Macadamia plant protection guide 2021–22

NSW DPI MANAGEMENT GUIDE

Jeremy Bright

www.dpi.nsw.gov.au

PROTECT YOUR NUTS

BORDEAUX WG

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

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

NASAA INPUT FOR ORGANIC PRODUCTION Cert. No. A6358M

HYDROCOP WG

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

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

NASAA INPUT FOR ORGANIC PRODUCTION Cert. No. A6358M

TRIBASIC LIQUID

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

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

CROP DOC 600

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

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

KINGFISHER

Systemic Fungicide
250g/L Difenoconazole

- Control of Husk spot
- Available in 5L packs

PEREGRINE

Contact and residual Insecticide
240g/L Methoxyfenozide

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

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*Always read product labels and permits before use.

Department of Primary Industries

Macadamia plant protection guide 2021–22

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (June 2021). However, because of advances in knowledge, users are reminded of the need to ensure that the information upon which they rely is up to date and to check the currency of the information with the appropriate officer of the Department of Regional NSW or the user's independent advisor.

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Always read the label

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

Permits

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

Image acknowledgements

Cover image: a macadamia tree in peak flower, Jeremy Bright.

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

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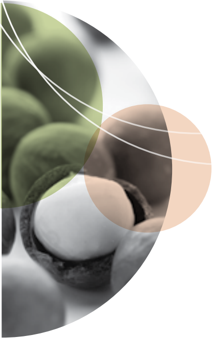

Contents

About this guide

This 7th edition of the *NSW Macadamia plant protection guide* aims to provide commercial macadamia growers with up-to-date information on all aspects of protecting your orchard from pests and diseases.

Feature article

Five years after introducing the concept of integrated orchard management to the macadamia industry, we look at the potential benefits this approach can have on pest and disease control. This article will look at stage two of each of the pillars and discuss the effects on orchard productivity and yield.

Pesticides

We do not list every pesticide that is registered for a specific use, but rather guide growers in their choice of chemicals. It is our policy to use common chemical names or active ingredients, not trade names, when referring to pesticides, crop regulation compounds and nutrient sprays. This practice is necessary because there can be many product names for the same active ingredient and it would be impossible to list them all at each mention in the guide.

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

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

Distribution

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

Acknowledgements

Special thanks to Dr Jay Anderson, Senior Research Fellow at Southern Cross University for reviewing the diseases section and to Jenene Kidston, Technical Specialist Farm Chemicals NSW DPI, for reviewing the pesticide recommendations.

Feedback please

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

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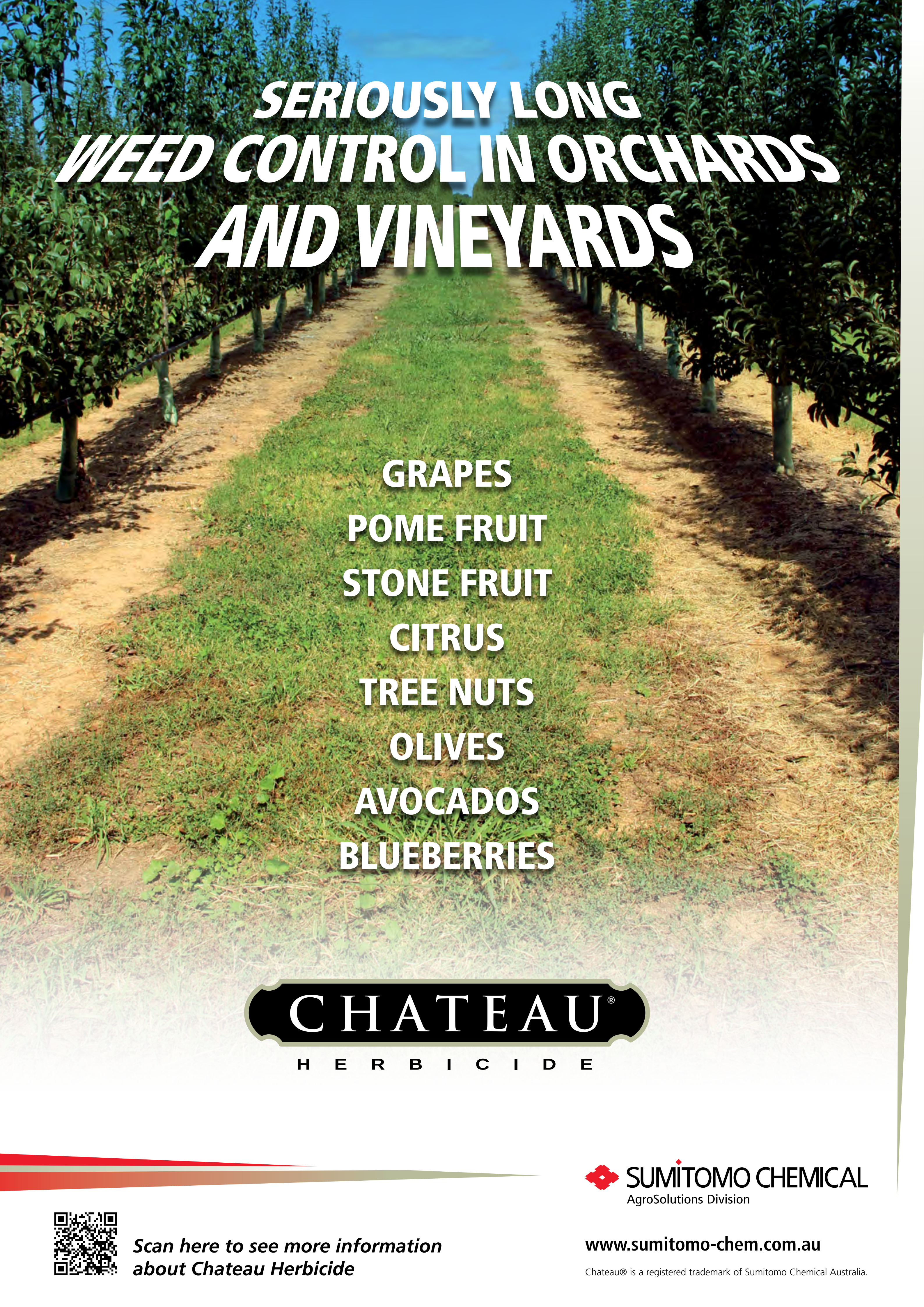
Figure 1. Macadamia landscape viewed from a hot air balloon.


SERIOUSLY LONG
WEED CONTROL IN ORCHARDS
AND VINEYARDS
GRAPES
POME FRUIT
STONE FRUIT
CITRUS
TREE NUTS
OLIVES
AVOCADOS
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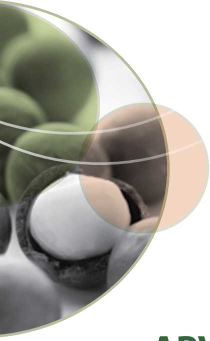

What's new?

APVMA review continues

The APVMA is reviewing several chemicals. The priority list includes the following that are relevant to the macadamia industry:

- acephate
- carbamate
- methomyl
- triazole
- trichlorfon.

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

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

End of the line for Supracide

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

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

This flowering (2021) will see the first year of zero methidathion use. NSW DPI has been investigating alternative options for the chemical and the pests that it controls. In many cases, we saw control of non-target pests, which could potentially become a problem. We are considering effects to other insects, pests and beneficials, costs, suitability in fitting into an IPDM system and the effects on the environment.

PER13689

PER13689 will expire on 30 September 2021. Renewal is pending with the APVMA. If you wish to use trichlorfon to control macadamia lace bug, fruit spotting bug, banana spotting bug or green vegetable bug, please check for the renewal at https://portal.apvma.gov.au/permits before doing so.

New pest added

The tea mosquito bug has been added to the pest section. This is mostly a pest for north Queensland macadamia growers but has been reported as far south as Brisbane.

New macadamia development stage

We have added bud break to the macadamia development stages because there are many pests and diseases active around this stage. The bud break images were generously supplied by Chris Fuller.

Permits

Due to the sheer volume of this guide and the impending expiry dates of some permits, individual permits are not in this publication. All permits relevant to the macadamia industry can be obtained through the APVMA website (https://portal.apvma.gov.au/pubcris). Each permit referred to in this guide is listed under the relevant pest or disease and is hyperlinked for ease of reference.

IPM project update year 4

The macadamia IPM project is now 4 years old. Some of the partners within this project have provided updates for the *NSW Macadamia plant protection guide* showing how their section of the project is progressing. IPM will not have a final destination. The industry will continue along the path as we understand further the significance of cultural, biological and chemical practices.

> ***"IPDM is not an outcome; it is a journey"***

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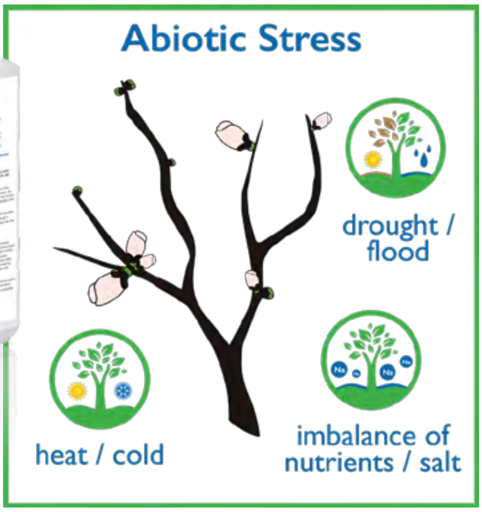

Stoller's range of products:

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Bundaberg Queensland

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Macadamia development stages

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

1. bud break: includes early small bud emergence until the green raceme is fully extended (Figure 2 and Figure 3)
2. pre-flowering: includes fully extended elongated green raceme. Buds/perianth tube along the raceme up to the stage of full elongation. Previously referred to as stage 1 flowering (Figure 4 and Figure 5)
3. early flowering: some bud/perianth tubes from pre-flower have started to open, generally starting from top of raceme to bottom of raceme order. Flower will still have some buds/perianth tubes that have not yet fully opened (Figure 6 and Figure 7)
4. peak flowering: most of the tree has fully extended and opened flowers. Formerly described as stage 2–3 flower development (Figure 8 and Figure 9)
5. nut set: pollinated nut is up to and including match head size. The ovary at the base of the style is starting to swell to 'red head' of a match size; was formerly described as stage 4 flowering (Figure 10 and Figure 11)
6. pea size nut and spring flush: nut is now expanding from match head size up to pea size (8–10 mm diameter) (Figure 12)
7. shell hardening and oil accumulation: nut sizing has ceased and nut is now accumulating oil for maturity and harvest (Figure 13).

Bud break

Figure 2. Bud break. Photo: Chris Fuller.

Figure 3. Bud break close up. Photo: Chris Fuller.

Pre-flowering

Figure 4. Pre-flowering.

Figure 5. Pre-flowering.

Early flowering

Figure 6. Early flowering.

Figure 7. Early flowering.

Peak flowering

Figure 8. Peak flowering.

Figure 9. Peak flowering.

Nut set

Figure 10. Nut set.

Figure 11. Nut set (match head size).

Pea size nut and spring flush

Figure 12. Pea size nut and spring flush.

Shell hardening

Figure 13. Shell hardening.

IPM project: year 4 updates

The Macadamia Integrated Pest Management (IPM) Program, using Hort Innovation funds from the Macadamia Levy, was launched in January 2017. The program involves a team of researchers and crop consultants with a diverse range of skills (Figure 14), focusing their efforts on developing sustainable pest management practices for the macadamia industry. Combinations of biological, cultural and chemical controls are being tested on commercial farms and research stations as part of the program. This section of the guide features updates from some of the program components.

Figure 14. The IPM project team.

New South Wales Department of Primary Industries

Dr Ruth Huwer,Entomologist, NSW DPI

The NSW DPI component of the project is assessing different insect pest management strategies across the four major growing regions of Australia, being Central Queensland (CQ), South East Queensland (SEQ), Northern Rivers of NSW (NRNSW) and Mid North Coast of NSW (MNNSW). The specific trials included:

1. Comparing established chemical controls with reduced/softer chemical controls

This trial, located at the NSW DPI Centre for Tropical Horticulture, will run for four seasons and will involve different chemistries and application timing in conjunction with biological and cultural controls to determine the effectiveness of different approaches. The trials aim to identify opportunities to reduce the impact of chemical control options by understanding if 'softer' chemistry options are viable and/or biological/ cultural controls can provide sufficient protection to reduce or eliminate the need for chemical control of particular pest insects.

