total wingspan is approximately 7 mm.

Macadamia leaf miner larvae are pale green to yellow and develop red bands when they are ready to pupate (Figure 114). 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 113. Macadamia leaf miner adult. Photo: CSIRO/BIO Photography Group, Centre for Biodiversity Genomics, University of Guelph.

Figure 114. Leaf miner larvae. Photo: Chris Fuller, Nutworks.

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 115). The mine is created by the miner eating the material between the leaf's upper and lower skin layers. A large 'blotch mine' might be seen on the upper side of the leaf. The larvae will be within the tunnels in fresh incursions and the tunnelling can develop into large blisters as the damage worsens. Severe infestations can impede the growth and yield of nursery and young trees. Older symptoms will appear as fire-scorched leaves on new flush.

Figure 115. Macadamia leaf miner trails. Photo: Chris Fuller, Nutworks.

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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, the problem is more severe because the few leaves that develop carbohydrates for growth can be destroyed by this pest. Treatment will be necessary if 60% of the leaves on a tree are damaged; monitoring is essential. Where minimal sprays have been applied, biological controls are an option.

Cultural and physical

Removing and destroying damaged leaves allows natural predators to build up in sufficient numbers to maintain control. Inspect nursery material regularly and do not accept new plants with leaf miner symptoms. Ensure your on-farm biosecurity is effective. Leaf miners have not yet been found in the Bundaberg region, so on-farm biosecurity is critical for this area.

Chemical

Spraying for macadamia leaf miner is 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 option for macadamia leaf miner is listed in Table 34.

Table 34. The chemical control option for macadamia leaf miner. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acephate (Lancer® 970)	S6	1B	0	High (10)	Do not spray when bees are foraging.

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). They also attack mangroves, so pressure can be greater on farms adjoining mangroves.

Risk period

Table 35. The peak risk period for macadamia nut borer is from pea-size nut to harvest.

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

Pest identification

The adult MNB is a moth. The female has a wingspan of up to 25 mm. They are reddish-brown with a distinctive black triangle marking on the hind margin of each forewing (Figure 116).

Macadamia nut borer 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 117). Eggs that have been parasitised by wasps will appear black after about 5 days (Figure 118).

Larvae are legless grubs that appear pinkish (Figure 119) 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 120), usually in the nut. Pupae are initially light brown but darken with age. The life cycle takes around 5 weeks in summer.

Figure 116. Macadamia nut borer adult.

Figure 117. Macadamia nut borer egg. Photo: Chris Fuller, Nutworks.

Figure 118. Parasitised macadamia nut borer eggs appear black after about 5 days. Photo: Chris Fuller, Nutworks.

Figure 119. Macadamia nut borer larvae. Photo: Chris Fuller, Nutworks.

Damage

Damage is easily identified as entry holes in the husk of nuts (Figure 121). These holes are usually close to the panicle and will have protruding frass (Figure 122). 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.

Figure 120. Macadamia nut borer larvae develop cocoons before pupating. Photo: Chris Fuller, Nutworks.

Figure 121. A macadamia nut borer at an entry hole. Photo: Chris Fuller, Nutworks.

Figure 122. A macadamia nut borer entry hole with protruding frass. Photo: Chris Fuller, Nutworks.

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 essential for good control. Releasing beneficial insects is most effective 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, especially with sticktight varieties. Monitoring is vital and will involve setting up pheromone traps to estimate populations and movement. Employing a pest scout will help 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 pest of the macadamia crop. It was not until the NSW DPIRD entomology team developed a system for mass-rearing and releasing *Trichogrammatoidea cryptophlebiae* (Figure 123) that this pest became manageable. This system is now called MacTrix and is an excellent tool for controlling MNB with an area-wide approach. The effectiveness of MacTrix has meant that spraying specifically for MNB after January is no longer required. Note, the effectiveness of MacTrix might be compromised in temperatures over 35 °C.

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

Figure 123. A female *Trichogrammatoidea cryptophlebiae* on an egg. Photo: R Llewellyn, BioResources.

Chemical

The control options for macadamia nut borer are listed in Table 36.

Table 36. Chemical control options for macadamia nut borer. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acephate (Lancer® 970)	S6	1B	0	High (10)	Do not spray when bees are foraging.
Beta-cyfluthrin (Bulldock® 25 EC)	S6	3A	7	High (10)	Do not use more than 2 sprays per season to avoid resistance. Dangerous to bees.
Beta-cyfluthrin + piperonyl butoxide (Cyborg® Plus)	S6	3A	7	High (10)	Do not spray when bees are foraging.
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High (10)	Do not use more than 2 sprays per season to avoid resistance. Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.
MacTrix release	0	0	0	NA	Releases should start after the last insecticide spray (usually early January).
Methoxyfenozide (Prodigy®)	0	18	28	Low (1)	Target eggs and newly hatched larvae.
Spinetoram (Success® Neo)	S5	5	7	Medium (5)	Toxic to bees but dry residue (after 3 hours) is non-toxic. Do not apply more than 4 applications in any one season.
Tebufenozide (Ecdypro 700 WP)	S5	18	28	Low (1)	Spray to thoroughly cover nuts when pest numbers reach economic threshold levels according to field checks.

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 region of NSW and Mareeba districts in Far North Qld, 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 37. The peak risk period for macadamia seed weevil adults is from bud break to shell hardening.

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

Pest identification

Adult weevils are grey–brown (Figure 124), about 6 mm long 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 wait until the nuts reach a vulnerable size (approximately 8 mm in diameter) in which to lay their eggs (Figure 125). The fully grown larvae can be up to 10 mm long.

Figure 124. Macadamia seed weevil.

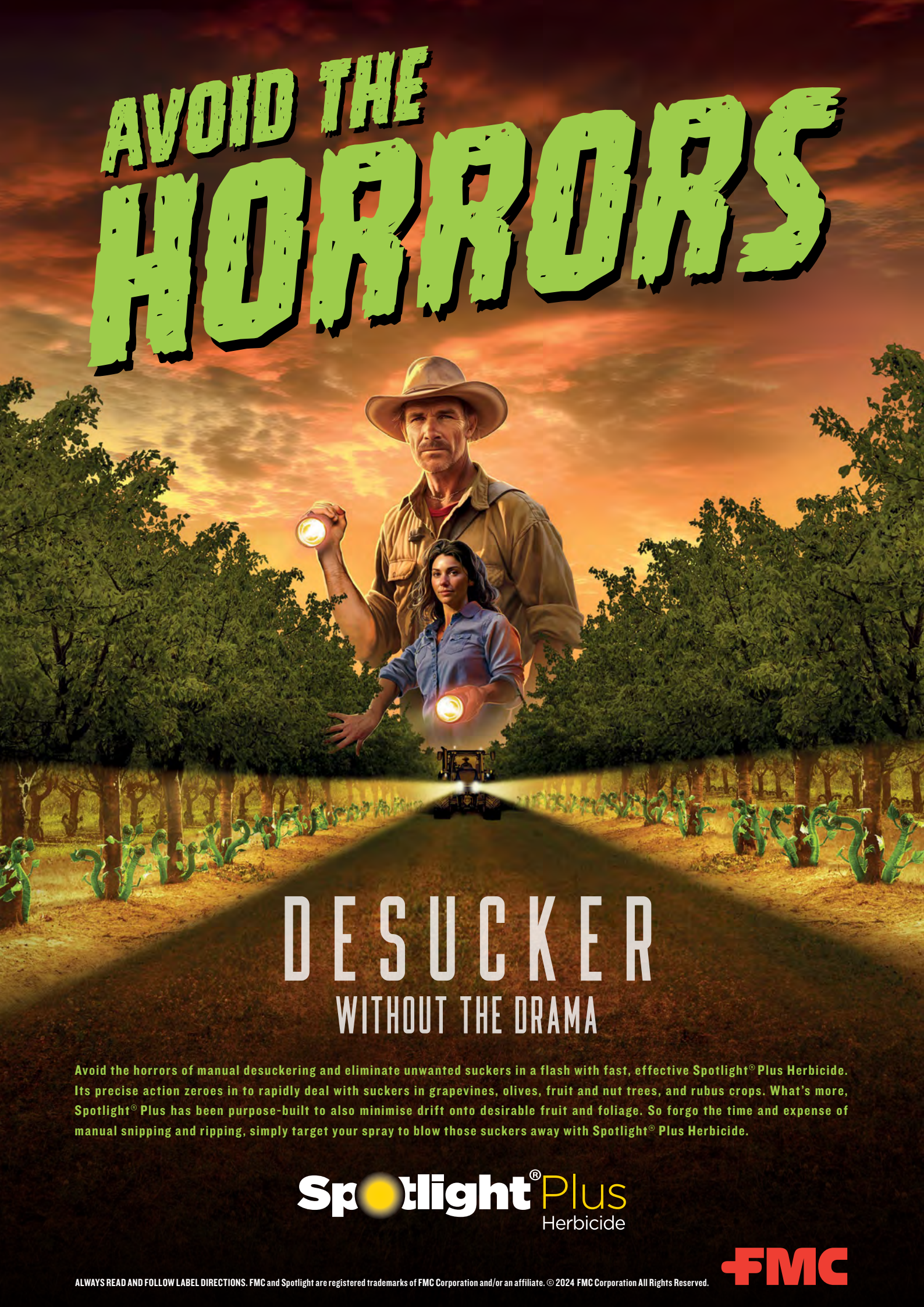
Figure 125. A macadamia seed weevil lays its egg on a chewed patch of husk.

Damage

The female weevil scarifies an area about 3–4 mm wide on the husk into which she lays a single egg. This will appear as a triangular lay mark at the stem end of the fallen nuts (Figure 126). 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 127), 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 cannot exit. Damage after shell hardening will appear as grazing marks all over the husk, giving it a golf ball appearance (Figure 128).

Figure 126. The typical mark left by macadamia seed weevil indicates egg-laying.

Figure 127. Macadamia seed weevil larvae and pupae overwintering in nuts.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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 occurred. However, it is not advisable to use ethephon on stressed trees.

To prevent MSW from thriving in an 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-infested areas
- do not allow infection transfer from neglected orchards.

Figure 128. Macadamia seed weevil damage after shell hardening appears as grazing marks all over the husk, leaving a golf ball appearance.

Cultural and physical

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

Biological

Field trials with *Metarhizium anisopliae* and *Beauvaria bassiana* were not as successful as hoped.

Chemical

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

The chemical control options for MSW are listed in Table 38.

Table 38. Chemical control options for macadamia seed weevil. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Indoxacarb (Avatar® eVo)	S6	22A	14	Low (1)	Best control is achieved when applied at match head size. Ensure thorough coverage. Sweep out affected nuts and expose them to full sunlight. Mulch affected nuts. Do not exceed a maximum of 2 applications per crop with a 10-day retreatment interval.
Indoxacarb, PER86827, expires 31.3.26	S6	22A	42	Low (1)	
Isocycloseram (Vertento® Plinazolin)	S6	30	14	High (10)	Do not spray while pollinators are foraging as it is harmful to beneficial arthropods. Do not apply more than 3 applications per season.
Tetraniliprole (Vayego® 200 SC)	S5	28	10	Low (1)	Start applications when weevils are active and after petal fall. Do not apply more than 3 applications within a season.

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Macadamia twig girdler

The larval stage of the macadamia twig girdler (*Xylorycta 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 39. Macadamia twig girdler can be in the orchard all year.

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

Pest identification

The MTG is usually identified by the damage it causes before the pest is seen. The 1–5 mm long larvae emerge from the egg and develop to about 23 mm long. The head is dark brown to black and the body is light brown with dark brown spots (Figure 129). The adult MTG is a silvery-white moth with yellow legs and a wingspan up to 26 mm. It is mostly active at night.

Damage

MTG larvae feed in webbed shelters that become cluttered with excrement (Figure 130). They can also reside in damaged foliage as larval development progresses (Figure 131). Numerous larvae at various stages will often be in one shelter, which can remain on the tree long after the life cycle is completed. This gives the tree a ragged appearance (Figure 132). Twigs weakened by girdling readily snap off and this tends to induce bunched growth. Tunnelling in the husks and kernels causes damage similar to MNB.

Figure 129. Macadamia twig girdler larva. Photo: Chris Fuller, Nutworks.

Figure 130. A webbed shelter made by macadamia twig girdler larvae. Photo: Chris Fuller, Nutworks.