Part A (standard vs soft chemistry/single vs split spraying)

- Generally, damage from macadamia seed weevil (MSW), fruit spotting bug (FSB) and macadamia nut borer (MNB) was higher in the softer chemistry treatments
- The greatest effect on FSB damage was achieved with the standard treatment

Figure 15. Inter-row planting for biodiversity can assist in pest control. Photo: Ruth Huwer.

- The split timing in the softer chemistry treatment improved bug control.

Part B (inter-row plantings for pest control)

- The unsprayed treatment showed that if there is no MSW management, losses are high early in the season
- The inter-row treatment (Figure 15) showed the importance of the single application of indoxacarb to manage MSW
- MNB damage is minimal in the inter-row block, possibly due to higher biodiversity that is not disturbed by chemical intervention, giving natural enemies the best chance.

2. Case studies of different pest management approaches

For each major macadamia growing region, two commercial macadamia sites are being monitored for the effects of insect pests on nut loss and yield over four harvest seasons. For each region, contrasting commercial orchards were selected to consider the opportunities and obstacles associated with pest management strategies that have varied emphasis on using chemical, biological or cultural controls.

There are several variables to consider when choosing pest management strategies. These can include site location, tree variety, pest pressure and tree phenology. Successful insect pest management is influenced by the interplay of these factors and an orchardist's preference for biological, cultural and chemical controls that align with their social, economic and environmental (triple bottom line) expectations in orchard management. This makes it beyond the scope of this project to provide prescriptive recommendations for pest control. Rather, the results from this work are aimed at providing a snapshot of different approaches and their relative success in achieving each pillar associated with triple bottom line outcomes.

Observations so far include:

- Improved management strategies have been implemented at each case study site using a combination of different management tools. Each case study site and the associated pest issues are different, thus there is not one single recipe for an IPM strategy that suits each farm
- Whatever approach the grower is using for pest

and disease management strategies, one thing is clear; **monitoring is essential**

- A holistic IPM approach must be based on monitoring and include a combination of cultural and biological control, as well as targeted, well-timed chemical control (Figure 16).

The main results are:

- Each case study site had unique pest problems and management approaches. One example is felted coccid (Figure 17). This pest has been particularly severe around the Bundaberg region. Each site used components of IPM to varying degrees
- The 'softer' chemistry approach in each region contributed to increased biodiversity
- Synthetic pyrethroids (e.g. Bulldock®) appear to have the strongest effect on beneficial populations (particularly spiders) and scale insects in general
- Data analysis from yellow sticky traps and bark beetle traps is ongoing
- Fruit spotting bugs are still the main pest problem across the regions, particularly the Mid North Coast. Management of FSB to avoid late damage is a key point and biological control does not seem to be sufficient on its own.

Certain tools need to be part of any IPM strategy for macadamia farms:

Monitoring

Monitoring is crucial for any IPM strategy. It is important to know the populations of different pests and beneficials. Using yellow sticky traps, MNB pheromone traps, monitoring of MNB eggs, FSB monitoring hedges, BSB pheromone traps and pheromone traps for different scolytid species were all part of an IPM strategy for the case study farms.

Figure 16. Cultural and biological control with supporting targeted chemical controls are being used on a MNC IPM case study site. Photo: Bob Maier.

Cultural control

Canopy management is essential to keep the orchard open and to ensure good coverage of chemical applications. Further cultural control measures are hygiene (e.g. removing infected nuts from the ground for MSW management) and having inter-row crops to increase biodiversity and therefore the presence of general predators and parasitoids. This also relates to hygiene and biosecurity between farms and regions.

Biological control

Releases of biological control agents (*Anastatus* spp. and/or *Trichogrammatoidea cryptophlebiae*) were made on all case study sites.

Chemical control

Strategic use of more specific chemicals based on life cycle monitoring rather than calendar spraying, using chemicals more compatible with biological controls and minimising the use of broad-spectrum insecticides were all implemented on the case study sites. This included the use of new chemicals like sulfoxaflor. A rotation of groups of chemicals to avoid secondary pests is also important.

Studies relating to inter-row plantings and effects on pests and beneficial populations will be reported in the next *Macadamia plant protection guide*, as results are still being analysed.

Hort Innovation
Strategic levy investment
MACADAMIA FUND

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

Figure 17. Felted coccid has been particularly bad around the Bundaberg region. Photo: Eddy Dunn.

BioResources

Abigail Makim, Christopher Carr, Alana Govender, Richard Llewellyn, BioResources Pty Ltd

The BioResources Inter Row Project (MC16008) found that inter-row vegetation management decisions strongly influence insect presence in the orchard. Overall, increased diversity and volume of plant species results in more beneficial insects. This is because there are improved habitats and food sources, particularly for beneficial predators and parasitoids. These natural predators of crop pests are conserved within the orchard and at times when the crop is most developmentally vulnerable to insect pests.

Three achievable options for managing inter-row vegetation to sustain biological control are:

1. reduced mowing of existing grasses and weeds in centre strips
2. reduced alternate row mowing of existing grasses and weeds
3. inter-row cover crops – sowing selected seed mixes in the inter-row for soil health and insectaries.

Detailed results from these options were presented in the *2019–20 Macadamia plant protection guide*.

Incorporating cover cropping into orchard management systems

In this year's guide, we present a case study of inter-row cover cropping (Figure 18 and Figure 19), which provided several useful insights for macadamia orchards. Many in the industry have been concerned that changes to conventional management for the inter-row could lead to significant problems such as increased rat activity, invasive weeds and/or insect pests. However, the results from this case study should reassure growers, because they showed that innovative and sophisticated strategies for cover cropping are achievable and can be incorporated into existing orchard inter-row management. Furthermore, with basic monitoring and management, there should be no increase in rat activity, invasive weeds or insect pests.

Figure 18. Cover crop strips in the inter-row. The seed mix included sunflowers, vetch, forage sorghum and other species.

Promising results for beneficial arthropods

We compared arthropods sampled in a 'close mow' block (Figure 20; this being representative of conventional orchard floor management with regular mowing) with a cover crop block (Figure 21). The two blocks were on the same farm and otherwise managed under one system.

Overall abundance of arthropods in the cover crop block was double that of the close mow block. Beneficial insect populations increased in the cover crop block without corresponding increases in macadamia herbivores or macadamia pests. Most notably, there were three times more parasitoids in the cover crop inter-row and more than double in the cover crop macadamia trees compared to the close mow treatment (Figure 23). Similarly, there were almost three times more predators in the cover crop block, and nearly double in the cover crop macadamia trees (Figure 24).

There were more insects in the cover crop block in both the inter-row and macadamia tree habitats, except for thrips (a potential pest), which were four times more abundant in the close mow block. When comparing the cover crop with the complete close mow proportionally, predators

Figure 19. The cover crop strip in the inter-row, with a regularly mowed area under the drip line for harvest. Inter-row cover crop strips are being managed on an alternate row basis to minimise disturbance to plant and arthropod ecology throughout the orchard. Ground preparation for re-seeding is visible (right).

and parasitoids were more abundant in a ratio of 80:20 in the inter-row and nectarivores (potential pollinators) had a ratio of 60:40 in the inter-row and trees. Overall, there were more insect families represented in the cover crop block in both the inter-row and the macadamia trees.

Figure 20. Case study – close mow 20 June 2019.

Figure 21. Case study – cover crop 20 June 2019.

Case Study – cover cropping and beneficial insects, northern New South Wales

Row width – 14 m

Centre seeded strip width – 3m

Excellent light to the orchard floor.

Plant species ID – seasonal seed mixes combining cover crops suitable for the macadamia orchard (e.g. vetch, smart radish, millet, crimson clover, sorghum, sunflower, flax, sunn hemp and rye corn). Different seed mixes for under the drip-line and the centre strip.

Comments – dedicated cover cropping system with specialised machinery and long-term soil health management. Specific planning and scheduling of seasonal reseeding year-round. Reseeding alternate rows to limit disturbing the insectary. In conjunction with conservation biocontrol, there are strong ecosystem services for soil microbiology, water storage and carbon sequestration.

This is a specialised system and further details and grower recommendations are available in the final report and on the BioResources website.

Figure 22. An inter-row with a seasonal seed mix providing habitat and food for beneficial insects.

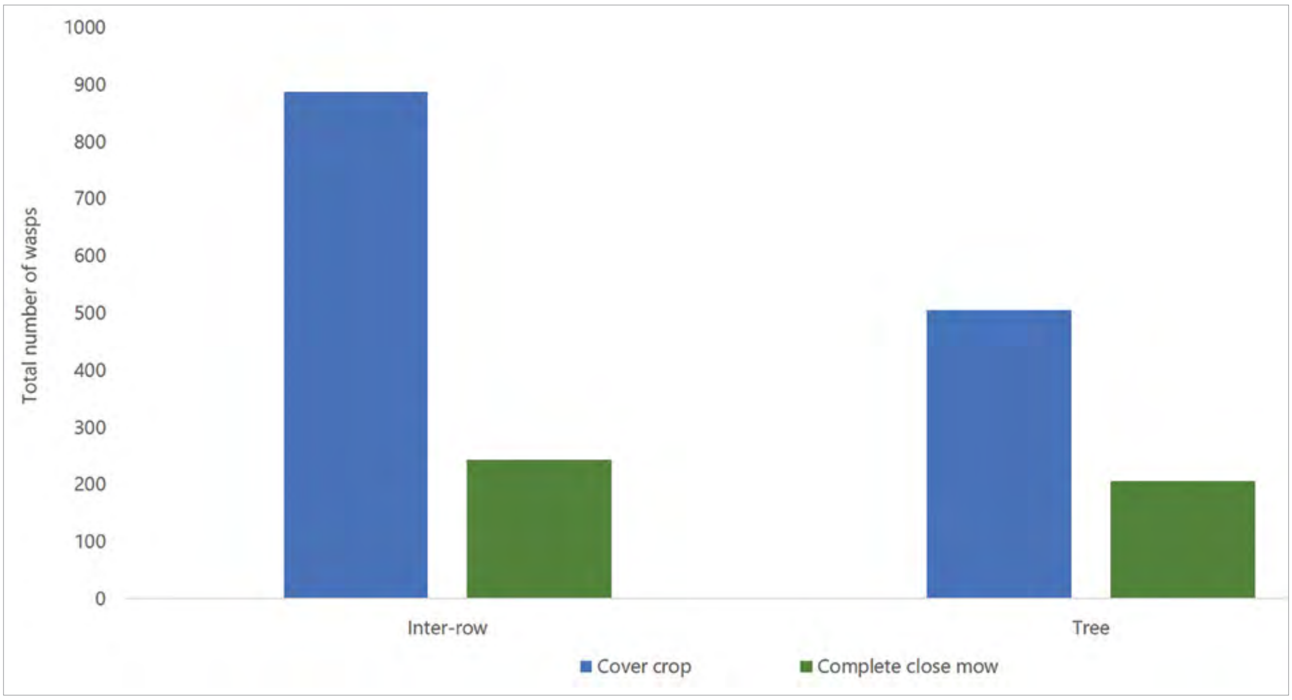


Figure 23. Comparison of the number of parasitoids caught in the inter-row and trees by treatment. The cover crop environment supports more parasitoids in both the inter-row and tree. Parasitoids are crucial beneficial insects in macadamia IPM.

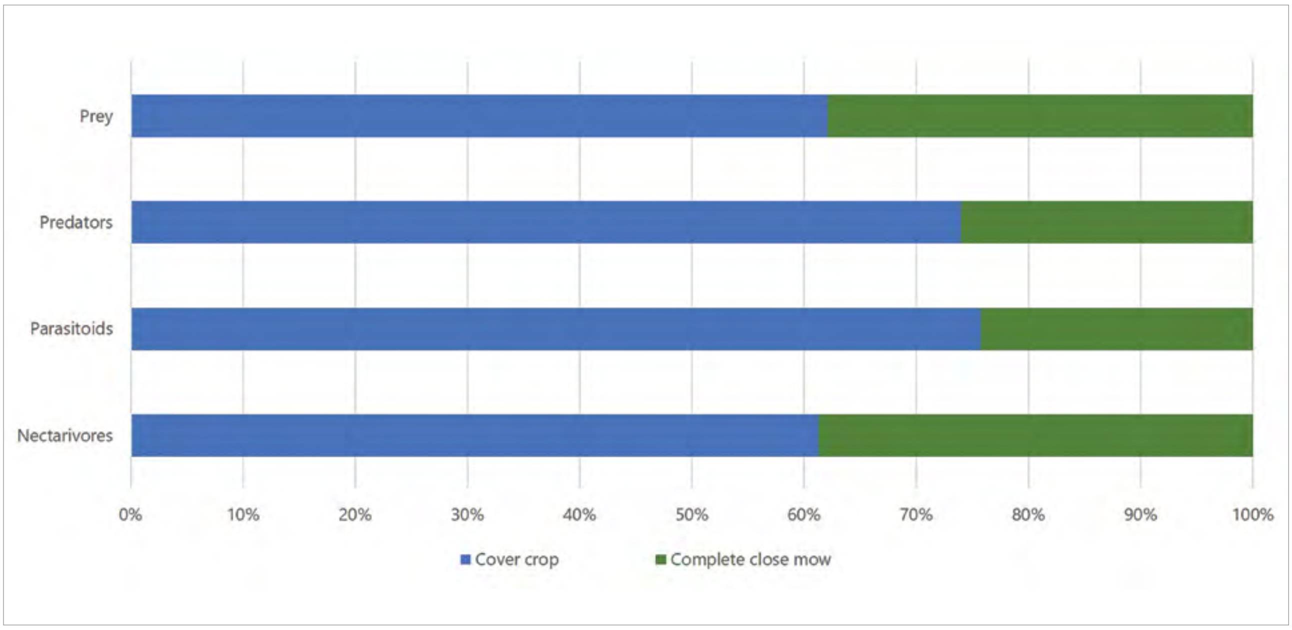


Figure 24. Comparison of simplified feeding guilds of beneficial insects – prey, predators, parasitoids and nectarivores (potential pollinators). More beneficial insects were caught in the cover crop.

Extension for growers interested in cover crops, insectaries and native vegetation on-farm

From June 2020, BioResources began extension work for growers interested in cover crops in their inter-row. This activity particularly targets growers with dark orchards or growers setting up new blocks. In 2021, BioResources began providing extension for growers interested in insectaries and native vegetation areas for ecosystem services on-farm. This extension work is done in partnership with Land Care.

The Final Report for the BioResources Inter-row Project (MC16008) can be found on the Hort Innovation and BioResources websites. See http://www.bioresources.com.au/inter_row_project/publications.html

Queensland Department of Agriculture and Fisheries

Shane Mulo and Grant Bignell

Benchmarking the macadamia industry

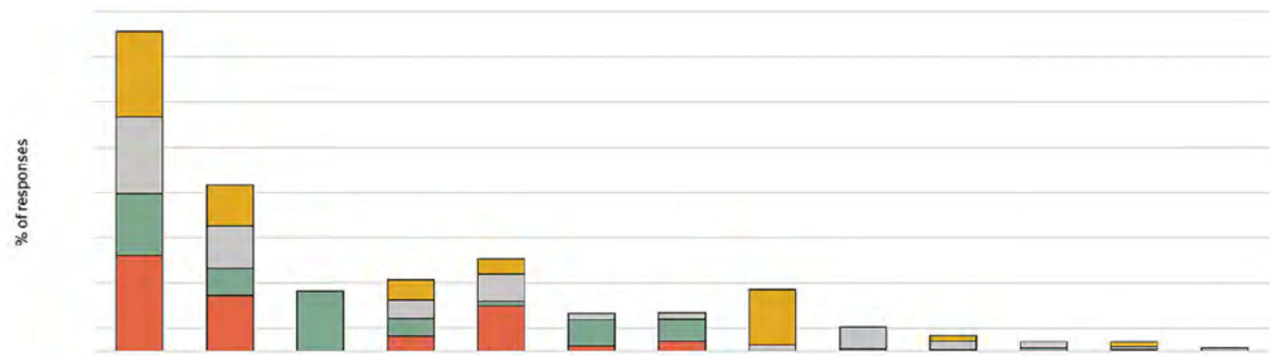
Benchmarking in the macadamia industry has been tracking farm productivity and quality for the past 12 years (2009–2020). This year, the benchmark team asked growers about the top three limitations to production in each region for the 2020 season. A total of 195 farms provided 373 responses, representing approximately 71% of all bearing farms in the benchmark sample.

Pests limiting production

Fruit spotting bug (FSB) was the most reported pest limiting production, averaging 32% of responses across all regions (Figure 25). The proportion of farms reporting limitations due to FSB was highest in the Mid North Coast of New South Wales (MNNSW; 42%), followed by Central Queensland (CQ; 38%), South East Queensland (SEQ; 34%) and Northern Rivers of New South Wales (NRNSW; 27%).

Rats were the next most significant pest limitation in all regions, averaging 16% of responses across the sample. The highest proportion of farms reporting limitations due to rat damage were again in MNNSW (24%), with all other regions reporting similar rates (16-19%).

Losses due to macadamia seed weevil were the next most common response (15% overall), although it is important to note that these were limited to the NRNSW region, where the pest accounted for 26% of responding farms.



	Fruit Spotting Bug	Rats	Macadamia seed weevil	Macadamia nut borer	Birds	Lace bug	None	Flower caterpillar	Leptocoris	Other	Bark beetle	Green vege bug	Feral pigs
CQ	38%	18%	0%	9%	7%	0%	0%	24%	0%	2%	0%	2%	0%
SEQ	34%	19%	0%	8%	12%	3%	3%	3%	9%	4%	3%	1%	1%
NRNSW	27%	12%	26%	8%	2%	12%	10%	0%	1%	0%	1%	0%	0%
MNNSW	42%	24%	0%	7%	20%	2%	4%	0%	0%	0%	0%	0%	0%
All regions	32%	16%	15%	8%	7%	7%	6%	3%	2%	1%	1%	1%	0%

Figure 25. Major pests limiting macadamia production in the 2020 season.

CQ = Central Queensland
SEQ = South East Queensland
NRNSW = Northern Rivers of New South Wales
MNNSW = Mid North Coast of New South Wales

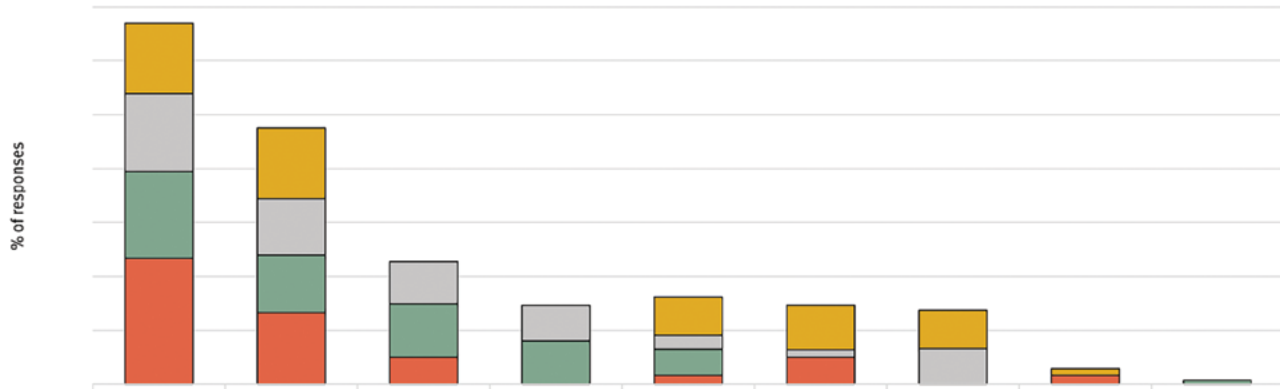
Diseases limiting production

The disease most reported as limiting production was Phytophthora root rot, which averaged 32% of responses across the sample (Figure 26). The highest proportion of responses were from MNNSW (47%) followed by NRNSW (32%).

Branch or tree dieback was the next most reported disease limiting production in 2020. The MNNSW and CQ had the highest proportion (27% and 26% respectively). In some cases, branch or tree dieback can be associated with bark beetles. Increased bark beetle activity has been observed on some farms over the last few seasons, including 2020.

Flower diseases were reported in NRNSW (16%) and SEQ (13%) making this the next most limiting disease. This was followed by husk spot (9% overall), most of which was reported in the CQ region. Although husk rot averaged just 4% of responses overall it was more prevalent in CQ (17%) and MNNSW (10%). Abnormal Vertical Growth (AVG) also averaged 4% of responses overall, with most in CQ (14%) and SEQ (13%).

Fifteen per cent of responses indicated no significant disease limitations. These were distributed among NRNSW (20%), SEQ (16%) and MNNSW (10%).



	Phytophthora	Branch or tree dieback	None	Flower diseases	Husk spot	Husk rot	AVG	Leaf diseases	Other
CQ	26%	26%	0%	0%	14%	17%	14%	2%	0%
SEQ	29%	21%	16%	13%	5%	3%	13%	0%	0%
NRNSW	32%	21%	20%	16%	9%	0%	0%	0%	1%
MNNSW	47%	27%	10%	0%	3%	10%	0%	3%	0%
All regions	32%	23%	15%	11%	9%	4%	4%	1%	1%

Figure 26. Major diseases limiting macadamia production in the 2020 season.

CQ = Central Queensland
SEQ = South East Queensland
NRNSW = Northern Rivers of New South Wales
MNNSW = Mid North Coast of New South Wales

The University of Queensland, Centre for Horticultural Science

Associate Professor Femi Akinsanmi

The **Macadamia Integrated Disease Management** (IDM) program aims to deliver **point-of-care solutions** to reduce the effect of endemic, emerging and exotic diseases. Endemic priority diseases such as husk spot and Phytophthora root rot, as well as tree decline and emerging diseases such as Phomopsis husk rot, flower blight (Figure 27 to Figure 29) and Botryosphaeria branch dieback, reduce orchard productivity, thus are a major concern to growers.

Emerging pathogens are **a constant threat to macadamia productivity**, accentuated by climatic variability, causing yield losses. For example, the economic importance of **flower blight (dry flower disease**) **at the farm level was estimated to result in $5,000 to $10,000 loss per hectare in affected orchards**. Potential gain in production from recent plantings is threatened by these emerging pathogens. The risk of losing market access and share due to potential reduced production capacity and poor nut quality are highly undesirable to all industry stakeholders.

The IDM research program has continued to **deliver tangible benefits** to the Australian macadamia industry. These include maintaining access to old agrochemicals, developing new agrochemicals and technologies, improved integrated disease management strategy, improved knowledge, awareness and skills required for practice change.

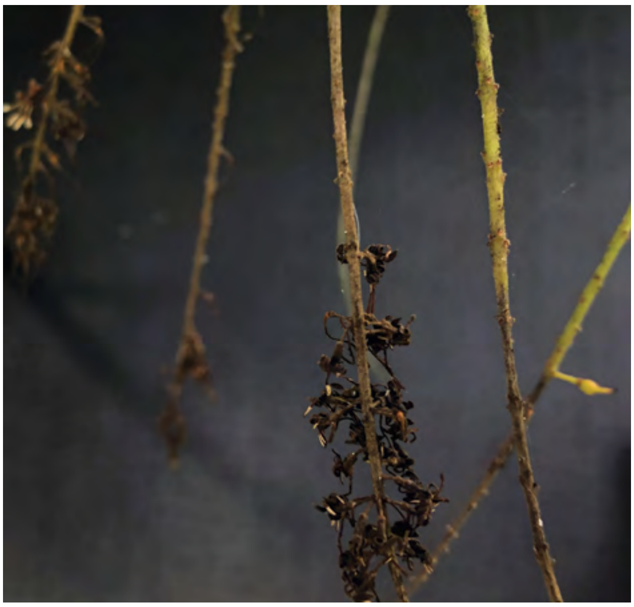


Figure 27. Close-up of flower blight (dry flower disease).

Figure 28. Macadamia racemes affected by flower blight.

Figure 29. Poor nut set due to flower blight.

Examples of recent outputs for growers

A video highlighting current IDM research about understanding the disease cycle and management strategies for **Botryosphaeria branch dieback in macadamia** was recently produced by the Australian Macadamia Society (https://www.youtube.com/watch?v=9kaLsYUwKM8).

IPM project updates

New knowledge on the biology and epidemiology of the range of fungal pathogens causing flower blight has underpinned the development of **disease forecasting models for flower blights** in macadamia. This new technology is a vital tool for protection against flower diseases.

Support for decision making (fungal spore monitoring)

We monitor the prevalence and seasonal dynamics of emerging pathogens in macadamia orchards. Monitoring (Figure 30 and Figure 31) should support control scenarios and options.