Figure 131. Macadamia twig girdler damage. Photo: Chris Fuller, Nutworks.

Figure 132. A young macadamia tree damaged by macadamia twig girdler. Photo: Chris Fuller, Nutworks.

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 not have many leaves to support growth, so these must be protected.

Management

Monitoring is essential, especially for new plantings and nursery plants. The suggested threshold for action is 15% damage to terminal shoots on young trees and 20% on mature trees (Queensland Department of Agriculture and Fisheries 2003). Management and control of other pests should help reduce MTG numbers. Good orchard 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 to identify the problem early and limit the spread.

Biological

Biological control should be encouraged where fewer knock-down chemical sprays are being used in nurseries and on young plantings. These include the parasitoid wasps *Elachertus* spp., *Agathiella* spp., *Goryphus turneri* and *Stiromesostenus albiorbitalis*.

Chemical

The chemical control options for MTG are listed in Table 40.

Table 40. Chemical control options for macadamia twig girdler. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High (10)	Do not use more than 2 sprays per season to avoid resistance. Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.
Spinetoram (Success® Neo)	S5	5	7	Medium (5)	Toxic to bees but dry residue (after 3 hours) is non-toxic. Do not apply more than 4 applications in any one season.

Mites

Mites are becoming more prevalent in macadamia orchards, causing branch dieback during hotter, drier times. While the mites are difficult to see, the damage they cause, such as bronzing of nuts caused by flat mites and husk silvering caused by broad mites, is not. Most mite damage is cosmetic but high populations from 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 41. The peak risk period for mites is from bud break to harvest.

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

Pest identification

Broad mites

Broad mites (*Polyphagotarsonemus latus*) are tiny (<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 the underside.

The larval stage has 6 legs and is about 0.1 mm long, white and very slow-moving. They moult into a clear torpedo-shaped nymphal stage that is immobile.

Females are about 0.15 mm long, oval and initially clear, but become yellowish with a white strip running down the centre of their back. The adult female has 8 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 females emerge from the nymphal stage, the males quickly mate with them. The life cycle can be completed in less than 7 days. Within a single generation, the population can increase 18-fold.

Figure 133. Broad mites on A16 macadamia.

Flat mites

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 they darken to a bright reddish–orange after a few minutes. There are 5 life stages: an egg stage, a 6-legged larval stage, a protonymph and a deutonymph (both 8-legged), and an adult stage. Each larval, protonymph and deutonymph stage has a resting stage that precedes the moult to the next stage. The life cycle can be completed in about 3 weeks in 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.

Signs of damage

Broad mites

Broad mites can destroy flower buds and eliminate any potential crop for the season. Broad mites feed on flowers, young leaves (Figure 133) and fruit. Symptoms of flower feeding include silver-bronze colouring and deformation. Broad mites will also attack the new leaf flush and will lay on the underside of the leaf. Symptoms will appear as cupping and distortion of the leaf (Figure 134).

Recently, eriophyid mites have become more of an issue, particularly in the A series trees. It causes leaf stunting (Figure 135) and branch dieback.

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 mites, the scratch easily reveals the normal green surface. Other damage, such as from flat mite or red-banded thrips, will not scratch off.

Flat mites

Feeding from flat mites typically results in 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.

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. Inspect the orchard thoroughly, recognising hotspots. Monitor 20 racemes with at least one raceme per tree. As eggs are only 0.2 mm, it is best to pick the raceme off the tree and examine it under a 10× lens. Shaking flower racemes can often help detect larvae.

Cultural and physical

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

Figure 134. Broad mite damage to A16 macadamia.

Figure 135. Eriophyid mite damage to A16 macadamia.

Biological

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

A timely spray to protect autumn flush might be required. The chemical control option for mites is listed in Table 42.

Table 42. Chemical control option for mites in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Abamectin (Vertimec®) PER87510, expires 28.2.29	S6	6	28	High (10)	Only apply once 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 mostly in spring and summer, particularly after rain.

Risk period

Table 43. The peak risk period for red-shouldered leaf beetles is from early flowering to shell hardening.

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

Pest identification

Red-shouldered leaf beetles are 6–8 mm long and about 3 mm wide. They are light yellow with red shoulders on the wing covers and a similarly coloured spot in the middle of each wing cover (Figure 136). The yellowish eggs are small and oval. Eggs are laid just below the soil surface, mainly in pastures with 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 pupating.

Figure 136. Red-shouldered leaf beetle.

Damage

The beetle can completely destroy flower racemes. Young nuts and lush foliage are also attacked. High beetle populations will shred leaves. This is of particular concern for newly planted macadamia and nursery trees. Infestations are likely after heavy rain (20–40 mm) following 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 essential for controlling red-shouldered leaf beetles. It takes approximately 2 months to complete and will usually be in 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 orchard regularly. 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 might 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

While 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 a few days, well before biological populations can control the pest.

Pest populations can peak while the beneficial population is building up, and then pest numbers decrease when the beneficial population is higher. 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 subsequent populations.

Chemical

Generally individual beetles or groups of fewer than 10 can be disregarded. 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 44.

Table 44. Chemical control options for red-shouldered leaf beetles in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acephate (Lancer® 970)	S6	1B	0	High (10)	Do not spray when bees are foraging.
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High (10)	Do not use more than 2 sprays per season to avoid resistance. Do not allow the spray to drift off-target onto sensitive areas. Dangerous to bees.

Scale insects

Scale insects 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 insects can cause serious damage to young plantings.

While latania scale (*Hemiberlesia lataniae*) is the predominant scale species 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 brimblecombei*), which affects leaves and nuts
- oleander scale (*Aspidiotus nerii*), which affects leaves.

Risk period

Table 45. The peak risk period for scale insects is from nut set to shell hardening.

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

Pest identification

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

Scale insects do not usually have legs and 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 137 and Figure 138).

Figure 137. Latania scale adult. Photo: Lorraine Graney, Bartlett Tree Experts, Bugwood.org.

Figure 138. Latania scale multiple life stages. Photo: United States National Collection of Scale Insects Photographs, USDA Agricultural Research Service, Bugwood.org.

Damage

Scale insects feed on young growing tips, which distorts foliage. 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 insect infestation is heavy. Green twigs will also be infested while woodier parts of the plant are not. Latania and white scale will also infest the macadamia husk, but damage and loss from scale insects are low.

Management

Generally scale insects are not considered 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 insect infestation.

The key to controlling latania scale is constant awareness of the pests in the trees. Pest scouts should take note of areas of higher pest prevalence. Scale insects can 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, as 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 reworked 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 roads and preventing ants from accessing the trees.

Biological

Biological controls would involve mass rearing and in-field releases of the beneficials before infestation. Further investigation is required on the many potential options for biological control. Other options 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 predator populations, allowing scale insect populations to increase. The chemical control option for scale insects is listed in Table 46.

Table 46. Chemical control option for scale insects in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acetamiprid + pyriproxyfen (Trivor®)	S6	4A + 7C	14	Medium (5)	Do not spray when bees are foraging.

Scarab beetles

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

Risk period

Table 47. The peak risk period for scarab beetles is from nut set to harvest.

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

Pest identification

Argentinian scarab (*Cyclocephala signaticollis*) larvae are usually cream, white or light brown. 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 the roots will reveal curled up larvae in a characteristic C-shape (Figure 139). They have 3 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 (Figure 140).

Adults are similar in size and shape to other scarab species including the African black beetle (Figure 141). They are tan-coloured with striping on the outer wing cover (Figure 142). It is not until the larvae become adults that clear identification is possible. Most scarab beetles are approximately 8–25 mm long.

Figure 139. Argentinian scarab larva.

Figure 140. Argentinian scarab larvae in the soil.

Figure 141. African black beetle. Photo: Hanna Royals, Screening Aids, USDA APHIS PPQ, Bugwood.org.

Figure 142. Argentinian scarab adult.

Damage

Scarab beetles prefer dry seasons, with populations building up during years with a dry spring and summer. Most damage is caused by the larvae feeding on the roots. Scarab beetles consume the roots of turf and grasses such as sweet smother grass (*Dactyloctenium australe*), which is the macadamia industry's preferred ground cover because of its persistence in a semi-shade environment.

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. Regular light trapping by NSW DPIRD entomology staff (Figure 143) revealed the peak flight times were around November–December.

Management

This root-feeding pest prefers the roots of turf and pastures including kikuyu (*Pennisetum clandestinum*), and in macadamia, the predominantly-grown sweet smother grass. In dry times, the beetles will feed on compost and roots that are under heavily applied organic matter. Note, as this is usually a dry-season pest, 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, sow a fast germinating and growing species such as millet or ryegrass to give immediate cover. Longer-term, a permanent cover crop can be established.

Figure 143. NSW DPIRD entomologists trialling different lights to see which is most effective at trapping beetles, especially scarabs.

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

There are no registered chemical controls for the Australian macadamia industry to control scarab beetle larvae.

Tea mosquito bug

The tea mosquito bug (*Helopeltis* spp.) is mostly a pest for north Qld macadamia but has been reported as far south as Brisbane. It is a significant pest globally, especially in Vietnam. The tea mosquito bug is a well-known pest in custard apple, mango and cashew and it could become a significant pest in all macadamia, should it spread.

Risk period

Table 48. The peak risk period for the tea mosquito bug is from bud break to harvest.

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

Pest identification

Adults are 6.5–8.5 mm long, dark to reddish-brown with an orange thorax. There is a dark pin-like protrusion from the centre of the thorax. The legs are long and fragile, similar to mosquito legs. Antennae are longer than the body (Figure 144).

Eggs are laid in plant tissue, mainly in stems and petioles of young leaves. They are white, elongated and about 1 mm long. They take about 1 week to hatch and nymphs will feed on young leaves and shoots. There are 5 nymphal stages with a developing period of 10 to 16 days. Later instar nymphs appear similar to adults, although they are wingless and orange-brown. Adults live for several weeks and females can lay 30–50 eggs.

Damage

Feeding by both nymphs and adults will produce black necrotic lesions on soft leaves, young shoots, flower panicles and developing fruit (Figure 145). Damage is similar to that caused by FSB or BSB.

Figure 144. Adult tea mosquito bug. Photo: QLD Government's Department of Primary Industries.

Figure 145. Adult tea mosquito bugs in custard apple. Photo: Phillip Banks.

Management

Cultural and physical

The tea mosquito bug prefers dense foliage within the plant and high humidity. Opening the canopy to allow ventilation and light will help make the environment less favourable to them as well as enhance spray penetration. Adults and nymphs are hard to spot so it is best to monitor for damage rather than the pest.

Biological

Green tree ants have been suggested for limited control, but as they have a symbiotic relationship with sap-oozing pests such as mealybugs, they can be pests themselves. Green tree ants are also not found south of Gladstone.

Chemical

No chemicals are registered to control tea mosquito bugs in macadamia.

Thrips

Flower thrips (*Scirtothrips dorsalis*), greenhouse thrips (*Heliothrips haemorrhoidalis*) and red-banded thrips (*Selenothrips rubrocinctus*) will all damage macadamia. Western flower thrips (*Frankliniella occidentalis*; Figure 146) are also becoming a problem in the Bundaberg region.

Risk period

Table 49. The peak risk period for thrips is from nut set to the end of spring flush.

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

Pest identification

Thrips are small insects, ranging from 0.5 to 2.0 mm long, making them hard to see with the naked eye. They are cylindrical, with the head often narrower than the prothorax or the rest of the body (Figure 147). Adult flower thrips are orange-brown while adult greenhouse and red-banded thrips are black. Red-banded thrips nymphs are light yellow (Figure 148) with a bright orange band. Flower thrips can also affect leaves.

Damage

Damage to the outer husk is caused when the sticky excrement hardens and gives the nut an uneven, reddish appearance. Over time it will become a uniformly brownish rust colour (Figure 149). 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 150). Continual attack on new flush is a concern as this can cause the plant to lose carbohydrates.

Figure 146. Western flower thrips. Photo: David Cappaert, Bugwood.org.

Figure 147. Adult thrips. Photo: Chris Fuller, Nutworks.

Figure 148. Thrips nymphs. Photo: Chris Fuller, Nutworks.

Figure 149. Thrips damage to a macadamia nut. Photo: Chris Fuller, Nutworks.

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 in the orchard are a useful monitoring tool. The traps will indicate thrips activity and can be used to formally identify the pest species. Traps 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 quickly. 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 or dehydrated flowers that will later fall off.