Detailed information on several aspects of the IDM program is listed in the following:

Scientific peer-refereed journals

Akinsanmi OA and Carvalhais LC. 2020. Draft genome of the husk spot pathogen, *Pseudocercospora macadamiae*, infecting macadamia. *Phytopathology* 110: 1503–1506 https://doi.org/10.1094/PHYTO-12-19-0460-A

Jeff-Ego OS, Drenth A, Topp BL, Henderson J and Akinsanmi OA. 2020. Prevalence of *Phytophthora* species in macadamia orchards in Australia and their ability to cause stem canker. *Plant Pathology* 69: 1270–1280 https://doi.org/10.1111/ppa.13208

Jeff-Ego OS, Drenth A, Topp B, Henderson J and Akinsanmi OA. 2021. Variability and inheritance in macadamia progenies to *Phytophthora cinnamomi* and *P. multivora* the causal agents of root rot and stem canker. *Plant and Soil* (accepted)

Jeff-Ego OS, Topp B, Drenth A, Henderson J and Akinsanmi OA. 2021. Resistance in wild macadamia germplasm to *Phytophthora cinnamomi* and *Phytophthora multivora*. *Annals of Applied Biology* 178: 519–526, https://onlinelibrary.wiley.com/doi/10.1111/aab.12668

Prasannath K, Galea VJ and Akinsanmi OA. 2020. Characterisation of leaf spots caused by *Neopestalotiopsis clavispora* and *Colletotrichum siamense* in macadamia in Australia. *European Journal of Plant Pathology* 156: 1219–1225 https://doi.org/doi:10.1007/s10658-020-01962-6

Figure 30. A spore monitoring station in a macadamia orchard.

Prasannath K, Galea VJ and Akinsanmi OA. 2021. Molecular methods for the detection and quantification of *Pestalotiopsis* and *Neopestalotiopsis* inoculum associated with macadamia. *Plant Pathology* 70: 1209-1218 https://doi.org/10.1111/ppa.13371

Wrona CJ, Mohankumar V, Schoeman MH, Tan YP, Shivas RG, Jeff-Ego OS and Akinsanmi OA. 2020. Phomopsis husk rot of macadamia in Australia and South Africa caused by novel *Diaporthe* species. *Plant Pathology* 69: 911-921 https://doi.org/10.1111/ppa.13170

Zakeel MCM, Geering ADW and Akinsanmi OA. 2020. Spatiotemporal spread of abnormal vertical growth of macadamia in Australia informs epidemiology. *Phytopathology* 110: 1294–1304 https://doi.org/10.1094/PHYTO-10-19-0396-R

Industry magazines and journals

Akinsanmi OA. 2021. Phytophthora disease control with phosphonates and holistic strategies in macadamia. *Australian Macadamia Society News Bulletin* 49: 71–73.

Akinsanmi OA. 2021. Understanding Botryosphaeria (Branch dieback) video https://www.youtube.com/watch?v=9kaLsYUwKM8

Akinsanmi OA, Jeff-Ego OS, Prasannath K and Mohankumar V. 2020. Macadamia integrated disease management. In *Macadamia Plant Protection guide 2020-21*. J Bright (ed). NSW Department of Primary Industries, pp. 18–21.

Akinsanmi OA, Mohankumar V and Jeff-Ego OS. 2020. Resilience of macadamia trees to diseases. *Australian Macadamia Society News Bulletin* 48: 49–52.

Akinsanmi OA and Searle C. 2020. Leaf diseases in macadamia. *Australian Macadamia Society News Bulletin* 48: 62–64.

McLeod A, Hamza Z, Schoeman MH, Joubert E and Akinsanmi OA. 2020. Phosphonate usage and *Phytophthora cinnamomi* root colonisation in macadamia. *SAMAC* (Macadamias South Africa NPC Journal), September 50–53.

Figure 31. Monitoring climatic conditions in macadamia tree canopies at flowering.

Integrated orchard management (IOM)

5 years down the track – how can it assist in pest and disease control?

Jeremy Bright, NSW DPI Development Officer

Since the *NSW DPI Integrated orchard management practice guide* (2016), *Integrated orchard management case study guide* (2016) and the *Integrated orchard management drainage guide* (2017) were released, changes in how canopies, orchard floors and drainage are managed has created more sustainable orchards (stage 2). The benefits in yield and productivity from having our orchards at stage 2 are clear, but what are the benefits for pest and disease control?

Canopy

General effect on pest and disease management

Adequate spray coverage is more easily achieved when the canopy is at stage 2 (Figure 32). Canopy height will be equal to or less than row width, i.e. it should be easily covered by annually-calibrated air-blast sprayers. Having good coverage is essential for adequate pest and disease control.

Having 13+ m high trees will extend the capabilities of most sprayers and full spray coverage might not be achieved. Most (60%) yield will be produced where most light penetrates the canopy. Within the middle of a 13 m high orchard block, that 60% will be in the top 1/3 of the canopy, i.e. from 9–13 m high. Unless the typical air-blast sprayer has incorporated cannons and increased output delivery height, it is unlikely to provide full coverage.

Examples for effect on pest management

Pests such as macadamia lace bug (MLB) and fruit spotting bug (FSB) prefer tall dark, closed-in canopies. FSB will be at the tops of these trees in the light, predating on the nuts, where the sprayer cannot reach. Similarly, MLB will be at the tops, predating on the new flowers. Dense canopies allow them to travel along adjoining tree branches, encouraging their spread throughout the orchard. Dense canopies also provide higher humidity, which is preferred by FSB, as well as making it easy for FSB to hide from predators such as birds. An integrated orchard management approach will limit the negative effects from these and other pests.

Examples for effect on disease management

Canopies that allow light to the orchard floor will generally have good ventilation and be less prone to diseases promoted by prolonged moisture at certain temperatures and relative humidity. Botrytis blight, flower blight and green mould are all less likely to occur in an open well-ventilated canopy.

Orchard floor

Stage 2 orchard floor should have adequate ground cover (Figure 33). This will usually be the semi-shade tolerant grass species, sweet smother grass (*Dactyloctenium australe*). Many within the industry are anxious that this grass species will lead to an orchard floor monoculture and therefore limit the biodiversity within the orchard. Less biodiversity could reduce the ability of beneficial insects to control pest insects.

NSW DPI's integrated pest and disease management (IPDM) program is investigating ground covers with a mix of flowering plants in a small unsprayed block. These plants include Rhodes grass (*Chloris gayana*), white clover (*Trifolium repens*), red clover (*Trifolium pratense*), mustard (*Brassica*), chicory (*Chichorium intybus*) and lucerne (*Medicago sativa*). Perennial flowering plants including *Grevillia* spp., *Banksia* spp., *Leptospermum* spp., *Westringia* spp. and *Lomandra* spp. were established adjacent to the block.

This type of ground cover should harbour many thousands of beneficials. We will be determining the population densities and the diversity of these. Specifically, we will investigate the effect of these beneficials on productivity; for instance, does having more beneficials within this mixed ground cover result in higher productivity as more pests are predated on by the increased population of beneficial insects?

Having a sound, grassy orchard floor can reduce erosion by 99% (Alt et al. 2009) and this allows us to build the soil around the tree roots. This creates a desirable system for tree health, which leads to strong sap flow. Healthy trees with strong sap flow are more likely to withstand attack from pests such as bark beetle that rely on low sap flow to enter the tree.

A healthy soil with high organic matter in the root zone provides the trees with more resistance and resilience to *Phytophthora* spp., and ultimately builds orchard resilience for extended dry periods. A simple test to determine the strength of soil and tree root structure is the 'snap test'. This involves pushing a shovel into the soil and if the soil does not 'snap' as the shovel enters (the 'snap' being the sound of breaking roots), it could indicate insufficient root structure in the soil. This means those roots might not be delivering sufficient moisture and nutrients to the tree. An integrated orchard management approach for the orchard floor, stage 2 would promote ideal root growth.

Drainage

Having stage 2 drainage means that excess water will be diverted to designated grassed water courses (Figure 34) and will exit the farm with minimal nutrients and sediment, instead of running randomly through the farm, taking with it valuable soil and nutrients. Good drainage also means that inputs should stay where they are placed, improving soil health and therefore tree health. If the organic matter placed around the tree is not washed away, the organic carbon within the soil will start increasing, as will the cation exchange capacity. Having higher organic carbon in the soil means there will be greater water holding capacity, which is critical, especially when water resources are limited. Increased water holding capacity also allows trees to function more effectively and maintain sap flow, which will strengthen their capacity to withstand attack from pests such as bark beetle. Good sap flow will also be less favourable for diseases such as Botryosphaeria dieback.

Conclusions

Over the past 5 years we have seen enormous efforts from growers to continue their IOM programs. These efforts are clearly worthwhile, with growers achieving a harvest through the worst drought in memory. Integrated orchard management, like IPDM, is a continual journey throughout the life of the orchard. As trees age and develop, the interactions between the orchard floor, canopy and drainage subtly change each year. Growers need to be aware of this and understand these changes as well as how to work with them to maintain good productivity. New initiatives are also being developed in the IOM system such as limb removal with excavators, making it possible to remove large limbs in a much more cost-effective way.

Alt S, Jenkins A and Lines-Kelly R. 2009. Saving soil: a landholder's guide to preventing and repairing soil erosion. Northern Rivers Catchment Management Authority.

Figure 32. Stage 2 canopy.

Figure 33. Stage 2 orchard floor.

Figure 34. Stage 2 drainage.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Drop-sheeting to understand pest and beneficial dynamics

Chris Fuller

Several insect pests can limit macadamia production and these pests can vary in severity from region to region and from one season to the next. Seasonal conditions can also affect certain pest populations. Leptocoris, while found in most growing areas and normally considered a minor or emerging pest, can explode in numbers in a dry season, causing significant damage.

Fruit spotting bugs (FSB) continue to be the industry's most serious and widespread pest. Traditional methods of measuring fallen stung nuts for FSB levels seem to be less accurate as we have more dry seasons and the trees appear to be holding stung nuts when normally they would drop, allowing for a more thorough assessment. As well as more accurate methods, we also need to develop techniques to determine FSB levels after November, when stung nuts do not drop.

Pest scouts have developed monitoring techniques to provide reasonably accurate estimations of the pests in orchards. This information, along with other data such as beneficial insect counts, orchard history and the grower's attitude towards acceptable pest damage levels, is used to determine when pest levels have reached a threshold where a recommendation for action is given. However, crop protection is a complex balancing act.

Some pest scouts are starting to use the drop-sheeting technique to determine which pests and beneficials are in the orchard. Drop-sheeting involves laying 'drop sheets' under the canopy (Figure 35). A broad-spectrum insecticide is then used to take a 'point in time' sample of the insect population dynamics within the selected tree. The trees chosen for drop-sheeting will then represent the population dynamics of the whole orchard, similar to how a census represents the ideas and opinions of Australia.

It is important to eliminate bias when drop-sheeting by:

- sampling a reasonable number of trees to represent the orchard
- randomise the sample by starting in a different area each time
- avoid border rows when sampling for the general insect population but use border rows as hotspot zones for specific pests
- always return for efficacy counts for the same duration after spraying.

As drop-sheeting becomes more popular and consultants have a network for sharing their data, the industry can be better informed about pest and beneficial populations in the various regions. Understanding these population dynamics, how they change throughout the year at different life cycle stages and what they mean for crop production and damage, will help us with overall crop protection. Furthermore, industry can then start to develop acceptable spray thresholds based on drop-sheet sampling. This will allow a more strategic spray regime that is more likely to be accepted by quality certification programs.

Drop-sheeting also allows 'real world' evaluation of chemical efficacy in the field. As new chemistry becomes available, drop-sheeting can be used to evaluate its effectiveness. For instance, if the drop sheet is in place when the new chemistry is applied, the target pest efficacy can be readily assessed. By repeating this process 7 days later with the known effective product, the presence or absence of the target pest insect population on the second spray will give you an objective assessment of the effectiveness of the new product in controlling the targeted pest.

Drop-sheeting seems to be more accurate than the current monitoring systems, but ideally would be used to complement the current systems.

Drop-sheeting tips

- Use relatively strong material that has some weight to it so it does not flap around; it should also be permeable so chemical run-off does not pool when insect assessments are made
- Always wear appropriate PPE; paint drop sheets are cheap but the chemicals can 'pool', potentially creating a hazard
- Geotech fabric may be an option to consider as it is relatively cheap and permeable
- Try to lift the corners while having weight at the middle of the sheet to funnel the insects and to stop them from blowing off the sheets (Figure 36)
- Try pinning the sheets down with a perimeter of star pickets or timber to give the sheets a raised edge that catches the dropped insects as they blow across the sheets.

Note

Once sprayed for drop-sheeting, be wary of the chemical re-entry period. Try to use a product that will allow re-entry for assessments at 2, 6 and 24 hours after spraying. A pyrethrin spray allows entry once dry, approximately 15 minutes. If the chemical label does not have a re-entry period, then it must be assumed that re-entry is allowed when the chemical has dried or 24 hours after application, whichever is longer.

Figure 35. The author, Chris Fuller, using the drop-sheet method to determine which pests and beneficials are in the orchard.

Figure 36. A drop sheet in place, under the canopy, with the corners raised.

Weathering the pest pressure in the Regional Macadamia Variety Trial (3) at Alstonville

Craig Maddox, Technical Officer – Entomology, NSW DPI, with a lot of help from David Robertson, Alister Janetzki, Carly Maddox, Ruth Huwer, Ian Purdue, Tina Robertson, Scott Ellem, Trevor Taylor and Kirsten Ellis (2020 SCU)

The search for better macadamia varieties is not purely about more nuts on trees with current production practices, but also about finding trees with reduced spray management needs. Macadamia is a long-lived crop and results from pruning and spray decisions can last 2 or 3 years. Seasonal yield or high kernel recovery are not the sole indicators of a superior tree, especially if it takes twice the inputs to achieve those results. Recent seasons have shown what changes could be ahead for the local industry; this article highlights some of these.

Long term research at the Centre for Tropical Horticulture (CTH), Alstonville on *Amblypelta nitida* (FSB) behaviour aims to help with its management by answering some key questions such as:

- what traits do resistant or more preferred varieties possess?
- how important is 'out of season' flowering to incursions?
- how important is tree density to pest abundance and damage severity?
- do seasonal conditions change the husk/kernel traits to make them more susceptible to FSB?

Since being planted in 2007, the CTH blocks (RVT3, Density and Sink) have experienced some extreme weather, providing us with excellent opportunities to learn some valuable lessons. Category 2–3 cyclones passed in 2009, 2011,

Table 1. How tree density, out of season flowering and targeted spraying influence the average kg/DNIS @ 10% moisture

Block	Variety	Trees	Treatment	2011	2012	2013
Planted 2007			MLB spray	none	none	none
			MSW spray	none	none	none
Density	246	16	10 × 10 m	0	1.5	2
Density	246	23	10 × 7.0 m	0	1.8	1.6
Density	246	18	10 × 3.5 m	0	1.8	1
Planted 2007			Sprays	none	none	none
Sink	246	10	Autumn flower	0	0.85	2.8
Planted 1998			MLB spray	none	none	
			MSW spray	none	none	
Entomology	741	9	IPM soft	12.4	15.1	single tree plots
Entomology	246	9	IPM soft	4.7	1.5	
Entomology	849	9	IPM soft	0.2	0.9	
Entomology	A4	9	IPM soft	0.4	0.4	
Planted 1998			MLB spray	none	none	
			MSW spray	endosulfan	endosulfan	
Entomology	741	9	Standard	19.9	14.2	single tree plots
Entomology	246	7	Standard	18.4	8.7	
Entomology	849	9	Standard	12.5	8.3	
Entomology	A4	9	Standard	9.4	4.2	

*2021 season data not complete. MLB = macadamia lace bugs, MSW = macadamia seed weevil, IPM soft = more targeted less twice in 2013 then again in 2017, destroying trees; in August 2009, a serious 3-day dust storm removed most of the early variety flowers throughout the northern rivers region, and three serious pests, macadamia lace bugs (especially *Cercotingis decoris,* MLB), macadamia seed weevil (*Kuschelorhychus macadamiae,* MSW) and *Leptocoris* sp. were affecting the crop in significant numbers.

By 2012 (year 5), FSB and MLB were favouring the tighter-spaced trees in the density trial, and FSB were causing far more damage in the high KR varieties than the cv246 when left unsprayed in the sink trial (Table 1). Also in 2012, FSB were showing a strong preference for *Macadamia ternifolia* from the wild macadamia germplasm collection at CTH Alstonville (Figure 37). These trees flower a month in front of the main crop and have fruit on terminal bearing branches. Monitoring the FSB population as the generations take flight from these trees has become the basis of our FSB spray timing between November and March. Two *M. ternifolia* trees are used as sentinel plants in the RVT3 plot and have been valuable assets (Table 1, Table 2 and Figure 38).

The northern rivers of NSW is normally associated with floods, but from August 2019 to January 2020, the area became extremely dry. This was accompanied by *Leptocoris* sp. (usually in Gympie QLD) and several other beetles attacking the stressed trees.

Excluding a 1 in 100-year drought, poor yields in NSW northern rivers macadamia crops from 2007 onwards were mainly from unmanaged out of season flowering. When spraying was timed monthly for November–February applications (no flower spraying), the entomology plots (2001–2012) had consistent crops in the standard areas (2 × endosulfan/2× beta-cyfluthrin) and poor crops in the parasitoid only areas. This is because the carry-over populations on the trunks between flowering were removed each year (Table 1). Cultivar 741 largely escapes MLB damage because it finishes setting early, the longer (cv 246) and later cultivars (cv A4 and 849) are exposed to the main MLB population (Table 1).

Since 2012, endosulfan was banned, and MSW arrived on the site causing total crop removal in any of the untreated trial plots (Table 1). Any out of season flower that sets becomes an over-wintering MSW breeding site (Figure 38). Setting the crop with well-timed sprays creates a positive feedback loop and having nuts on racemes limits

per tree for macadamia (cv 246 especially) in various blocks at CTH Alstonville NSW.

2014	2015	2016	2017	2018	2019	2020	2021*
none	none	none	none	none	none	none	none
none	none	none	none	none	none	indoxacarb	indoxacarb
7.2	0	0	0	0	0	16.9	17.2
7.4	0	0	0	0	0	11.7	12.4
4	0	0	0	0	0	3.9	4.3
none	none	none	none	none	none	none	none
3.7	0	0	0	0	0	0	0
	diazinon			clittoria ternatea extract	flupyradifurone	flupyradifurone	flupyradifurone
	acephate			beauvaria	tetraniliprole	indoxacarb	indoxacarb
single tree plots	23.8	canopy height		2.1	20.1	29.4	7.3
	18.2	trials		2.5	13.2	19.9	11.5
	19.4			3.1	10.2	17.8	*
	16.6			0.9	7.7	19.3	*
	diazinon			diazinon	diazinon	diazinon	diazinon
	acephate			acephate	acephate	acephate	acephate
single tree plots	20.6	canopy height		25.3	19.6	20.8	13.8
	20.6	trials		12.2	18.8	17.8	13.5
	17.4			18.9	15.7	16.9	*
	15.2			14.0	18.4	16.7	*

broad-spectrum, Standard = well-timed broad-spectrum sprays.

early flowers (Table 1). RVT3 has been sprayed specifically to minimise each of these pests with a single targeted spray. Other pesticides applied are primarily focused on limiting FSB and *Leptocoris* invasions. These are determined by fortnightly nut drop inspections and monitoring weekly FSB levels and age stages on the *Murraya* trap hedges and the *Macadamia ternifolia* trees (Figure 40).

Crop quantity and quality have improved significantly since the change to flight timing the later spray during 2018–2021 (Table 5). Now the block can be used to reinvestigate FSB preferences because the heavy losses from MSW and MLB can be excluded.

Other pests of interest include the macadamia nut borer (*Crytophlebia ombrodelta*), thrips (*Scirtothrips albomaculatus*), broad mite (*Polyphagotarsenemus latus*), and macadamia felted coccid (*Acanthococcus ironseidei*).

Figure 37. Adult *Amblypelta nitida* (FSB) on macadamia ternifolia nuts being monitored for FSB flights.

Table 2. Management changes and effects of drought on the pest insect fauna populations in the RVT3 at CTH Alstonville. Each tree is sampled mid-harvest (May, 30 nuts from each canopy). During the drought (2020 crop) nuts were on average 21.4% smaller and had 17.6% more kernel. *Leptocoris* sp. accounted for about 75% of damage in 2020, the rest was from *Amblypelta nitida* (FSB), which is the primary cause in the other seasons.

RVT3 management changes (170 trees)	2015	2016	2017	2018	2019	2020	2021
Total rain in mm (1,800 mm 40 year mean)	1,939	1,489	1,970	1,397	787	2,299	–
August–December (534 mm 40 year mean)	632	448	663	466	213	645	–
Diazinon for MLB	none	yes	yes	yes	yes	yes	yes
Trichogrammatoidea releases for MNB	yes	yes	yes	yes	yes	yes	yes
Acephate/beta-cyfluthrin for MSW/FSB	none	yes	yes	yes	–	–	–
Hedge/*M. ternifolia* FSB flight spray timing	none	–	–	yes	yes	yes	yes
Indoxacarb for MSW	none	–	–	–	yes	yes	yes
RVT3 crop changes (block averages)	–	–	–	–	–	–	–
Nut size (g) @ 1.5% moisture DNIS	7.8	7.9	7.0	7.5	7.0	5.9	7.7
%TKR @ 1.5% moisture DNIS	38.2	37.2	38.8	40.0	39.7	45.6	39.1
RVT3 insect activity	–	–	–	–	–	–	–
% bugloss in kernel per tree	4.9	1.2	4.1	0.3	0.8	0.8	0.6
FSB seen on *M. ternifolia* (Oct–Mar)	–	274	521	–	189	103*	339
% nut fed on by MSW	0.4	1.3	19.7	6.3	0.5	0.1	1.7
Male MNB moth catch rate Nov–Mar	9.3	3.9	26.0	35.8	18.7	54.7	50.8
MNB eggs per 100 nuts	15.7	13.3	64.9	14.4	21.7	13.1	31.1
MNB tunnels per 100 nuts	3.6	3.5	19.5	2.0	1.6	0.4	2.2
% Thrip/mite damage on husk	7.2	6.3	30.5	40.8	43.4	75.1	34.8
% Nut with felted coccid (> 10 live)	0.3	1.4	1.4	6.0	23.6	38.4	34.8
Variety A538 % nut with felted coccid	0.0	0.0	1.3	0.0	3.4	0.0	0.0
Variety A447 % nut with felted coccid	0.0	0.0	0.0	0.0	0.6	0.0	1.1

*264 *Leptocoris* spp. seen on *Macadamia ternifolia* trap trees.

Figure 38. Macadamia lace bug damage to flowers and macadamia seed weevil infesting out of season nut set during May–June 2021.

Figure 39. Macadamia lace bug damage and the potential to move on to the main flowering from May to June 2021 on cv 344.

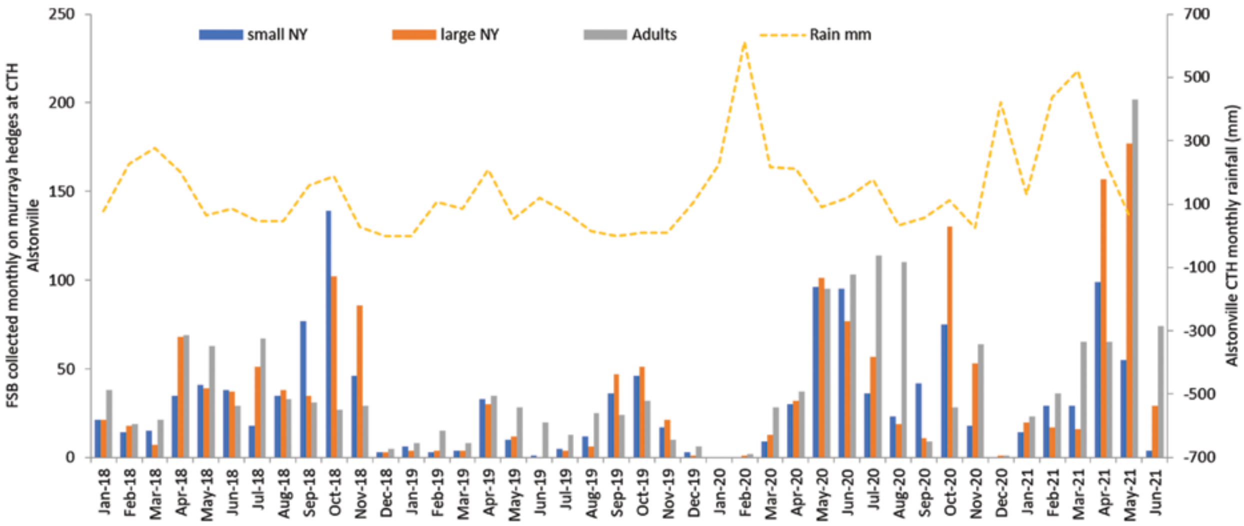

Figure 40. Monthly capture of various life stages of *Amblypelta nitida* (FSB) on the *Murraya paniculata* hedges at the CTH Alstonville Research Station, and how the rainfall pattern of extended dry spring reduces the numbers, and how quickly they bounced back after the January rain in 2020. Comparative % bugloss in the high-risk untreated 849 plots (n=5 plots of 3 trees) was 13.7 in 2018, 27.7 in 2019, 13.1 in 2020, 49.0 in 2021 and halved in the corresponding treated areas.