Figure 150. Thrips damage to macadamia leaves. Photo: Chris Fuller, Nutworks.

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 several natural predators for thrips including predatory mites, brown and green lacewings, predatory thrips, lady beetles and parasitoid wasps. However, these are unlikely to provide full control, particularly during rapid influxes.

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 50.

Table 50. Chemical control options for thrips in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Abamectin (Vertimec®) PER87510, expires 28.2.29	S6	6	28	High (10)	Only apply once per season. Dangerous to bees.
Acephate (Lancer® 970)	S6	1B	0	High (10)	Qld, NT, WA only. Do not spray when bees are foraging.
Spinetoram (Success® Neo)	S5	5	7	Medium (5)	Toxic to bees but dry residue (after 3 hours) is non-toxic. Do not apply more than 4 applications in any one season.

References and further reading

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

Bright J (2017) Macadamia seed weevil orchard management. *Primefact 1585*, NSW DPIRD, https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/diseases-pests-disorders/sigastus-weevil,-orchard-management

Bright J (2017) Macadamia seed weevil life-cycle and monitoring. *Primefact 1586*, NSW DPIRD, https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/diseases-pests-disorders/sigastus-weevil,-life-cycle-and-monitoring

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

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

George A, Broadley R, Hutton D, Redpath S, Bignell G, Nissen B, Bruun D and Waite G (2015) *Integrated pest and disease management manual for custard apple*. Queensland Department of Agriculture and Fisheries. https://www.horticulture.com.au/globalassets/hort-innovation/resource-assets/cu13001-custard-apple-ipdm-manual.pdf

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

Herbison-Evans D and Crossley S (2019) *Tiracola plagiata*. Coffs Harbour Butterfly House, http://Lepidoptera.butterflyhouse.com.au/hade/plagiata.html

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

Ironside DA (1995) *Insect pests of macadamia in Queensland*. Queensland Department of Agriculture and Fisheries, Brisbane.

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

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

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: 104–113.

O'Hare P, Quinlan K, Stephenson R, Vock N, Drew H, Ekman J, Firth D, Gallagher E, O'Farrell P, Rigden P, Searle C, Vimpany I and Waite G (2004) *Macadamia information kit, your growing guide to better farming guide*. Agrilink Series Q103052. Department of Primary Industries, Queensland Horticulture Institute. Brisbane, Queensland, http://era.daf.qld.gov.au/id/eprint/1964/

Queensland Department of Agriculture and Fisheries (2003) *Macadamia problem solver and bug identifier*, part 2, http://era.daf.qld.gov.au/id/eprint/1964/10/mac-problemsolver_Part2.pdf

Queensland Department of Agriculture and Fisheries (2003) *Macadamia problem solver and bug identifier*, part 4, https://era.daf.qld.gov.au/id/eprint/1964/12/mac-problemsolver_Part4.pdf

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

Queensland Department of Agriculture and Fisheries (2017) *Helopeltis*, https://www.daf.qld.gov.au/business-priorities/agriculture/plants/fruit-vegetable/insect-pests/helopeltis

Queensland Department of Agriculture and Fisheries (2017) *Red-shouldered leaf beetle*, https://www.daf.qld.gov.au/business-priorities/agriculture/plants/fruit-vegetable/insect-pests/red-shouldered-leaf-beetle

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

Diseases in macadamia

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 at susceptible development stages that have been wet for 6–8 hours.

Risk period

Table 51. The peak risk period for botrytis blight is during early and peak flowering.

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

Symptoms

Botrytis blight is more likely when flowering peaks coincide with optimal cool, wet conditions. Diseased flowers appear dark brown and cluster together on the rachis with fungal strands and greyish fungal spores, hence the name. Complete destruction of the raceme can follow with grey fuzzy mould covering dead flowers (Figure 152).

Figure 152. Botrytis blight. Photo: Femi Akinsanmi, University of Queensland.

Management

Cultural and physical

Dense canopies can increase botrytis blight risk, so opening up the canopy to improve air movement and spray coverage will reduce infection risk. A good guide is to ensure that tree height is 80% of the 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 turn brown. The chemical control options for botrytis blight are listed in Table 52.

Table 52. Chemical control options for botrytis blight in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Fluopyram + tebuconazole (Luna® Experience)	S5	3 + 7	Not required when used as directed.	Low (1)	Following advice from Bayer in August 2023, using Luna® Experience (although registered) is not recommended as it may exceed export MRLs.
Iprodione (Rovral® Aquaflo)	S5	2			Apply as a thorough cover spray to flower racemes when they open. A follow-up spray might be required 7 days later if wet conditions persist during flowering.
Pyraclostrobin + fluxapyroxad (Merivon®)	S5	7 + 11	21	Low (1)	Apply before flowering stage 1 (fully elongated rachis, unopened green flower). Under high pressure, follow up with a second application at stage 3 (fully open white flower).

Branch dieback

Cause

Branch dieback is caused by the fungus *Dothiorella ribis* (formerly *Botryosphaeria ribis*). It is most often seen in trees over 15 years old and is becoming more prevalent. The dry weather during the 2019–20 season highlighted the importance of this disease.

Risk period

Table 53. Branch dieback can be in the orchard all year.

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

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 a healthy sheen. The plant parts become 'blighted' and die back (Figure 153). 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 (Figure 154).

Figure 153. Branch dieback in macadamia. Photo: Femi Akinsanmi, University of Queensland.

Figure 154. A discoloured cross-section typical of branch dieback.

The disease will often appear where trees have been stressed, such as in waterlogged areas, extremely dry weather, or a poor growing environment. However, it can also appear in orchards with good soil, perhaps through physical damage.

Fungal spores (both air and water-borne) 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, 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 in trees younger than 4 years, the leaves can appear a dull khaki green with the whole tree dying (Figure 155) within 3 to 4 weeks. This is common in diseases associated with the *Botryosphaeriaceae* group of fungi. Similar to phytophthora, dieback is more likely at the end of the rows where waterlogging can occur or on hilltops where the soil is poorer or shallower. Generally, symptoms will appear from mid-summer to early autumn after prolonged warm, humid 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 a clean-cut cross-sectional area appears. Ensure the cut is made on an angle so water does not pool on the cut surface. If discoloured cross-sections continue to the trunk, the tree will need to be removed. 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. Finely chipped dead and decaying timber can be incorporated into a composting pile where temperatures range between 50 and 65 °C before turning. This should kill any beetles that could potentially be associated with this disease. For more information about composting, refer to *How to compost on farm* (https://www.dpi.nsw.gov.au/agriculture/soils/improvement/compost).

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 can be associated with this disease.

Chemical

There are currently no registered products or permits to control branch dieback.

Figure 155. A macadamia tree with advanced branch dieback.

Dry flower disease

Cause

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

Risk period

Table 54. The peak risk period for dry flower disease is from bud break to nut set.

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

Symptoms

As its name suggests, dry flower disease is characterised by the dry appearance of the raceme (Figure 156). Infections can occur at any stage of raceme development, but symptoms will mostly be seen from pre-flowering to nut set. 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 156. Rachis dieback and early dry flower from the tip. Photo: Femi Akinsanmi, University of Queensland.

Management

Cultural and physical

Dense canopies can increase dry flower disease risk, so opening up the canopy to improve air movement and spray coverage will reduce infection risk.

The risk is lower for younger trees. For new orchards, plan for the tree density so the canopy has sufficient ventilation.

Chemical

The chemical control option for dry flower disease is listed in Table 55.

Table 55. Chemical control option for dry flower disease in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Penthiopyrad (DuPont™ Fontelis®)	0	7	14	Low (1)	Apply the first application at bud break and the second 14–21 days later, when conditions are conducive to disease development to protect flower formation and retention.

Green mould

Cause

Cladosporium gloeosporioides is a dark mould that attacks the leaves and fruit of many plants. It produces 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, green mould is emerging as a more common issue in Australia.

Risk period

Table 56. The peak risk period for green mould is from bud break to nut set.

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

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 fungal strands and spores (mycelia and conidia, Akinsanmi et al. 2017; Figure 157). The disease is most likely to appear at the end of pollination.

Figure 157. Cladosporium blight in macadamia raceme. Photo: Femi Akinsanmi, University of Queensland.

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, opening up the canopy for better air movement will reduce infection risk.

Chemical

There are currently no products with label registration or permits for green mould.

Husk rot and canker

Cause

Husk rot and canker are caused by various fungi, including *Diaporthe* spp., *Phomopsis* spp. and *Colletotrichum* spp. These are more likely to appear after wet weather and warm temperatures. The prevalence of husk rot is increasing in macadamia orchards.

Risk period

Table 57. The peak risk period for husk rot and canker is close to harvest.

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

Symptoms

Soft and spongy black lesions up to 10 mm in diameter will appear on the green fruit pericarp (Figure 158). These lesions can form a greasy decay of the entire fruit pericarp.

Figure 158. Husk rot on macadamia nuts.

The husk rot fungi can spread rapidly and can 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 MNB or other injuries, including hail damage or wind rub, can predispose the husk to infection.

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 coloured wedge.

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.

Management

Cultural and physical

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

Good orchard hygiene and insect control will help prevent husk rot. Removing old sticktight husks is a good practice to prevent the husk rot fungi from being dispersed by rain splash. Prune trees to allow good ventilation and remove and destroy old branches and cankers.

Where branches with *Phomopsis* canker are found, cut them out of the tree. Ensure the cut is at least 150 mm below the lesion/good wood intersection. Disinfect tools between trees as the disease can be spread through pruning cuts. Protect freshly cut wounds with copper and water-based white paint. Always ensure cuts are made on an angle so that water does not pool on exposed cuts.

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 58.

Table 58. Chemical control option for husk rot and canker in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Copper-based fungicides (various)	S6	M1	1	Low (1)	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 splashes easily spread fungal spores from diseased sticktights to developing nuts in the tree canopy. Macadamia husk spot can cause heavy premature nut shedding.

Risk period

Table 59. The peak risk period for macadamia husk spot is from bud break to pea-size nut and spring flush.

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

Symptoms

Early symptoms appear as pale yellow flecks with a diffuse halo on the husk. These spots become darker yellow to tan-brown (Figure 159) and expand to approximately 5–10 mm in diameter. The spots will appear later in the season on 3/4 to full-size nuts. Dry husk spots are woody and harder to cut through than unaffected ones. While the shell and kernel are unaffected, macadamia husk spot can cause nut drop 4–6 weeks early. These nuts will be immature, have low oil accumulation and will not be suitable for processing.

Figure 159. Macadamia husk spot damage.

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. Removing sticktights from the trees will significantly reduce husk spot infections.

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

Cultural and physical

Cultural practices are important for limiting macadamia husk spot damage. Growing varieties that do not have 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 from husk spot, which suggests that combining cultural and chemical controls is critical.

Reduce favourable conditions for spore development. Do not move husks with macadamia husk spot between farms as this can spread the infection to new orchards. In areas with 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 60.

Table 60. Chemical control options for macadamia husk spot. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Azoxystrobin + tebuconazole (Custodia®)	S5	3 + 11	15	Low (1)	Beware of resistance; do not apply more than 2 consecutive sprays of either Group 3 or 11 fungicides.
Carbendazim (Spin Flo®)	S7	1	14	Medium (5)	Do not apply more than 2 consecutive applications.
Copper-based fungicides (various)	S6	M1	1	Low (1)	Ensure adequate coverage.
Difenoconazole (Score®)	S5	3	0	Low (1)	Use in a protective fungicide program containing fungicides from different chemical groups. Do not apply more than 2 applications per season.
Mefentrifluconazole (Belanty®)	S5	3	14	Low (1)	Use in a protective fungicide program containing fungicides from different chemical groups. Be aware that Score® is also a Group 3 fungicide.
Penthiopyrad (DuPont™ Fontelis®)	0	7	14	Low (1)	Apply the first application when the crop is at match head stage and the second application 14–28 days later, depending on prevailing weather conditions. Do not apply more than 2 sequential applications of a Group 7 fungicide before rotating to a fungicide with a different mode of action.
Pyraclostrobin (Cabrio®)	S5	11	Not required when used as directed.	Low (1)	Do not apply more than 2 sprays per season as part of a complete disease control program. Start applying at match head stage and repeat 14–28 days later. Ensure that fungicides from an alternative chemical group are included in the spray program each season.
Pyraclostrobin + fluxapyroxad (Merivon®)	S5	11 + 7	21	Low (1)	Start applications at match head growth stage. Do not apply more than 3 applications a year and no more than 2 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 *Phytophthora cinnamomi*, a soil-borne water mould. Phytophthora can reduce tree vigour and productivity and ultimately kill the tree. It will often appear at the bottom of slopes where water can pond, 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 62. Phytophthora can occur throughout the year.

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

Symptoms

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

Trunk canker mostly occurs on the main trunk but can also spread to the tree's limbs. It appears as cracking up the length of the trunk from the ground. Red resin will often ooze from these vertical cracks (Figure 160). Over time, the bark will become corky and deeply furrowed when it can be easily peeled away, revealing reddish wood. The affected trees often have healthy suckers sprouting from the rootstock at ground level. If cankers girdle the trunk, the tree can die.

Figure 160. Sap oozing from a severe case of phytophthora. Photo: Femi Akinsanmi, University of Queensland.

Management

Unfortunately, the *Phytophthora* spp. mould 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* spp. pathogen is in the soil, it cannot be eliminated.

Cultural and physical

Only use clean planting material. Nurseries supplying tree stocks should use sterile (steamed) material to eliminate *Phytophthora* spp. pathogens. Ensure new plants have a strong, well-developed root system. Plant trees where there is adequate drainage and no waterlogging. In low-lying areas, consider using mounding and/or drainage in a way that will not compromise mechanical harvesting.

Compost, chicken manure and urea will help improve soil health and inhibit phytophthora. However, be careful when adding fertilisers and uncomposted animal manure that can release ammonia and salts, which can damage young roots.

Trunk canker generally results from wounds near the base of the tree. Avoid cutting or wounding the tree near ground level. Place guards around the base of the tree to prevent mechanical 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 63.

Table 63. Chemical control options for phytophthora in macadamia. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Copper-based fungicides (various)	S6	M1	1	Low (1)	Preventative not curative. Do not use more than 5 applications per season.
Metalaxyl (Ridomil Gold® 25G)	S5	4	28	Low (1)	Best results will be achieved when this is used in conjunction with good soil health management practices.
Metalaxyl + copper oxychloride (Axiom® Plus)	S6	4 + M1	28	Low (1)	Best results will be achieved when this is used in conjunction with good soil health management practices.
Phosphorous acid (Agri-fos® 600)	S5	33	14	Low (1)	Do not apply to trees under severe water stress or during hot weather.

References and further reading

Anon (nd) The pest identification tool, developed by Nursery and Garden Industry Queensland with support and assistance from Greenlife Industry Australia and Hort Innovation, https://pestid.com.au/

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/

Akinsanmi OA (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

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, https://apsjournals.apsnet.org/doi/10.1094/PDIS-05-16-0630-RE

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, Vock N, Drew H, Ekman J, Firth D, Gallagher E, O'Farrell P, Rigden P, Searle C, Vimpany I and Waite G (2004) *Macadamia information kit, your growing guide to better farming guide*. Agrilink Series Q103052. Department of Primary Industries, Queensland Horticulture Institute. Brisbane, Queensland, http://era.daf.qld.gov.au/id/eprint/1964/

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: 484, https://pubmed.ncbi.nlm.nih.gov/30769697/

Non-bearing and nursery trees

Young trees that are not bearing nuts do not need the same intensive spray schedule as bearing trees, however, they still require continual monitoring for pests and diseases. The types of problems most likely to be encountered with young, non-bearing macadamia trees are listed in Table 64.

Table 64. Problems most likely to be encountered with young, non-bearing macadamia trees.

Pest or disease	Damage	Control
Hares and rabbits	Tree growth is reduced and the tree can die from ringbarking.	Protecting the tree with trunk guards and/or wire netting are the most reliable means of preventing an attack.
Macadamia felted coccid	Can severely hinder young tree development. Can enter through infested nursery stock. Heavy infestation will stunt and distort growth.	Inspect nursery stock thoroughly before planting in the orchard. Spray infested trees and promote natural predators.
Macadamia leaf miner	Appearance of tunnelling under the leaf surface, causing the leaf to crinkle. Generally seen on new flush, it can cause reduced photosynthesis.	Softer sprays can be used if the damage is widely spread in the orchard or nursery.
Macadamia twig girdler	Damage to branch forks and leaf whorls. Leaves can be skeletonised and webbed together.	Inspect and spray only affected plants. There are many natural predators for twig girdlers.
Phytophthora	Leaves will appear yellowish. In severe cases, sap will ooze from the trunk.	Ensure effective soil preparation before planting.
Red-shouldered leaf beetle	Generally will swarm in the orchard. The affected leaves will appear scorched, causing premature leaf drop and poor tree establishment. Be alert as this pest has become more prevalent in recent years.	Monitor trees, especially after rain in spring and summer. Only treat affected trees.
Scale insects	Many types of scale insects 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 beneficial insects within the orchard or nursery.
Wallabies	Reduced tree growth, trees can die from ringbarking (Figure 161).	Protect trees with wire netting fence.

Figure 161. A young macadamia tree damaged by wallabies.

Nutrient disorders

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Introduction

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

Good soil nutrition begins before planting, so site preparation is vital. Before planting, soil testing should be conducted throughout the orchard, separating samples that might vary due to changes in soil characteristics. Sampling depths should be about 0–200 mm and 200–400 mm pre-planting. In well-drained red soil in higher rainfall areas, testing to 400–600 mm will determine subsoil acidity. In planted orchards, include samples from different tree varieties and ages. Given the 2-year lead time from ordering plants to delivery, growers have plenty of time 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.

The images in this section are intended to show some of the symptoms that can be seen in the field where specific nutrients are at either deficient or toxic levels. It is hoped they can assist growers and macadamia orchard staff to identify the disorders and, therefore, the 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 an essential component of chlorophyll and protein. Chlorophyll is also required for synthesising plant hormones that control tree growth.

Deficiency: lack of N reduces photosynthetic capacity and, therefore, growth. Nitrogen deficiency can reduce flowering and fruit set, which decreases production (Figure 162). Nitrogen is quite mobile in plants and younger leaves recycle it from older leaves, which then turn yellow (Figure 163) and drop off prematurely.

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

Figure 162. Nitrogen deficiency in a macadamia tree. Photo: Andrew Sheard.

Figure 163. Older and younger leaves with general yellowing, which is worse in older leaves. Photo: Andrew Sheard.

Phosphorus

Phosphorus (P) is important for cell division and growth. It is involved with sugar and starch formation as well as carbohydrate translocation within the plant.

In certain acidic ferrosols, the low pH (usually <5) can bind P, making it unavailable to the plant. Therefore, 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 164). These indicate minimal proteoid roots and, therefore, an inability to extract available P, thus leading to deficiency.

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

Toxicity: soil with high P often induces iron deficiencies.

Figure 164. Exposed roots indicate decreased proteoid roots, creating an environment less able to absorb phosphorus. Photo: Andrew Sheard.

Potassium

Potassium (K) regulates plants' water balance by controlling the stomata's opening and closing. It is important for photosynthesis and the movement of starch, sugars and oils. Potassium directly affects nut yield and quality, which are essential for nut development and oil accumulation.

Cation exchange capacity (CEC) and the amount of K available will influence whether plants will suffer from K deficiency. Ensure correct CEC ratios and sufficient available K is in the soil.

Deficiency: K 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 165).

Figure 165. 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.

Check the Ca levels in the soil as well as the exchangeable Ca in comparison with other nutrients. The amount of Ca in the soil can affect the availability of other nutrients such as potassium and magnesium.

Deficiency: low Ca levels can be associated with leached, low pH soil. 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, including yellowing of the leaf tips (Figure 166 and Figure 167).

Figure 166. Calcium deficient leaves. Photo: Andrew Sheard.

Figure 167. Yellowing leaf tips is a symptom of calcium deficiency. Photo: Theunis Smit, Mayo Macs.

Iron

Iron (Fe) is required for chlorophyll production.

Deficiency: macadamia plants deficient in Fe will have interveinal yellowing with the leaf veins remaining green (Figure 168). 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 and become pale yellow (Figure 168). Iron is not very mobile in the plant, so the symptoms will be on the younger leaves and nutlets.

Iron deficiency is induced by high soil pH and phosphorus levels. Low organic matter can also contribute to Fe deficiency. Organic matter compounds can form Fe complexes that improve availability. Excessive amounts of phosphorus fertiliser can reduce Fe uptake. Iron deficiencies can be induced by high levels of competing elements such as phosphorus.

Toxicity: poorly aerated soil that is acidic can create Fe toxicity.

Figure 168. Yellowing of iron-deficient plants and nutlets due to the lack of chlorophyll. Photo: Andrew Sheard.

Magnesium

Magnesium (Mg) is an important component of chlorophyll and is essential for photosynthesis. It regulates plant nutrient uptake and essential cellular functions.

Deficiency: Mg is mobile in the plant, moving from older to newer plant tissues (Figure 169). Magnesium deficiency will appear as interveinal yellowing from the leaf tips and edges towards the central midrib areas (Figure 170). Exchangeability and the ratio of Mg to other nutrients in the soil such as Ca and K will influence its uptake. Deficiencies mainly occur in high rainfall areas with low pH sandstone soil and ferrosol. Heavy applications of potassium can also induce Mg deficiency.

Figure 169. Magnesium deficiency: older leaves are most affected as magnesium is mobile within the plant. Photo: Andrew Sheard.

Figure 170. Magnesium deficiency: interveinal yellowing from the leaf tips to the midrib while the leaf base remains green. 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 B availability. Boron is easily leached from coarse-textured acidic soil and organic matter in the soil can hold B to make it available to the plant.

Deficiency: as B 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 171) become apparent. To rectify the deficiency, B is best applied by spreading on the ground and 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 to precede peak flowering.

Recent work showed that a foliar B spray on B-deficient plants was beneficial for first-grade kernel yield and recovery (Russ Stephenson, personal communication).

There is a fine line between boron deficiency (Figure 171) and boron toxicity (Figure 172).

Figure 171. Poor internode growth and leaf dieback from boron deficiency. Photo: Andrew Sheard.

Figure 172. 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: Zn 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 173 and Figure 174).

Soil Zn availability decreases as pH increases. High P, Ca, or K levels also contribute to Zn deficiency. Aim to build up Zn levels in the soil. However, if regular leaf analysis shows deficient Zn levels (especially in ferrosol), then foliar applications might be warranted. Zinc should be applied on the summer flush.

Figure 173. Distinct intercellular chlorosis, which is typical with zinc deficiency. Little leaf or rosetting is also present. Photo: Andrew Sheard.

Figure 174. 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: Mn is relatively immobile so deficiency symptoms will appear on young leaves as interveinal chlorosis close to the midrib (Figure 175). Leaves usually maintain a distinct band of darker green along the midrib and veins. High pH soil will reduce Mn availability and high organic matter can also tie up Mn.

Toxicity: in soil on the NSW north coast, particularly where pH is low (<5), many plants have Mn toxicity. Their symptoms include interveinal brown spots along the outside edge of older leaves (Figure 176). Leaves might eventually brown off and die back. Correcting soil pH and increasing organic matter will alleviate Mn toxicity.

Figure 175. Chlorosis with dark green along the midrib due to manganese deficiency. Photo: Andrew Sheard.

Figure 176. Manganese toxicity shows as brown spots along the outer edges of the leaves. Photo: Alan Mason.

Copper

Copper (Cu) is necessary for energy transfer for photosynthesis and N metabolism. It is also necessary for lignin production, which strengthens the lateral branches. Copper is a constituent of several enzyme systems that build and convert 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 inhibit Cu uptake, including alkaline soil.

Deficiency: as Cu is important for lignin production, deficiencies will be displayed as twisted or distorted lateral branches. The most obvious indicator of Cu deficiency is the appearance of a 90-degree branch angle of new flush (Figure 177), almost in the shape of a 'C'.

Figure 177. A 90-degree branch angle of new flush is a typical sign of copper deficiency. Photo: Andrew Sheard.