Are we seeing more MNB and FSB activity? YES!

MNB flight trapping was developed originally at CTH Alstonville in macadamia (1996–2008; Campbell et al. 1999, Maddox et al. 2002). The primary MNB population source is coastal each year. With the assistance of the QFF monitoring grid staff (Norm Green and Magda Verbeek), trapping occurred on the river systems between the Brisbane airport estuaries and Yamba (Huwer et al. 2006 and 2011). MNB breed in seed pods and aerial roots of mangroves all year then migrate onto many plants with seeds and pods via wind and floods (Komai and Nasu 2003).

Managing MNB involves using an egg parasitoid (*Trichogrammatoidea cryptophlebiae*) and well-timed sprays when eggs are seen on the nuts (usually a week after the main moth flight). The invading population has surged in 4 of the last 5 seasons but the 2017 crop was the only season affected by the pest (Table 2).

What makes a bad MNB season?

Flight levels during 2016–17 were similar to those measured between 2000–2008; > 25% was MNB-tunnelled on-tree (15 February 2006).

If there are clusters of nuts > 20 mm diameter, susceptible varieties (eg 344, 849, A4), warmer nights and higher humidity, then the highest levels of 1st instar penetration can occur if the wasp has not been established. While it is important to measure flights and egg laying, it is the level of tunnelling that correlates best with the actual damage as crop loss is from immature fallen nuts and kernel damage.

During the 2016–17 season, we:

1. were not releasing wasps or monitoring in the mangroves in spring (the current IPM project directions were being debated)
2. had large flights into the CTH orchards in the first 2 weeks of December 2016 (15–18 males/day, usual seasons had a maximum of about 10 males/day)
3. had 6 days in a row above 40 °C in mid January 2017, which meant a further wasp release and a follow-up spray were required

Since the 2016–17 season, we improved crop management to keep production high and damage low despite higher pressure; so far 2021 has had more moths and good laying conditions with the wetter weather (Table 2).

Fixing the spray drift issue

Taller trees lead to more FSB damage; varieties with higher kernel recovery and late maturity are more likely to be attacked (Huwer et al. 2006). The current equipment at CTH Alstonville is now suitable for trees taller than 10 m, which keeps the FSB damage levels low, but does not fix the drift issues. **Coverage must be effective but drift must be minimal; a tough mix for an increasingly urban area**. Using course droplets with appropriate nozzle selection and adjuvants helps reduce drift. Reduced tree height makes management easier, especially with varieties that do not normally need protection after Christmas (Huwer et al. 2006) unless there is out of season flowering.

A significant part of MNB management is relying on the wasp to control damage within the season. Is that true for the other key pests? Other questions include, how effective is FSB egg parasitism in reducing the adult population? Can we rely on beneficials to prevent the winter expansion of MLB if you are not setting the crop? Are the beneficials remaining effective?

Drought conditions reduced FSB flights into macadamia crops at CTH Alstonville, which was effective at reducing damage. In high pressure seasons, not having to spray for FSB late or macadamia felted coccid at all because the right varieties were planted might make a difference.

Take home messages

1. How a macadamia crop is protected will have the greatest influence on yield
2. We need smaller trees and no spray drift
3. Extreme water stress followed by excess water can increase kernel recovery by reducing shell thickness and nut size
4. When assessed by nut size and kernel recovery, the Hawaiian standard cv246 was least affected by drought conditions
5. Drought-induced changes in nuts will favour more FSB attacks later in the season
6. There has been increasing pest pressure from FSB and MNB over the last 5 years in the RVT3 at CTH Alstonville
7. Management changes can reduce the effects from MLB and MSW and this will allow more screening for FSB tolerance. Earlier work shows cv 741 has more FSB tolerance than other varieties when unsprayed. New selections are not superior to those in the managed situation for FSB tolerance
8. Varieties A538 and A447 had remarkably low macadamia felted coccid prevalence during the climatic extremes encountered. There appears to be a resistance trait given the high pressure building throughout the block, which requires further investigation.

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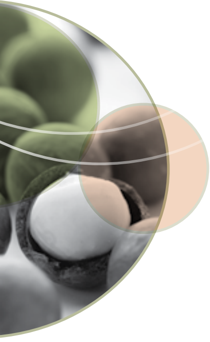

Integrated pest and disease management score card

'Keep it under 50'

In the 2021 Macadamia plant protection guide, we are including an integrated pest and disease management (IPDM) score card system.

In the regular pest tables, there is a column labelled 'Effect on beneficials (IPDM score)'. Within this column, there are values for each active ingredient available for use. Each time you use one of these chemicals, record the number as you apply the relevant treatment. On Page 140, there is a tally sheet where you can record the values and obtain an overall score for the season. Also on this tally sheet, is a space for you to record your yield. This IPDM value, in conjunction with your yield, will assist us in developing an IPDM score range.

At the end of the season, we would like you to send this tally sheet to jeremy.bright@dpi.nsw.gov.au

The trick is to have a low enough score but also have reasonable yields.

The values for each of the products are sourced from *The pesticide manual, a world compendium*. This publication identifies each active ingredient and considers their mammalian toxicology, ecotoxicology (in particular bees and other beneficials) and environmental fate.

Where a highly toxic (LD_{50} < 2 µg/bee) product is used, 10 points are accrued. A moderately toxic product (LD_{50} 2–10.99 µg/bee) accrues 5 points and a practically non-toxic product (LD_{50} > 11 µg/bee) accrues 1 point.

Where beneficials are released into the orchard e.g. trichogrammatid wasps, then 1 point per release is deducted from the tally.

Here are some example pest management strategies and IPDM scores for the 2020 season (Table 3 to Table 5).

Table 3. Example 1: pest management strategy and IPDM score for 2020 season.

Pest	Product used	IPDM score
Macadamia lace bug	Sulfoxaflor	1
Macadamia seed weevil	Indoxacarb	10
Husk spot	Carbendazim	5
Fruit spotting bug	Acetamiprid + pyriproxyfen	10
Husk spot	Pyraclostrobin	1
Fruit spotting bug + macadamia nut borer	Beta-cyfluthrin	10
Fruit spotting bug	Beta-cyfluthrin	10
Phytophthora (first treatment)	Phosphorous acid	1
Phytophthora (second treatment)	Phosphorous acid	1
IPDM sub total		49
Macadamia nut borer	8 wasp releases	-8
Total		**41**

Table 4. Example 2: pest management strategy and IPDM score for 2020 season.

Pest	Product used	IPDM score
Macadamia lace bug	Diazinon	10
Macadamia seed weevil	Acephate	10
Husk spot	Carbendazim	5
Macadamia seed weevil	Acephate	10
Husk spot	Pyraclostrobin	1
Fruit spotting bug + macadamia nut borer	Beta-cyfluthrin	10
Fruit spotting bug	Beta-cyfluthrin	10
Phytophthora (first treatment)	Phosphorous acid	1
Phytophthora (second treatment)	Phosphorous acid	1
IPDM sub total		58
Macadamia nut borer	8 wasp releases	-8
		50

Table 5. Example 3: pest management strategy and IPDM score for 2020 season.

Pest	Product used	IPDM score
Macadamia lace bug	Sulfoxaflor/flupyradifurone	1/5*
Macadamia seed weevil	Indoxacarb	10
Husk spot	Carbendazim	5
Fruit spotting bug	Acetamiprid + pyriproxyfen	10
Husk spot	Pyraclostrobin	1
Fruit spotting bug	Trichlorfon	10
Fruit spotting bug	Acetamiprid + pyriproxyfen	10
Phytophthora (first treatment)	Phosphorous acid	1
Phytophthora (second treatment)	Phosphorous acid	1
IPDM sub total		49/53*
Macadamia nut borer	8 wasp releases	-8
		41/45*

*when flupyradifurone becomes available, currently only has shelf registration.

More information

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Acknowledgements

We are very grateful for the contributions from Ruth Huwer, Craig Maddox and Femi Arkinsanmi in developing this score card.

Controlling pests and diseases in macadamia

While cultural controls will help to reduce pest and disease pressures in the orchard and should be used alongside chemical control programs, neither pesticide nor alternative management systems alone will give consistently satisfactory results; integrated management is required. Therefore, this section offers macadamia growers suggestions for integrated approaches to managing pests and diseases, incorporating responsible 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, 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, supports pest and disease control. Darker canopies have higher pest pressure. By opening up an orchard through canopy management, there can be substantial reductions in pests.

Reducing canopy height and maintaining it at or below the row width helps with pest control. 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 is able to coordinate the release of wasps to control the pest.

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

Very rarely will vertebrate pests be controlled through any one method, except perhaps exclusion fencing for pigs and deer. In most cases, vertebrate pest solutions require a good understanding of the pest and its habitat, feeding and breeding patterns (Figure 41).

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

Figure 41. Pigs are getting very comfortable browsing in macadamia orchards.

Insect pests in macadamia

Banana fruit caterpillar

The banana fruit caterpillar, *Tiracola plagiata*, has been a pest in banana plantations for over 100 years. In 1919, the Queensland Agricultural Journal noted the pest being located throughout the Queensland coast. The mature banana fruit caterpillar (BFC) was even featured on a Norfolk Island stamp (Figure 42). In macadamia it appears to be a serious pest in Emerald, Rockhampton, Baffle Creek, Bundaberg and on occasions, Gympie. The pest has a very large host range and also appears to be in greater numbers where inkweed (*Phytolacca octandra*) is present.

Figure 42. The 1976 Norfolk Island stamp featuring the banana fruit caterpillar adult.

Risk period

Table 6. The peak risk period for the banana fruit caterpillar is from early flowering 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

Adults are medium to large moths (Figure 43) 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 44) have two pairs of black marks on the top of the body and grow to about 60 mm (Figure 45). The life cycle takes approximately 6 weeks.

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

Management

Banana fruit caterpillars feed during nut set, so monitoring should start at flowering. Look for chew marks on developing nuts up to 20 mm in diameter (Figure 46). Monitor the leaf litter under the tree weekly early in the season as adult moths will come in distinct flights. Usually there has to be a thick layer of leaf litter for the caterpillars to hide in.

At night the caterpillars can be found on the lower limbs of the tree or hanging via long silk threads that will glisten in torch or tractor lights (Figure 47).

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

Figure 43. Banana fruit caterpillar adult.

Figure 44. Banana fruit caterpillar larvae.

Cultural and physical

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

Biological

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

Figure 45. A banana fruit caterpillar. Photo: Chris Searle.

Figure 46. Banana fruit caterpillar damage to macadamia. Photo: Chris Searle.

Figure 47. Banana caterpillars 'abseiling' from the tree to the ground on a silken thread, glistening in the light. Photo: Chris Searle.

Chemical

The chemical control option for BFC is listed in Table 7.

Table 7. The 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 48) have recently become more prevalent in the macadamia industry. This situation becomes far more complicated because scolytid beetles represent a family of beetles with many species that attack different parts of the macadamia plant. This section will describe the scolyitds we are beginning to understand. Since certain effective broad-spectrum pesticides are no longer available, these beetles have become a major concern worldwide, particularly in the forestry industry. NSW DPI is working towards obtaining accurate morphological taxonomies of these beetles to correctly identify them. In general, they all sit under Scolytinae, but as identification becomes more exact, the beetles will be allocated to their own categories.

Figure 48. *Cryphalus subcompactus*, scolytid adult.

Risk period

Table 8. Beetles can be present 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.

Pin hole borers

Hypothenemus eruditus (predominantly NSW) and *H. seriatus* (predominantly Bundaberg) are beetles that infest the nuts in shell (Figure 49). The damage will be influenced by shell thickness, how long the fallen nuts have been left on the ground between harvests and orchard cleanliness. They are normally on the husk but in December and January, they can move into the shell and kernel. Areas of Queensland also have *H. birmanus*, which feeds on avocado trunks as well as macadamia. The Bundaberg region now has the auger beetle (Figure 50), which will cause similar issues.