Further reading

Bright J and Alt S (2023) Nutrition and soil health – part 2: the next level, in *Macadamia grower's guide*, NSW DPIRD, https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/macadamia-growers-guide/macadamia-growers-guide-nutrition-and-soil-health-part-2-the-next-level

O'Hare P, Quinlan K, Stephenson R, Vock N, Drew H, Ekman J, Firth D, Gallagher E, O'Farrell P, Rigden P, Searle C, Vimpany I and Waite G (2004) *Macadamia information kit, your growing guide to better farming guide*. Agrilink Series Q103052. Department of Primary Industries, Queensland Horticulture Institute. Brisbane, Queensland, http://era.daf.qld.gov.au/id/eprint/1964/

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

Honey bee best practice management

Chris Fuller, Nutworks

Communication to organise beehive placement timing and location before flowering is essential.

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 bees 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, especially as honey bees can easily fly up to 2 km 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 orchardists 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, orchardists can enter their property location. If this is within 10 km of 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 a secure messaging service.

Orchardists can register the time and location of their planned crop protection activities, such as pesticide spraying. Using a smartphone, orchardists can find their paddock by exploring near their current location, a registered property, or searching Google Maps (https://www.google.com/maps). Switching between street and satellite view makes it easier to find specific paddocks using nearby roads and geographical features. BeeConnected (http://beeconnected.org.au/) is optimised for Android and Apple smartphones.

Figure 178. A honey bee pollinating a macadamia flower.

Figure 179. The BeeConnected app. Source: CropLife Australia.

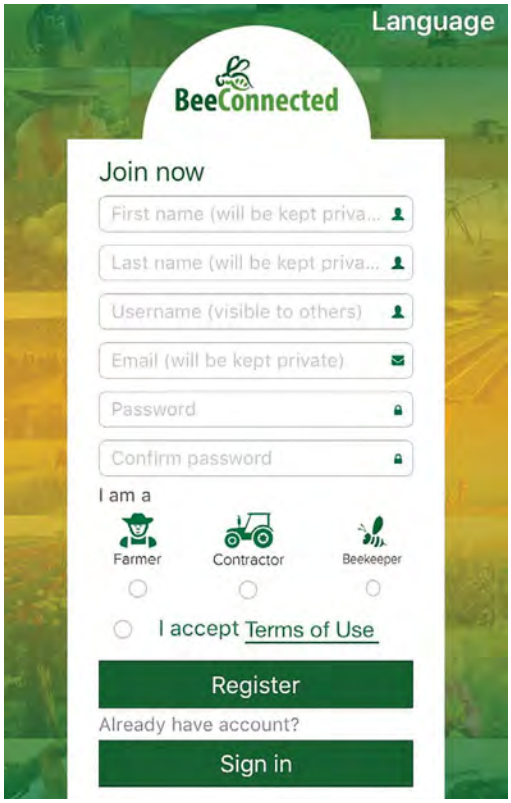

Figure 180. The BeeConnected app enables orchardists and beekeepers to be connected. Source: CropLife Canada.

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.

Certain rules apply for bee protection, including:

- always choose short-acting chemicals
- finish spraying 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
- avoid directly spraying bees in flight (Figure 181) or beehives
- turn off nozzles when near beehives, even if at night
- remove hives at nut set when no pollination is occurring (bees will travel long distances to find alternative food sources and can come in contact with insecticide-treated crops).

Figure 181. A native bee approaching a macadamia flower. Photo: Chris Fuller, Nutworks.

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. This 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 should be cleaned and refreshed regularly (i.e. daily).

For good colony strength and bee health, provide alternative pollen sources before and after macadamia flowering, and always place hives away from areas prone to shade and flooding.

Bee aware when spraying during pollination

Many beekeepers place beehives on macadamia farms during flowering so bees can help with pollination. This can be at the request of the orchardist or beekeeper. Pollination services have mostly been provided at no cost to the orchardist, as the beekeeper hopes to obtain macadamia honey from the crop. Unfortunately, this has not always happened and some beekeepers have yielded little to no honey. Sadly, this has been a direct result of bees being poisoned by chemical sprays on the immediate farm or neighbouring properties. This has severely affected or destroyed entire apiaries.

Beekeepers work very hard to manage their bee colonies and many rely on them for their livelihood, so please consider the negative effects chemical spraying can have on bee colonies located nearby (within 1–3 km). Please advise nearby orchardists if you have bees on or near your farm and ask that sufficient consideration and notice be given if they intend to spray.

If beehives placed on macadamia properties continue to suffer, then fewer bees will be placed on-farm for free and would likely see an increase in the bees being placed under a paid pollination contract. Current commercial contracts (e.g. blueberry, avocado, almonds) request a minimum of 3 days notice of intent to spray so the beekeeper can remove the bees before spraying. For more information, refer to *Best practice bee management in macadamia* (https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0016/1214341/Best-practice-bee-management-in-macadamia.pdf).

Macadamia pesticides

Table 65. Products registered[1] for managing macadamia pests. Always read the label.

For managing...	Active constituent	IPM rating	Comment[2,3]
Australian plague locust	Malathion	High (10)	Non-systemic insecticide and acaricide active by contact, ingestion and respiration. PER13642, expires 30.4.30.
Banana fruit caterpillar	Methomyl	High (10)	Systemic and contact insecticide, PER90592, expires 30.4.26, Qld only.
Fall armyworm	*Bacillus thuringiensis*	Low (1)	Stomach poison.
Flower looper	*Bacillus thuringiensis*	Low (1)	Stomach poison.
Fruit spotting bug	Acephate	High (10)	Contact insecticide with stomach action.
	Acetamiprid + pyriproxyfen	Medium (5)	Contact and ingestion; targets the central nervous system.
	Beta-cyfluthrin	High (10)	Systemic and contact insecticide with stomach action.
	Beta-cyfluthrin + piperonyl butoxide	High (10)	Systemic and contact insecticide with stomach action.
	Isocycloseram	High (10)	Contact insecticide
	Sulfoxaflor	Medium (5)	Systemic and contact insecticide with stomach action.
	Trichlorfon	High (10)	Insecticide and acaricide with contact and stomach action, PER13689, expires 28.2.27.
Green vegetable bug	Trichlorfon	High (10)	Insecticide and acaricide with contact and stomach action, PER13689, expires 28.2.27.
Macadamia felted coccid	Petroleum oil	Low (1)	Insecticide and acaricide with ovicidal activity, PER11635, expires 30.4.30.
	Sulfoxaflor	Medium (5)	Systemic and contact insecticide with stomach action.
Macadamia flower caterpillar	Acephate	High (10)	Contact insecticide with stomach action.
	Bacillus thuringiensis	Low (1)	Stomach poison.
	Methoxyfenozide	Low (1)	Insecticide that lethally accelerates the moulting process.
	Spinetoram	Medium (5)	Insecticide with contact action.
	Tebufenozide	Low (1)	Insecticide that lethally accelerates the moulting process.
	Trichlorfon	High (10)	Insecticide and acaricide with contact and stomach action.
Macadamia lace bug	Flupyradifurone	Medium (5)	Systemic insecticide with contact and ingestion action.
	Pyrethrin	High (10)	Contact insecticide with stomach action.
	Sulfoxaflor	Medium (5)	Systemic and contact insecticide with stomach action.
	Tau-fluvalinate	High (10)	Contact and ingestion; targets the central nervous system.
	Trichlorfon	High (10)	Insecticide and acaricide with contact and stomach action, PER13689, expires 28.2.27.
Macadamia leaf miner	Acephate	High (10)	Contact insecticide with stomach action.

Table 58. Products registered[1] for managing macadamia pests, page 2. Always read the label.

For managing...	Active constituent	IPM rating	Comment[2,3]
Macadamia nut borer	Acephate	High (10)	Contact insecticide with stomach action.
	Beta-cyfluthrin	High (10)	Systemic and contact insecticide with stomach action.
	Beta-cyfluthrin + piperonyl butoxide	High (10)	Systemic and contact insecticide with stomach action.
	Carbaryl	High (10)	Contact insecticide with stomach action.
	Methoxyfenozide	Low (1)	Insecticide that lethally accelerates the moulting process.
	Spinetoram	Medium (5)	Insecticide with contact action.
	Tebufenozide	Low (1)	Insecticide that lethally accelerates the moulting process.
Macadamia seed weevil	Indoxacarb	Low (1)	Contact insecticide with stomach action.
	Isocycloseram	High (10)	Contact insecticide
	Tetraniliprole	Low (1)	Anti-feedant with residual activity in all life stages.
Macadamia twig girdler	Carbaryl	High (10)	Contact insecticide with stomach action.
	Spinetoram	Medium (5)	Insecticide with contact action.
Mites	Abamectin	High (10)	Acaricide with stomach action and translaminar movement, PER87510, expires 28.2.29.
Rats	Cholecalciferol	NA	Elevates blood calcium and causes kidney failure.
	Coumatetralyl	NA	Inhibits blood coagulation.
Red-shouldered leaf beetle	Acephate	High (10)	Contact insecticide with stomach action Qld, WA and NT only.
	Carbaryl	High (10)	Contact insecticide with stomach action.
Scale insects	Acetamiprid + pyriproxyfen	Medium (5)	Contact and ingestion; targets the central nervous system.
Thrips	Abamectin	High (10)	Acaricide with stomach action and translaminar movement, PER87510, expires 28.2.29.
	Acephate	High (10)	Contact insecticide with stomach action Qld, WA and NT only.
	Spinetoram	Medium (5)	Insecticide with contact action.

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

[2] Adapted from *The Pesticide Manual*, 19th Edition, British Crop Protection Council 2021.

3 The APVMA website (https://portal.apvma.gov.au/permits).

IPDM ratings

Low (1) indicates that, when used with care, a chemical will have little effect on beneficials and is recommended in an IPDM program.

Medium (5) indicates that this pesticide can be used with caution in an IPDM program, but the chemical's effect on beneficials present should be assessed before application.

High (10) indicates that this chemical is likely to have a negative off-target effect including on beneficial insects.

Table 66. Chemicals registered[1] for managing macadamia diseases. Always read the label.

For managing...	Active ingredient	IPM rating	Comment[2,3]
Botrytis blight (grey mould)	Fluopyram + tebuconazole	Low (1)	Protective fungicide.
	Iprodione	Low (1)	Contact fungicide with protective and curative action.
	Pyraclostrobin + fluxapyroxad	Low (1)	Protective and curative fungicide.
Dry flower disease	Penthiopyrad	Low (1)	Systemic protective fungicide.
Husk rot and canker	Copper-based fungicides	Low (1)	Protective fungicide.
Macadamia husk spot	Azoxystrobin + tebuconazole	Low (1)	Systemic fungicide with protective and curative action.
	Carbendazim	Medium (5)	Protective fungicide.
	Copper-based fungicides	Low (1)	Protective fungicide.
	Difenoconazole	Low (1)	Systemic fungicide with protective and curative action.
	Mefentrifluconazole	Low (1)	Systemic fungicide with protective and curative action.
	Penthiopyrad	Low (1)	Broad spectrum fungicide with preventative, curative and locally systemic activity.
	Pyraclostrobin	Low (1)	Protective and curative fungicide.
	Pyraclostrobin + fluxapyroxad	Low (1)	Protective and curative fungicide.
Phytophthora	Copper-based fungicides	Low (1)	Protective fungicide.
	Metalaxyl	Low (1)	Protective fungicide with slow release activity.
	Metalaxyl + copper oxychloride	Low (1)	Systemic fungicide with protective and curative action.
	Phosphorous acid	Low (1)	Systemic protective fungicide.

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

[2] Adapted from *The Pesticide Manual*, 19th Edition, British Crop Protection Council 2021.

[3] The APVMA website (https://portal.apvma.gov.au/permits).

Managing spray drift

Farm Chemicals Unit, Biosecurity and Food Safety, NSW DPIRD

What is spray drift?

Spray drift is the air-borne movement of chemicals that can potentially cause injury or damage to humans, plants, animals, the environment or property in a non-target area. All pesticides are capable of drift. Users have a moral and legal responsibility to prevent pesticides from drifting and contaminating or damaging neighbours' crops and sensitive vegetation areas. In areas where diverse agricultural enterprises co-exist, conflicts can arise, particularly from pesticide use. Some labels have 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 can lead to vapour drift damage to highly susceptible crops such as tomatoes, sunflowers, soybeans, cotton and grapes. This can happen hours after the herbicide has been applied.

Vapours and minute particles float in the airstream and are collected on 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 compared to 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: the closer the spraying is to the susceptible crop, the greater the risk.

Application method and equipment used:

- aerial application releases spray at about 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 very fine droplets that use wind to carry them to the target.

Amount of active ingredient applied: the more active ingredient applied per hectare, the greater amount available to drift or evaporate.

Efficiency of droplet capture: crops, erect pasture species and standing stubble catch drifting droplets, which would otherwise land on bare soil.

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 severely damage highly sensitive plants.

Minimising spray drift

Successfully managing spray drift requires using a range of complementary strategies, including:

Before spraying

- Always check for susceptible crops and sensitive areas such as houses, schools and riparian areas.
- Notify neighbours of your spraying intentions.
- Record weather and relevant spray details. This is essential under the *Pesticides Act 1999* (https://www.epa.nsw.gov.au/Your-environment/Pesticides/pesticides-nsw-overview/regulating-pesticides-nsw/pesticides-act-regulation). An example spray record form is provided in Table 67 on page 143.

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 areas.

The potential adverse effect will depend on the nature of the sensitive area and 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, what needs 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 arise 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 hazards.
- 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 spraying.
- 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 downwind buffer that could be in the 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 deliver coarse droplets with 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 and the correct spray rates.

Pressure: always operate within the pressure range recommended by the nozzle manufacturer. Fine droplet production increases with increased operating pressure. Lower volumes produce more 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 spraying time is increased. This increases off-target risks and the likelihood that conditions such as temperature, humidity and wind direction will change 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, orchardists and spray applicators should carefully read label directions.

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: do not spray 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 182) exceeds 10 °C. Spraying when Delta T is between 8 °C and 10 °C is considered high risk. High humidity extends droplet life and can greatly increase the drift hazard from fine droplets under inversion conditions, particularly from an increased life of droplets smaller than 100 microns.

Wind: avoid spraying during calm or still conditions as droplets are more likely to remain suspended in the air. The ideal safe wind speed is 7–10 km/h, identified by leaves and twigs being in constant motion (a light breeze). Wind speeds of 11–14 km/h (moderate breeze) are suitable for spraying with low-drift nozzles or higher-volume applications. Small branches move, dust is raised and loose paper will be moving. When wind speed is greater than 15 km/h, avoid spraying. For detailed information on wind speeds, refer to 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 183). This is the opposite (inverse) of the normal temperature decrease with height.

Hazards of surface inversions

Surface inversions strongly suppress air-borne pesticide (and similar) dispersion. Surface inversions can cause air-borne 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 in low-lying regions
- be transported, often in unpredictable directions.

Radiation inversions – the most hazardous

Surface inversions usually begin 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, making the lowest layer of air cooler than higher layers. This is radiation cooling or a radiation inversion.

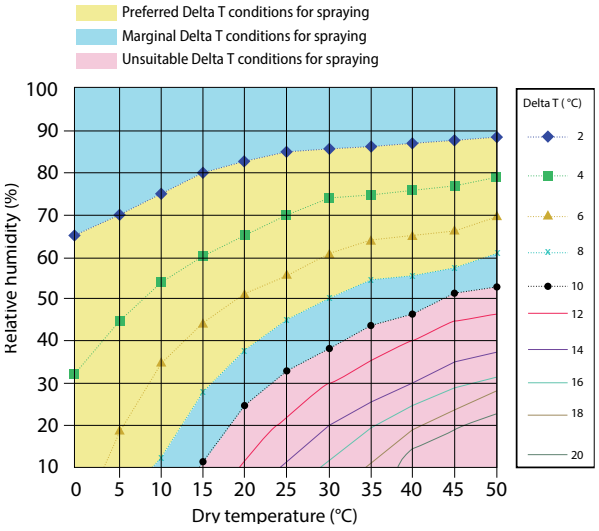

Figure 182. Delta T conditions for spraying. Source: Bureau of Meteorology.

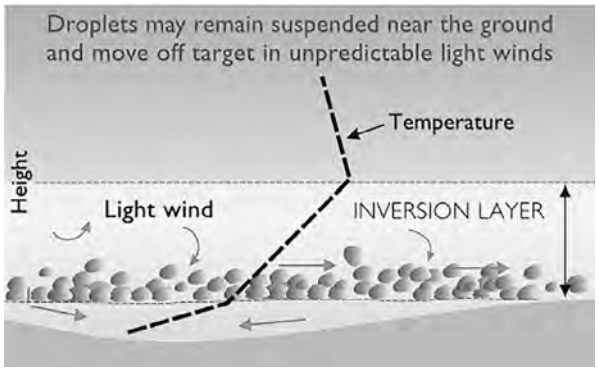

Figure 183. Surface inversion layer. Source: Bureau of Meteorology.

Inversions caused by radiation cooling are the most hazardous to pesticide applications because they can severely restrict dispersion and promote transport (drift) of air-borne 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 air-borne 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 to cotton crops and vineyards in northern river valleys in the Murray Valley.

How to anticipate and recognise radiation inversions

The potential for inversions to occur and to adversely hold high concentrations of air-borne pesticides near the surface should always be anticipated between sunset and up to 1 or 2 hours 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 fact sheet on temperature inversions (http://www.cottonmap.com.au/Content/documents/Temperature%20Inversions.pdf)
- the GRDC fact sheet on inversions and spraying (https://grdc.com.au/Resources/Factsheets/2014/08/Surface-temperature-inversions-and-spraying)
- the Bureau of Meteorology (BOM) fact sheet on 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 orchard 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 many websites. Data from the Bureau of Meteorology (BOM; http://www.bom.gov.au/) weather stations for the previous 72 hours can help when planning spray activities and are useful for understanding the current daily patterns of meteorological conditions.

However, if the closest weather station is many kilometres from the spray site, the information might not be as accurate as required. Therefore, growers would benefit from investing in a weather station (Figure 184) on-farm (around $3,000) as these data will be more accurate and thus assist with spraying decisions.

As well as a weather station, another measure to help combat spray drift is to install windsocks throughout the orchard. Taking a video (on your mobile) of the current conditions and comparing them to the Beaufort scale (http://www.bom.gov.au/lam/glossary/beaufort.shtml) will give an accurate account of conditions throughout the orchard on the day of spraying.

Meteograms

Meteograms are helpful when planning spray programs for periods of lowest drift risk and highest pesticide efficacy. They are mostly available by subscription. An example can be found at Weatherwise (https://www.weatherzone.com.au/models/meteograms). Meteograms provide 7-day forecasts for:

- temperature
- relative humidity
- Delta T
- rainfall
- wind speed and direction.

Source: M Scott, former Agricultural Chemicals Officer, NSW DPIRD, Orange.

Figure 184. A weather station in a macadamia orchard. Photo: Graham Wessling.

Further reading

Charles G and Koetz E (2015) *Reducing herbicide spray drift* (originally written by Andrew Storrie). NSW DPIRD, https://www.dpi.nsw.gov.au/biosecurity_old/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/resources-and-publications/all-publications/publications/2022/weather-essentials-for-pesticide-application

Your responsibilities when applying pesticides

Farm Chemicals Unit, Biosecurity and Food Safety, NSW DPIRD

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

Agricultural and Veterinary Chemicals Code Act 1994 (Commonwealth)

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

Permits for off-label use

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

Any individual or organisation can apply for a permit by contacting the APVMA on 02 6770 2300 or by email (enquiries@apvma.gov.au).

The label

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

Signal heading

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

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

Re-entry intervals

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

Pesticides and the environment

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

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

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

Withholding period

The withholding period (WHP) is the minimum time that must elapse between the last application of a pesticide and harvest. 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. However, some chemicals can also travel long distances as a vapour after spraying. There could be a risk of injury or damage to humans, plants, animals, the environment or property.

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

Safety instructions

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

Note: before opening and using any farm chemical, read the label and the safety data sheet (SDS) for safety directions.

NSW Pesticides Act 1999

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

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

The Act and Regulation require pesticide users to:

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

Training

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

Record keeping

Anyone who uses pesticides for commercial or occupational purposes must make a record of their pesticide use within 24 hours of applying the pesticide, and include:

- date, start and finish time
- operator details – name, address and contact information
- crop treated, e.g. macadamia
- property address and a clear delineation of the area where the pesticide was applied
- type of equipment used to apply the pesticide, e.g. knapsack, air-blast sprayer, boom spray
- full name of the product or products (e.g. Bayfidan 250 EC Fungicide® – not just 'Bayfidan')
- total amount of concentrate product used
- total amount of water, oil or other products mixed in the tank with the concentrate
- size of the block sprayed and the order of blocks treated
- an estimate of the wind speed and direction at the start of spraying the block and any changes if they occur
- weather conditions at the time of spraying and weather conditions specified on the label
- changes to wind and weather conditions during the application
- records must be made in English and kept for 3 years.

An example spray record from SMARTtrain is provided in Table 67.

Globally Harmonised System of classifying and labelling of chemicals

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

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

Commonwealth Work Health and Safety Act 2011

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

The Act defines the responsibilities of employers or the person conducting a business or undertaking (PCBU) and the responsibilities of workers.

The Regulation covers hazardous substances and dangerous goods, including applying the GHS in Australia.

SafeWork Australia has published several Codes of practice (https://www.safeworkaustralia.gov.au/law-and-regulation/codes-practice) for different industries and situations to guide industries.

NSW Work Health and Safety Act 2011

SafeWork NSW administers the *Work Health and Safety Act 2011* (WHS Act; https://legislation.nsw.gov.au/view/pdf/asmade/act-2011-10) and the Work Health and Safety Regulation 2017 (https://legislation.nsw.gov.au/view/html/inforce/current/sl-2017-0404).

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

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

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

- correctly labelling containers
- maintaining a register of hazardous chemicals
- identifying risk and ensuring the stability of hazardous chemicals
- ensuring that exposure standards are not exceeded
- information, training and supervision for workers
- spill containment kits are to be kept on-site
- SDS for chemicals are kept on-site
- controlling ignition sources and the accumulation of flammable and combustible materials
- provision of fire protection, firefighting equipment, emergency and safety equipment
- developing and displaying 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.

Acknowledgements

Brian McKinnon, Lecturer in Farm Mechanisation

Bruce Browne, former Farm Chemicals Officer, Biosecurity and Food Safety

Natalie O'Leary, Profarm Trainer.

Analytical laboratories

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

Eurofins Agroscience Testing
Phone 02 9900 8442
Website https://www.eurofins.com/

National Measurement Institute
Phone 1800 020 076
Website https://www.industry.gov.au/national-measurement-institute

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

Information sources

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

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

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

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

Hazardous substances information system (http://hcis.safeworkaustralia.gov.au/)

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

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

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 67. 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 (e.g. pH, hardness)	Droplet size	Boom height (above target)	Other
Chemical details							
Full product name (including additives)	Chemical rate	Water rate	Total amount of concentrate	Total amount of chemical mix used	Mixing order	Re-entry period	WHP (days)
Weather details							
Rainfall (amount and time from spraying)	Before: mm		During: mm		After: mm		
Time of spraying:	Temperature (°C)	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.

Avoiding pesticide resistance

Farm Chemicals Unit, Biosecurity and Food Safety, NSW DPIRD

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 the same 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 to all pesticides is an important consideration when choosing a control strategy. One strategy used is to rotate the chemical groups so the insect, mite, fungus or weed, are not continually treated with the same type of chemical. Repeated treatment with the same chemical group will lead to the organism developing resistance to that group.

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.

There is currently 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 (MOA).

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. However, there are options that must be used 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 control options are limited to a range of 1B chemicals. There should be a conscious decision to try to use alternative groups early and save the 1B chemistry for later when it will be most useful.

A typical scenario could be to spray macadamia lace bug early with a 4C or 4D product. Continue monitoring regularly for pests at this critical stage; it is unlikely that a second lace bug spray will be required. 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 later spotting bug and nut borer spray could be an opportunity to use the 3A chemistry before biocontrol release.

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 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 to achieve better IPDM 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. Using the same fungicide repeatedly allows these spores to multiply, until almost all the spores are resistant to, and unaffected by, the fungicide. Using a fungicide with a different MOA means 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. Unfortunately, in macadamia there are limited options to prevent husk spot, which is one of the industry's main fungal concerns.

Management strategies for husk spot control, including which chemicals should be used to prevent resistance, have been developed by Professor Olufemi Akinsanmi, plant pathologist at the University of Queensland. These strategies are outlined in Table 68.