Ambrosia beetle

The ambrosia beetle (*Xyleborus* spp.; Figure 51) will burrow into the tree. They cause physical damage with the tunnels they create and pathogenic damage by introducing the ambrosia fungus into the xylem. They then cultivate their fungal garden as a food source for their offspring. This fungus contributes to plant dieback.

In 2016–17, the NSW DPI entomology team found several trees that were destroyed by lightning strikes. *Xylosandrus crassiusculus* (Figure 52) and *Cnestus solidus* were subsequently found in the damaged trees. *C. solidus* drills into the hardwood and forms spaghetti-like sawdust masses (Figure 53). A clear sign of ambrosia boring damage is the sap exudation (Figure 54) and waste product collected at the base of the trunk (Figure 55).

Classic bark beetle

The classic bark beetle, *Cryphalus subcompactus*, feeds on the cambium layer and can potentially ring-bark branches (Figure 56), causing significant dieback (Figure 57 and Figure 58).

Longicorn beetle

Longicorn beetles (Cerambycidae; Figure 59) lay eggs into the bark crevasses. 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 (Figure 60) inhabits nuts in shell that other pests have recently exposed. Carpophilus will feed on the kernel and, if they make it into silos and breed, will become a problem. Pheromone lures have worked well in controlling carpophilus beetle in other crops.

Figure 49. Pin hole beetle (*Hypothenemus seriatus)* damage, Bundaberg, Queensland.

Figure 50. Auger beetle (*Xylopsocus gibbicollis,* left) and *Euwallacea* spp. (right).

Figure 51. *Xyleborus* spp. damaging macadamia.

Figure 52. A 2 mm long scolytid, *Xylosandrus crassiusculus,* found in a dead tree in Queensland.

Figure 53. The spaghetti-like sawdust masses caused by ambrosia beetles.

Figure 54. Sap holes in the trunk of an infected tree.

Figure 55. The sap collection caused by ambrosia beetles at the base of a tree.

Figure 56. Ring barking caused by *Cryphalus subcompactus.*

Figure 57. *Cryphalus subcompactus* exit holes in a dead branch.

Figure 58. A close-up of the *Cryphalus subcompactus* exit holes.

Figure 59. A longicorn beetle (*Urocanthus* spp.) found on a young macadamia tree.

Figure 60. Adult carpophilus beetle (left) and larvae (right and above). Photo: Craig Maddox.

Management

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

Traps (Figure 61) are available to monitor the presence of most bark beetles and to indicate their flight times, but they will not control the pest. In general, beetle pests are somewhat controlled during the regular spray season. It is after March through to August, when no sprays are applied, that these pests can become prevalent in the orchard. If you find an affected tree, particularly if you see beetle exit holes, it is important to regularly check nearby trees, because when beetles leave an infested tree, they usually move onto other adjacent trees.

Figure 61. A trap for monitoring bark beetle numbers.

Cultural and physical

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

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

Postharvest sorting and hygiene will help to remove any nuts infested with carpophilus and *Hypothenemus* spp. It is easier to prevent the pests from establishing in the orchards and creating the holes through which the carpophilus beetle enters, rather than dealing with them at postharvest.

A clear sign of bark beetle infestation is dieback. Any areas of dieback should be cut out of the tree and when cutting, check the cross-sectional cut. It should be clean and without any discoloured wedging (Figure 62) as this could indicate that the fungus that causes branch dieback (*Botryosphaeria ribis*) has also infested the branch (see 'Branch dieback' on page 89). Keep cutting the branch lower until you see a clean cross-section.

Figure 62. A discoloured cross-section potentially indicating that *Botryosphaeriaceae* has also infested the branch.

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

Another non-burn chipping 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.

Do not leave burn piles anywhere in the orchard.

Biological

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

Chemical

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

Black citrus aphid

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

Risk period

Table 9. The peak risk period for the black citrus aphid is from bud break to 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
■	■	■	■				

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

Figure 63. Black aphids and ants on flower. Photo: Chris Fuller.

Management

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

Biological control

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

Chemical

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

Fall armyworm

Fall armyworm (FAW) is the name commonly attributed to the larval stage of the *Spodoptera frugiperda* moth. It is an insect pest that is a serious threat to a wide range of 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. FAW has been found in Queensland, Northern Territory, Western Australia and New South Wales.

Risk period

Table 10. 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 9–12 °C and where frosts occur.

The eggs are pale yellow and usually laid on the under-surface of leaves in clustered 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. Large larvae grow to 30–40 mm, becoming darker as they mature, with pale white stripes along the length of the body. The large caterpillars have a pale inverted 'Y' shape between the eyes. Two dark spots with dark spines occur on each body segment on the upper body surface, with 4 black spots arranged 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 one surface of the leaf, leaving an opaque layer of cuticle referred to as a 'window', which are typically more evident than the presence of larvae. The symptoms on the foliage will be similar to those caused by other caterpillars and chewing insects.

Management

Cultural and physical

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

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 have been seen to parasitise FAW larvae and *Trichogramma* spp., which is known to parasitise FAW eggs.

Chemical

The control options for FAW are listed in Table 11.

Further information

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

Table 11. The chemical control options for fall armyworm in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Chlorantraniliprole PER89353, expires 31.5.2023	S4	28	10	High (10)	Beware of spray drift, refer apvma.gov.au/spraydrift. Use enough water to ensure thorough crop coverage.
Indoxacarb PER89278, expires 31.3.23	S6	22A	42	High (10)	Do not exceed a maximum of 2 applications per crop with a 10-day retreatment interval.
Methomyl PER89293, expires 30.4.23	S7	1A	0	High (10)	Do not spray tree foliage, flowers or developing nutlets.
Spinetoram PER89241, expires 31.3.23	S5	5	7	Medium (5)	Treat when pests appear, targeting eggs at hatch or small larvae (before third instar stage) before the pest becomes entrenched. Toxic to bees but dry residue (after 3 hours) is non-toxic.

NSW GOVERNMENT | Department of Primary Industries

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 hind wing
- ✓ Eggs – pale yellow in colour 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 subrufata*) damages flower racemes but is considered to be a minor pest for macadamia.

Risk period

Table 12. The peak risk period for the flower looper is from pre-flowering to 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

Identification and damage

Flower looper larvae are up to 15 mm long and light green with brown spots running along the body (Figure 64). The larvae feed on flower buds, mainly at the bulbous ends.

The adult moth has brown and green areas on the wings (Figure 65).

Figure 65. An adult flower looper on a raceme. Photo: Craig Maddox.

Management

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

An IPM approach should help control this pest.

Chemical

There is currently no chemical registered for the macadamia industry to control flower looper.

Figure 64. A flower looper. Photo: Chris Fuller.

Fruit spotting bugs

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

Risk period

Table 13. 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 spotting bugs have seven life stages including an egg stage, five nymph stages and an adult stage. Eggs are oval, about 1.7 mm long and pale green with a slight opalescence. They are laid singularly on fruit, leaves and branches. Wing buds appear at the third nymph stage, growing until the fifth stage. The first instar nymphs of both species look similar, but the later stages can be distinguished by colour patterns. Fruit spotting bug (FSB) nymphs have reddish–black legs and antennae and an orange–brown abdomen (Figure 66). Banana spotting bug (BSB) nymphs are a pinkish red and white and have a distinctive light red stippling surrounding the pair of large black spots on the abdomen (Figure 67). The adult stages of both species are winged and relatively narrow. Both species are approximately 15 mm long and differ primarily in colour. The FSB is generally a slightly darker green with a black background sheen, while the BSB is generally slightly more rectangular with a yellowish–brown background. The BSB has distinctive white halos around the abdominal spots.

Damage

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

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

Natural thinning is a normal process of macadamia. However, about 2 months after 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.

Figure 66. *Ambypelta nitida* nymph.

Figure 67. *Amblypelta lutescens lutescens* nymph.

Management

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

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

Monitoring

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

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

Key steps for effective monitoring include:

- identifying FSB and BSB entry points and natural harbours
- monitoring bordering vegetation
- identifying hotspots in the crop (FSB often return to a damaged tree)
- check at least 10 trees in hotspots and 20 trees in other areas
- understand the timing and methods for monitoring, for example, when searching for fresh FSB and BSB damage:
  - start when small pea-size nuts start dropping in October
  - after the initial nutlet shedding, dissect 10 fresh green fallen nuts per tree and check for sting lesions in the husk and shell (Figure 68)
  - identify other insect damage e.g. macadamia nut borer and macadamia seed weevil (Figure 69)
  - repeat fortnightly until nut drop stops in December
  - late damage is difficult to detect as the nuts remain in trees.

Fallen nuts need to be checked for fresh damage from early in the season until mid-December. This ceases to be an accurate indicator of recent activity the further into the season you measure. Activity after the shell hardens from January onwards, particularly on the thinner shelled varieties (e.g. A4, 849), is hard to detect from the ground and 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 macadamia seed weevil, macadamia nut borer and fruit spotting bug feeding (Figure 69).

Using a trap crop

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

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

Figure 68. Checking for sting lesions in husk and shell.

Figure 69. Common causes of nut drop include macadamia seed weevil (top left), macadamia nut borer (top right) and fruit spotting bug feeding (bottom).


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During spring, an FSB hotspot will appear in the trap crop before the macadamia crop. The FSB stay in the hedge once feeding starts and monitoring should detect a build-up of large 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 for the first FSB wave of the season. The hedge should be continually monitored for further generations to emerge.

Cultural controls

To reduce the risk and damage from FSB:

- select appropriate varieties (avoiding thin-shelled macadamia varieties)
- reduce tree height to improve spray coverage
- reduce canopy density by selective limb removal or new growing systems
- reduce tree density (tree removal)
- reduce out-of-season flowering
- use cover crops in the inter-row
- improve bordering 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 ant (*Oecophylla smaragdina)* and big head ants (*Pheidole* spp.)
  - predatory bugs e.g. assassin bug (*Pristhesancus papuensis)* and lacewings, e.g. brown lacewing (*Micromus tasmaniae)*.

Chemical control

Timing is critical for FSB. Spraying a week early will not be effective. Therefore monitoring is key to the control. Trap crops of *Murraya paniculata* are good FSB indicators and can help determine pressure levels. Monitor orchard boundaries, particularly if backing onto host species. Use previous incidences to help predict incursion. The chemical control options for FSB are listed in Table 14.

Table 14. The chemical control options for fruit spotting bugs in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (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	High (10)	Do not spray when bees are foraging.
Beta-cyfluthrin (Bulldock® 25 EC)	S6	3A	7	High (10)	Do not use more than two sprays per season to avoid resistance. Dangerous to bees.
Sulfoxaflor (Transform® Isoclast™)	S5	4C	0	Medium (5)	Do not spray when bees are foraging.
Trichlorfon (Dipterex® 500 SL) PER13689, **expires 30.9.21**	S6	1B	2	Low (1)	Apply when premature nut fall is evident. Toxic to bees.

Green vegetable bug

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

Risk period

Table 15. 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 70). The nymphal stage looks similar to the adult, but with a range of green, yellow and black markings. Females lay clusters of 40 to 80 pale yellow eggs that become pink, then hatch after about 1 week. The nymphs develop through five stages before becoming adults. The complete life cycle takes approximately 5–8 weeks and there are about 3–4 generations a year. The GVB will overwinter on other host crops, under bark or in sheds. In warmer coastal areas, GVB will feed and breed all year round.

Damage

There might not be any signs of GVB damage on the shell, but when the kernel is extracted, the signs will be similar to those caused by FSB (Page 43). Most damage occurs from early shell-hardening onwards. Lack of external damage requires pest scouts to physically crack open the nuts to assess them.

Management

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

Cultural and physical

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

Biological

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

Chemical

Timing is critical. Monitor orchard boundaries, particularly if backing onto GVB host species for the full season. Use previous years' incidence to help predict incursion. The chemical control option for GVB is listed in Table 16.

Figure 70. Adult green vegetable bug.

Table 16. The chemical control option for green vegetable bug in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Trichlorfon (Dipterex® 500 SL) PER13689, **expires 30.9.21**	S6	1B	2	Low (1)	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 Queensland. They will leave their native host and attack cultivated plants such as macadamia.

Risk period

Table 17. The peak risk period for *Leptocoris* spp. bugs 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 71). Underneath, the body is dull red with a dark green area in the middle of the abdomen. Legs and antennae are black. *Leptocoris* spp. nymphs have a bright red abdomen with a brown–black head (Figure 72). There are most likely two species of *Leptocoris*; *L. rufomarginatus*, found in Northern NSW and *L. tagalicus*, found in the Amamoor region, Gympie. Both species will feed on macadamia.