> There should be no more than 2 consecutive applications of the same chemical group. This includes within season sprays one to 4, and between seasons, 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 2 fungicides with different MOA.

Specific recommendations for avoiding fungicide resistance are shown on many labels and chemicals are classified into groups. The principal groups adopted by the agrochemical industry through the APVMA and CropLife Australia are shown in Table 69 and Table 70. Only fungicides referred to in this guide are included.

Table 68. An example 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	Pyraclostrobin only or copper only	Copper only
2	Pyraclostrobin only	Pyraclostrobin only	Copper only or carbendazim + copper	Copper only or carbendazim + copper
3	Pyraclostrobin only	Carbendazim + copper	Pyraclostrobin only or carbendazim + copper or copper only	Copper only
4	Carbendazim + copper	Pyraclostrobin only	Pyraclostrobin only or copper only or carbendazim + copper	Copper only or carbendazim + copper

Table 69. 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®
		Trichlorfon	Tyranex® 500 SL
3A	Pyrethroid	Beta-cyfluthrin	Bulldock®
		Pyrethrin	Pyganic®
4A + 7C	Neonicotinoids + pyriproxyfen	Acetamiprid + pyriproxyfen	Trivor®
4C	Sulfoximines	Sulfoxaflor	Transform® Isoclast®
5	Spinosyn	Spinetoram	Success® Neo
6	Avermectin	Abamectin	Vertimec®
11C	Microbial	*Bacillus thuringiensis*	Bacchus®
18	Hydrazide	Tubufenozide	Ecdypro®
18	Diacylhydrazine	Methoxyfenozide	Prodigy®
22A	Oxadiazine	Indoxacarb	Avatar®
28	Anthranilamide	Tetraniliprole	Vayego® 200 SC

Table 70. 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®
		Mefentrifluconazole	Belanty®
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	Penthiopyrad + fluxapyroxad	Merivon®
11	Strobilurin	Pyraclostrobin	Cabrio®
33	Ethyl phosphonate	Phosphorous acid	Agri-fos®
M1	Inorganic	Copper fungicides	Kocide®

[1] Trade names that include the common name are not listed. Source: APVMA (https://portal.apvma.gov.au/pubcris) and CropLife Australia (https://www.croplife.org.au/).

[2] The information in the table shows insecticide and fungicide groups based on mode of action (MOA) only. For a chemical's compatibility with IPM, please refer to the chemical listings for individual crops.

* Example only. Other products are registered.

Minimising glyphosate resistance in Australian orchards and vineyards

This information (Table 71) on glyphosate resistance has been produced by the Australian glyphosate sustainability working group (AGSWG), a collaborative initiative to promote the sustainable use of glyphosate in Australian agriculture. The AGSWG gratefully acknowledges the financial support of the GRDC.

Table 71. Tip the scales in your favour to minimise glyphosate resistance risk in orchards and vineyards.

Risk increasing	Risk decreasing
Continually relying on glyphosate knockdown as a control agent under the tree or vine.	Strategic use of alternative knockdown groups.
Not using alternative herbicide mode of action (MOA) groups, including residual herbicides.	Using alternative mode of action (MOA) herbicides including residual herbicides.
Relying on herbicides for weed control instead of other means, e.g. mowing, mulching, tilling or grazing.	Adopting non-herbicide practices for weed control, e.g. mowing, mulching, tilling or grazing.
Allowing weeds to set seed.	Preventing weeds from setting seed.
Entering the cropping phase with high weed numbers.	Entering the cropping phase with low weed numbers.
Poor farm hygiene (machinery and stock coming onto the farm), which spreads resistant seeds.	Ensuring that all machinery and stock coming on the farm are 'clean'.
Lack of crop competition on weeds.	Using cover crops to compete with weeds.
All Group 9 (previously M) herbicides are glyphosate herbicides.	Using a double knock technique: full glyphosate rate followed by tilling or a full label rate of paraquat (Group 22, previously L).

Timing, calibration and spray coverage

Jeremy Bright, Development Officer – Macadamia, NSW DPIRD

Achieving effective pest and disease control requires understanding the significance and interaction of calibration, coverage and timing. Each is individually essential; if one is missing, the pest and disease control strategy will fail.

Calibration is making sure the right amount of product hits the target.

Coverage is ensuring the spray application covers the whole target area, including the high production front at the tops of the trees.

Timing is understanding the pest's life cycle and identifying the correct time to spray to achieve maximum efficiency and the least amount of product loss.

Where all 3 elements align, effective control is achieved (Figure 185).

The coverage needs to be checked to ensure it reaches the tops of the trees because this is where the production front predominates.

Inspect the 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 complement this knowledge.

Finally, ensure all spray equipment is calibrated. Just as other machinery is checked (e.g. the car every 10,000 km and the tractor every 1,000 hours), sprayers also need to be checked yearly. When the spray equipment is calibrated, the right amount of chemical should hit the target pest or disease.

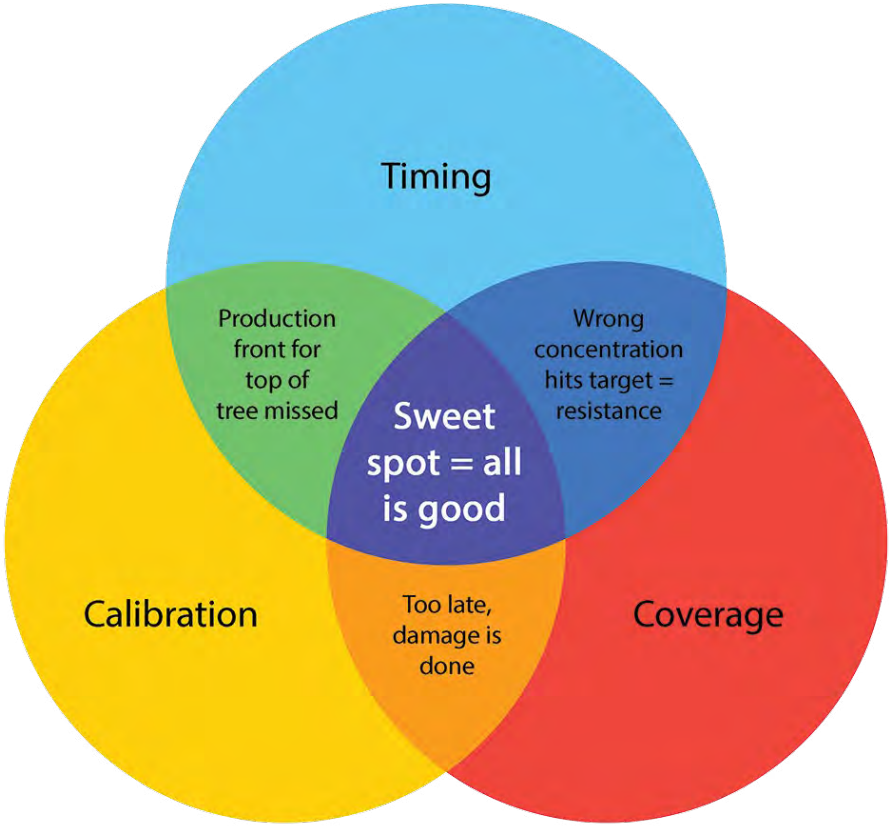

Figure 185. The 3 components needed to interact to achieve good control and production.

Tank mixing chemicals

Mark Whitten, Agricultural Liaison, Marquis Macadamias

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 to reduce the number of spray operations. Done incorrectly, incompatibility issues can lead to poor results and/or a big mess to clean out of the tank, filters, screens, nozzles and lines.

Top tank mixing tips

1. Keep mixes simple, i.e. only use 2–3 products.
2. Know the 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 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 a crop protection consultant or reseller.

Figure 186. Physical incompatibilities in tank mixes are evident when the chemicals fail to mix thoroughly. Photos: Purdue University.

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, multiple agricultural chemicals will often be combined into a single spray application. These chemicals include crop protection products, adjuvants, fertilisers, plant growth regulators and bio-stimulants.

This article provides a general guide on correct tank mixing to ensure the spray operations are efficient and effective. The information is general; if you are in doubt about the compatibility of certain products, first check the label. If the information is not on the label, conduct a jar compatibility test or contact the reseller or manufacturer.

Spray tank incompatibility

There are 2 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 the products separating into layers, or by gels, crystals or solids forming (Figure 186).

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 spray efficacy.

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.

- Do not add oils, surfactants or emulsifiable concentrates 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.

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 indoxacarb, which is available in solid (e.g. Avatar®) and liquid (e.g. Steward® EC) formulations. Table 72 lists registered pesticides used in macadamia, the active ingredient, an example trade name and formulation. Regardless of the product used, 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. Always 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 them a milky appearance and require agitation to remain dispersed in the tank.
- **Soluble concentrates/liquids (SL)** are true solutions, and once fully mixed, do not require agitation.

Tank mixing order

When adding multiple products to the spray tank, they must be added in a specific order so they can be properly mixed. This order relates to the 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. It is good practice to record products in your spray record in the order of mixing. This is useful when investigating poor spray results or failure.

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 disperse properly. 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® 600

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.

Table 72. Registered products used in macadamia management, their active ingredient, an example trade name, the 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
Acetamiprid + pyriproxyfen	Trivor®	DC	4A + 7C
Bacillus thuringiensis	Bacchus® WG	Various	11C
Beta-cyfluthrin	Bulldock® 25	EC	3A
Carbaryl	Bugmaster® Flowable	SC	1A
Indoxacarb (PER86827)	DuPont™ Steward®	EC, WG	22A
Methomyl (PER12796, Qld 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	Ecdypro 700 WP	WP	18
Tetraniliprole	Vayego® 200	SC	28
Trichlorfon (PER13689)	Tyranex® 500	SL	1B
Fungicides			
Carbendazim	Spin Flo®	SC	1
Copper ammonium acetate	Cop-IT®	SL	M1
Copper hydroxide	Kocide® Blue Xtra™	WG	M1
Copper oxychloride	Coppox	WP, WG	Y
Copper sulfate (tribasic)	Tri-base Blue®	SL	M1
Cuprous oxide	Ag Copp 750	WG	M1
Difenoconazole	Score®	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
Phosphorous acid	Agri-Fos 600®	SL	33
Pyraclostrobin	Cabrio®	EC	11
Pyraclostrobin + 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 spend extra time filling tanks for spraying, allowing enough time between each product addition is important to ensure they are fully dispersed in the spray tank. Adding products too quickly, even in the correct order, can result in physical incompatibility. This is particularly important when the AI is suspended and does not dissolve in water (e.g. many copper fungicides). Allow 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, 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 6–7). Some organophosphates (Group 1B) are especially sensitive to high water pH. For example, trichlorfon (e.g. Tyranex®) has a half-life of 3.7 days at pH 6 and a half-life of only 63 minutes at pH 8. This means that if the water in the spray tank 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 the water source, but also the pH of the products being added. Table 73 shows 2 water sources and their pH as well as the effect of various products. For example Seasol® has a pH between 10.4 and 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. 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 2 water sources is shown in Table 73. 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®.

The initial water pH and its buffering capacity (i.e. the water's resistance to change) will vary depending on the water source. Therefore, measuring the starting water pH and tank pH after product additions using either pH strips or a calibrated pH pen is important. If the starting pH is above 7 and you are using products likely to increase the pH, consider using a buffer.

Table 73. The effect of buffers on different water sources and product combinations.

Product	Rate (mL/100 L)	Dam water (pH)	Change	Rainwater (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 values will differ with time and location.

Water volume

The amount of water used affects the concentration of the products in a spray tank. The more concentrated the mix, the higher the chance of incompatibility. This can be a problem when concentrate spraying and/or not having enough water in the tank before adding any product. This is particularly important for WG formulations as they need to absorb water before they can properly break down and disperse. If there is insufficient water surrounding these products, their wetting and dispersing agents will not work. As a result, they can form clumps or gels, and settle to the bottom of the tank. This is why pre-mix WG formulations (e.g. Avatar® or Kocide®) should not be mixed 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 might be required from the reseller, manufacturer or through technical notes and product guides.

To avoid issues with water volume, always ensure spray tanks are 70% full before adding products. Additionally, when concentrate spraying, simplify tank mixes to reduce the chance of adverse product interactions and do not exceed 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 product mixing in 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 phosphorous 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 187). Generally, 10% of the pump's capacity is required for agitation, which must be considered when calibrating the spray unit.

Figure 187. Copper fungicide that has settled due to inadequate agitation.

Take home message

Tank mixing mistakes cost time and money, but they can easily be avoided by following the basic principles of correct tank mixing. This will improve orchard efficiencies and ensure effective spray applications.

Further reading

Gordon B and Betts G (2012) Spray mixing requirements: northern, southern and western regions mixing requirements for spraying operations. *GRDC fact sheet*, https://grdc.com.au/__data/assets/pdf_file/0023/224636/grdc-fs-spray-mixing-requirements.pdf.pdf

Gordon B and Betts G (2019) Water quality for spraying operations. *GRDC fact sheet*, https://grdc.com.au/__data/assets/pdf_file/0041/387896/GRDC_FS_Spray-Water-Quality1902_screen.pdf.

Kitt J and Gordon B (2017) Mixing and decontamination: avoiding potential problems. In *Spray application for grain growers*, Module 7, GRDC Grownotes, https://www.adama.com/australia/sites/adama_australia/files/product-documents/2025-05/GRDC%20GROWNOTES%20%20-%20Mixing%20and%20decontamination.pdf

Martin A, Whitford F and Jordan T (2011) *Pesticides and formulation technology*. Purdue Extension, PPP-31, www.extension.purdue.edu/extmedia/ppp/ppp-31.pdf

Whitford F, Olds M, Cloyd R, Young B, Linscott D, Deveau J, Reiss J, Patton A, Johnson B, Overley T and Smith K (2018) Avoid tank mixing errors: a guide to applying the principles of compatibility and mixing sequence. *Purdue Extension,* PPP-122, https://ppp.purdue.edu/wp-content/uploads/files/PPP-122.pdf

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 (http://www.drummuster.org.au) while chemicals can be disposed of through ChemClear® (http://www.chemclear.org.au). 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. These are in addition to bagMUSTER (https://www.bagmuster.org.au/).

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, 35 million containers have been recycled.

Once collected, containers are recycled into 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, unwanted containers can be turned into useful, sustainable products rather than placing them into landfill or building up on farms.

Only containers with 'drumMUSTER eligible container' printed on the label, as a sticker or embossed on the container (Figure 188) are accepted. To contact drumMUSTER, visit the drumMUSTER website (https://www.drummuster.org.au/) or phone 1800 008 707 or 02 6230 6712.

Figure 188. A chemical container with a 'drumMUSTER eligible container' printed on the label. Photo: drumMUSTER.

Cleaning containers for collection

When rinsing chemical containers, the personal protective equipment (PPE) specified on the label for applying, 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. Using the rinsate this way avoids the necessity of 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 to 20% of the container volume (e.g. 1 L per 5 L).
3. replace the cap and shake vigorously for 1 minute.
4. remove the cap, invert and drip drain into the mixing tank for 30 seconds.
5. repeat twice.
6. wash the cap separately and replace it 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 2 main types of nozzle. One has a rotating spray head, which can be used 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 has 4 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 pressure.
3. Insert the pressure rinsing probe into the container opening or through the pierced base of the container (depending on the nozzle type).
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 with a flushing cycle and 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 drumMUSTER (http://www.drummuster.org.au) or call 1800 008 707.

ChemClear®

ChemClear® provides Australian agvet chemical users with a collection and disposal pathway for unwanted chemicals. ChemClear® complements drumMUSTER by providing agvet chemical users with a recycling and disposal option.

ChemClear® collects 2 categories of agvet chemicals:

Group 1 chemicals are 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 2 years). A per litre/kilogram fee for disposal applies.

Disposing of rinsate or dilute chemical

Labels contain a prohibition on disposing of concentrate on-site or on-farm, as per state environmental legislation. The unused chemical must first 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 1 m deep, lined with plastic sheeting over which has been spread hydrated lime, and any waste covered with at least 0.5 m 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.

For more information or to register for the program, visit ChemClear® (http://www.chemclear.org.au) or call 1800 008 182.

Macadamia growers' resources

NSW DPIRD Primefacts are available free from the NSW DPIRD website (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

NSW Macadamia plant protection guide (this book) can be collected from the NSW DPIRD Wollongbar office and from processors, and can be downloaded from the NSW DPIRD website (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

The ***Macadamia grower's guide*** has been updated, and all 6 modules can be downloaded from the NSW DPIRD nuts webpage (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts).

Macadamia integrated orchard management practice guide introduces canopy, orchard floor and drainage management as the 3 pillars of integrated orchard management. It also introduces stages of orchard development and provides a framework for assessing orchard blocks across the 3 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 guide can be collected from the NSW DPIRD office at Wollongbar or processors, and can be downloaded from the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management).

Macadamia integrated orchard management case studies is a companion to the ***Macadamia integrated orchard management guide***. 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 (2 from each Australian macadamia growing region). These books can be collected from the NSW DPIRD Wollongbar office, from processors and can be downloaded from the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management).

Macadamia integrated orchard management drainage can be downloaded from the NSW DPIRD website (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.

macSmart (www.macsmart.com.au) has more than 50 short and informative YouTube video interviews with growers and researchers on canopy management, innovative farm practices, orchard floor management, top performing farms, and the latest research.

Macadamia problem solver and bug identifier is an excellent reference for pest and disease identification. It can be downloaded from the Queensland Department of Primary Industries website free in several sections (http://era.daf.qld.gov.au/id/eprint/1964/).

Macadamia variety identifier is a useful resource that helps with identifying 24 varieties. The publication can be downloaded from the Queensland Department of Primary Industries website (https://era.daf.qld.gov.au/id/eprint/1964/14/mac-varieties.pdf).

Australian Macadamia Society grower resources is an up-to-date industry resource library containing fact sheets, grower case studies and manuals, research reports and updates, videos and more. It has been compiled by the Australian Macadamia Society with the assistance of industry experts and can be downloaded free (to members) from the Australian Macadamia Society website (www.australianmacadamias.org/industry/resources).

Establishing and managing smother grass on macadamia orchard floors is a guide on how to establish smother grass, including costs and management. It can be downloaded from the NSW DPIRD website (https://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 and can be downloaded from the NSW DPIRD website (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/soil-macadamia).

Internet sites for macadamia growers

Agricultural industry organisations

Australian Macadamia Society (www.australianmacadamias.org/industry)

Australian Nut Industry Council (https://nutindustry.org.au/)

Horticulture Innovation Australia (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)

Alternative systems (organics)

Australian Certified Organic (https://aco.net.au/)

Australian Organic (https://austorganic.com/)

Australian Organic Certification and Grower Groups (www.nasaa.com.au)

Biosecurity

Farm Biosecurity (https://www.farmbiosecurity.com.au/crops/fruit-nuts/fruit-nut-pests/nut-pests/)

NSW DPIRD Plant Biosecurity (https://www.dpi.nsw.gov.au/dpi/biosecurity/plant-biosecurity)

Department of Primary Industries, Queensland (https://www.dpi.qld.gov.au/business-priorities/biosecurity/plant)

Climate

Climate Outlook (http://www.bom.gov.au/climate/)

Bureau of Meteorology (http://www.bom.gov.au/)

National Centres for Environmental Prediction (https://www.weather.gov/ncep/)

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 (https://www.dcceew.gov.au/)

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

Office of Environment and Heritage (www.environment.nsw.gov.au)

Qld Department of Environment and Heritage Protection (https://environment.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 (https://www.austrade.gov.au/)

Department of Agriculture and Water Resources (www.agriculture.gov.au)

Land and Water Australia (www.lwa.gov.au)

Plant Health Australia (www.planthealthaustralia.com.au)

Grower services

Suncoast Gold Macadamias (Aust) Ltd (www.suncoastgold.com.au)

Integrated pest management

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

Biological Services (https://www.biologicalservices.com.au/)

BioResources (https://bioresources.com.au/)

Bugs for Bugs (https://bugsforbugs.com.au/)

Pesticides – use and disposal

Australian Pesticides and Veterinary Medicines Authority (www.apvma.gov.au)

bagMUSTER (https://www.bagmuster.org.au/)

ChemClear (www.chemclear.com.au)

drumMuster (www.drummuster.org.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 (https://marquis.com/)

MWT Foods (www.mwtfoods.com)

Nambucca Macnuts (www.macnuts.com.au)

Nutworks (www.nutworks.com.au)

Pacific Farm Services (http://linkedin.com/company/macadamias/?originalSubdomain=au)

Plenty Foods (https://www.plentyfoods.com.au/)

Stahmann Webster (https://stahmannwebster.com.au/)

Suncoast Gold Macadamias (Aust) Ltd (www.suncoastgold.com.au)

Swiss Gourmet (www.swissgourmet.com)

Waliz Nuts (https://waliznuts.com/)

Rural assistance

Centrelink (www.centrelink.gov.au)

Health NSW (www.health.nsw.gov.au)

Qld Health (www.health.qld.gov.au)

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

Queensland Rural and Industry Development Authority (https://www.qrida.qld.gov.au/)

Rural Skills Australia (https://rist.edu.au/)

State government

Department of Primary Industries, Queensland (https://www.dpi.qld.gov.au/)

Local Land Services NSW (www.lls.nsw.gov.au)

NSW Department of Primary Industries and Regional Development (www.dpird.nsw.gov.au)

SafeWork NSW (https://www.safework.nsw.gov.au/)

WorkSafe Queensland (https://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 in rural and regional NSW. LLS bring together agricultural production advice, biosecurity, natural resource management and emergency management into one organisation. LLS horticulture officers help producers with the challenges they face today and take advantage of future opportunities to improve 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 DPIRD Biosecurity and Food Safety

NSW DPIRD 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. All enquiries should 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

IPDM Scorecard

Instructions

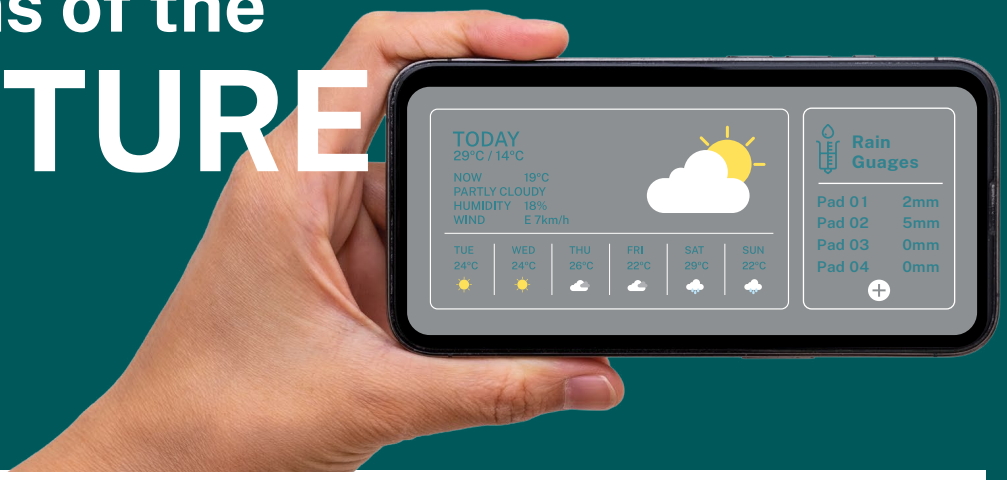
- record the pest or disease, chemical and IPDM score in the table.
- at the end of the season, tally up the IPDM score.
- insert production in tonnes of NIS @ 10% in the bottom corner.
- scan the document and email it to jeremy.bright@dpird.nsw.gov.au.

Pest	Product and active ingredient	IPDM score
E.g. macadamia lace bug	Transform® Isoclast®, sulfoxaflor	5
Total		

Production t/ha (NIS@10%) _____

Farms of the FUTURE

NSW GOVERNMENT



Grow with Agtech

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

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

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

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

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

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

Subscribe for events and training

A Smarter Way to Tackle Your Farm's Pain Points

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

Merivon®
Fungicide

Belanty®
Fungicide

Protect your macadamias with this powerful duo

Use Merivon® early in the season for flower blight complex, followed by Belanty® for effective husk spot management.

Why choose this powerful pair?

- Wide application windows
- Short withholding periods
- Excellent in spray rotation for resistance management
- Compatible in an IPM program

For more information, scan the QR code or visit crop-solutions.basf.com.au

BASF
We create chemistry

ALWAYS READ AND FOLLOW LABEL DIRECTIONS.