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

Damage

The damage from *Leptocoris* spp. will appear similar to fruit spotting bugs (FSB) and green vegetable bug (GVB) damage but it will be shallower in the kernel (Figure 73). The damage from all of these pests will render the kernel unsaleable.

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

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

Figure 71. *Leptocoris* spp. Photo: Ruth Huwer.

Figure 72. *Leptocoris* spp. nymph. Photo: Ruth Huwer.

Management

Monitoring is the key to controlling *Leptocoris* spp. Growers can identify potential pressures by monitoring any surrounding host plants. 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 74). Pest consultants will also have control strategies and as they are working within the region your farm is located, will be able to alert growers to population pressures. As *Leptocoris* spp. populations increase within the orchard, so will the damage to the crop.

Cultural and physical

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

Biological

A fly parasite *Gymnoclytia* spp. (Figure 75) has been isolated in the field by NSW DPI entomology staff and identified by Ainsley Seago, NSW DPI. 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. There is a requirement for registration of a product that will control it. Talk to your crop consultant regarding control strategies.

Figure 73. Fruit spotting bug feeding damage on the left and *Leptocoris* spp. damage on the right. Photo: Craig Maddox.

Figure 74. *Leptocoris rufomarginatus* on a macadamia after shell hardening. Photo: Craig Maddox.

Figure 75. The parasitic fly (*Gymnoclytia* spp.) of *Leptocoris* spp. identified in the field by NSW DPI entomology team. Photo: Craig Maddox.

Macadamia felted coccid

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

Risk period

Table 18. Macadamia felted coccid can be present 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

Macadamia felted coccid (MFCoccid) appear similar to mealybugs. The name comes from the felt-like appearance of the adult female and pupal case of the males. Adult females will moult twice and then become immobile and look like scale. Adult males moult once before developing wings and spend their adult life looking for females to mate with. Once mated, the female will develop its felted sac covering where it deposits eggs (Figure 76). There can be up to six generations a year with the life cycle taking around 40 days.

Figure 76. Felted sacs where the female macadamia felted coccid will lay her eggs. Photo: Chris Fuller.

Signs of damage

MFCoccid can damage all above ground parts of the tree (Figure 77), including the macadamia husk (Figure 78). Young leaves will be distorted and stunted as the individual coccids insert their needle-like mouthparts into the plant tissue and remove sap (Figure 79). MFCoccid will also excrete droplets of sugary honeydew onto the lower branches. The damaged leaf will develop yellow spots, turn brown and eventually die. On bearing plants, nut yields can be reduced and nut drop might be delayed.

Figure 77. Macadamia nuts covered with macadamia felted coccid. Photo: Ryan Finnerty.

Figure 78. Macadamia felted coccid on a nut husk. Photo: Chris Fuller.

Figure 79. A macadamia leaf that has been damaged by macadamia felted coccid. Photo: Chris Fuller.

Management

MFCoccid travels best with movement of infested material such as budwood, cuttings and potted nursery trees. This path has seen MFCoccid move between farms, regions and even countries. Growers should enforce strict disinfestation of any new plant material coming onto their orchard 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 available.

Biological

Natural MFCoccid predators include:

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

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

Chemical

Regular monitoring will provide early identification so treatment can be applied before MFCoccid numbers reach damaging levels. This is the key to effective integrated pest management. The chemical products available to control MFCoccid are listed in Table 19.

Table 19. Chemical control options for macadamia felted coccid in macadamia in NSW and Qld. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Diazinon (Diazinon)	S6	1B	14	High (10)	Do not use more than two sprays per season to avoid resistance. Use at pre-flowering only. Toxic to bees.
Petroleum oil (Summer spray oil) PER11635, expires 30.6.25	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.

Macadamia flower caterpillar

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

Risk period

Table 20. The peak risk period for macadamia flower caterpillar is from bud break to 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

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 80), making them easily confused with immature scale insects. There are five larval stages and they all feed on the flowers or buds. Larvae usually start out yellow but when fully developed, will become light green to grey and up to 12 mm long. MFC (Figure 81) can severely reduce a nut crop if not controlled. Adult moths are grey, 6–7 mm long with a wingspan of 14–18 mm and generally most active at night.

Figure 80. Macadamia flower caterpillar egg on a flower bud. Photo: Chris Fuller.

Figure 81. 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 82), destroyed buds as well as webbing (Figure 83) and frass covering the flowers and racemes. As with most pests active at flowering, early flowering cultivars are not as heavily affected. Later flowering cultivars and those with prolonged flowering are likely to suffer the most damage from MFC.

Figure 82. Browned-off flowers from macadamia flower caterpillar. Photo: Chris Fuller.

Figure 83. Flowers and racemes covered in webbing. Photo: Chris Fuller.

Monitoring

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

Cultural and physical management

Infestation will be worse where there are warm dry springs. Alternative hosts such as rough and smooth shell macadamia, red bottlebrush, *Grevillea* 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 within surrounding host plants such as *Grevillea* spp. could keep MFC in check and protect the control species when operations call for spraying. The following biological controls are commercially available:

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

Chemical control

The chemical control options for MFC are listed in Table 21.

Table 21. Chemical control options for macadamia flower caterpillar in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (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 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 four applications in any one season.
Tebufenozide (Mimic 700 WP)	S5	16A	28	Low (1)	Apply when pest numbers reach economic threshold levels according to field checks.
Trichlorfon (Dipterex® 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 22. 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 85) are moths that have dark brown forewings with a black mark halfway along the costa and a black tip. The hindwings are fawn with dark veins. The wingspan is between 13 and 21 mm. Larvae are cream and grow to about 15 mm long. The kernel grub often pupates within the hard nut. The pupae are about 10 mm long.

The kernel grub is usually recognised by the larvae which gain access to the kernel either through damage caused by other pests such as the 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 85).

Figure 84. Macadamia kernel grub adult.
Photo: Craig Maddox.

Damage

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

Management

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

Cultural and physical

Management and control of other pests should prevent most macadamia kernel grub damage. Monitoring is the key to controlling this pest. Using egg traps for navel orangeworm can be helpful.

Biological

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

Chemical

There are no products registered to control macadamia kernel grub.

Figure 85. Macadamia kernel grub larvae.
Photo: Chris Fuller.

Macadamia lace bug

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

Risk period

Table 23. The peak risk period for macadamia lace bug is from bud break to 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

Pest identification

Macadamia lace bugs are small insects, approximately 3–4 mm long (Figure 86). This makes them difficult to see with the naked eye, therefore it is important to look for symptoms to identify their presence in your orchard. They are named for the intricate 'lace-type' pattern on their hemelytra and thorax. Adults lay eggs into the plant tissue and nymphs emerge within days to begin feeding. The nymphs go through five instar stages before becoming adults. The adults can fly well and have been reported to disperse to form other populations up to 20 km away, making it easy for them to recolonise in areas from which they had previously been eradicated.

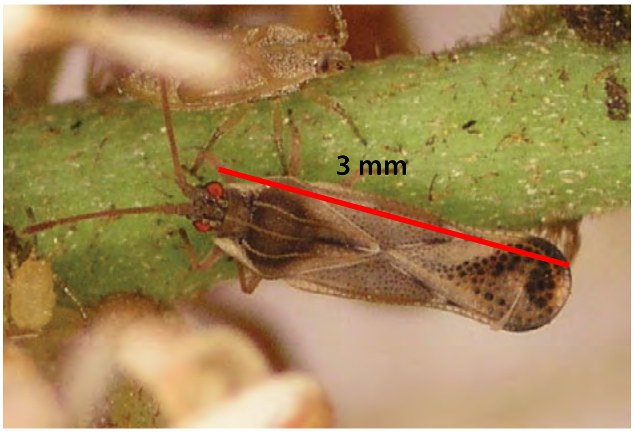

Figure 86. Adult macadamia lace bug (*Cercotingis decoris*) on a raceme. Nymphs are also present, left of the adult. Photo: Craig Maddox.

Damage

MLB pierce the plant tissue to feed on sap, damaging the leaves and flowers (Figure 87), starting at the tips where they appear blackened (Figure 87). Left unchecked, the whole flower blackens and dies (Figure 88). Shaking the head of infested flowers reveals MLB. Nut set is prevented when MLB is not treated, causing > 90% production losses in later varieties. These losses can happen quickly, so monitoring your crop early (e.g. at pre-flowering) and consistently is essential. Look for cast lace bug skins on dead florets and live nymphs on racemes (Figure 89).

Figure 87. Pre-flowering racemes with macadamia lace bug damage highlighted. Photo: Craig Maddox.

Controlling pests in macadamia

Figure 88. Florets damaged by macadamia lace bug. Photo: Craig Maddox.

Figure 89. Cast macadamia lace bug skins on dead florets. Photo: Craig Maddox.

Figure 90. Lacewing larva (right) versus macadamia lace bug nymph. Note the dead bodies on the lacewing's back. Photo: Chris Fuller.

Management

MLB populations increase over successive seasons as they overwinter on the bark of trees. Start monitoring at bud break, especially if MLB was a problem the previous year. Early action now 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.

Cultural and physical

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

Biological

Macadamia lace bug has many naturally occurring predators such as predatory bugs, lacewing larvae (Figure 90), lady beetle larvae and spiders. While these beneficial species 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 in macadamias. NSW DPI researchers have been conducting preliminary trials incorporating commercial beneficial insects such as lacewings. Results will be provided as soon as they are available.

Chemical

Careful consideration is needed when applying control compounds during flowering to ensure minimal effect on bees and other insect pollinators. Applying crop protection compounds onto flowers should be avoided where possible. If deemed necessary, then flower sprays using trichlorfon should be applied late in the afternoon after bees have finished foraging. Communication with beekeepers is essential for protecting the crop and pollinators. Early identification of MLB, e.g. at pre-flowering, means that spraying open flowers will be eliminated, thus preventing any harmful effects to bees. The chemical control options for MLB are listed in Table 24.

Table 24. Chemical control options for macadamia lace bug in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Diazinon (Diazinon) PER14276, expires 30.11.22	S6	1B	14	High (10)	Use at pre-flowering only. Do not use more than two sprays per season to avoid resistance. Highly toxic to bees.
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 system.
Trichlorfon (Dipterex® 500 SL) PER13689, **expires 30.9.21**	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. It is found in Queensland and New South Wales. It is a significant nursery pest, with the larvae feeding on macadamia species, including *Macadamia integrifolia* and *Macadamia tetraphylla*.

Risk period

Table 25. Macadamia leaf miner can be present 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 (Figure 91) have dark forewings with three white bars across each one. The hindwings are narrow and have an extensive plume of hairs along the hind margin. The total wingspan is approximately 7 mm.

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

Figure 91. Macadamia leaf miner adult. Photo: CSIRO/ BIO Photography Group, Centre for Biodiversity Genomics, University of Guelph.

Damage

Macadamia leaf miner larvae live in the mid-tissue of the leaf where they mine nutrients from the leaves, leaving a trail or tunnel where they have been (Figure 92). The mine is created by the miner eating the leaf material between the upper and lower skin layer of the leaf. A large 'blotch mine' might be seen on the upper side of the leaf. The larvae will be present within the tunnels in fresh incursions and the tunnelling can develop into large blisters as the damage worsens. Severe infestations can retard the growth and yield of nursery and young trees. Older symptoms of leaf miner will appear as fire scorched leaves on new flush.

Figure 92. Macadamia leaf miner trails. Photo: Chris Fuller.

Management

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

Cultural and physical

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

Chemical

Spraying for macadamia leaf miner is made difficult as the larvae are protected by their mines and the pupae are protected by the pupal chamber. Consider sprays if young trees are heavily infested. The chemical control options for macadamia leaf miner are listed in Table 26.

Table 26. Chemical control options for macadamia leaf miner in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acephate (Lancer® 970)	S6	1B	0	High (10)	Do not spray when bees are foraging.
Diazinon (Diazinon)	S6	1B	14	High (10)	Do not use more than two sprays per season to avoid resistance. Use at pre-flowering only. Toxic to bees.

Macadamia nut borer

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

Risk period

Table 27. 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 a reddish-brown with a distinctive black triangle marking on the hind margin of each forewing (Figure 93).

Figure 93. Macadamia nut borer adult.

MNB eggs are scale-like and are laid singularly on the surfaces of green husks. Eggs can be found anywhere on the nut, but are often laid along the suture line. They are ivory white when first laid but turn red just before hatching (Figure 94). Eggs that have been parasitised by wasps will appear black after about 5 days (Figure 95).

Figure 94. Macadamia nut borer egg.
Photo: Chris Fuller.

Figure 95. Parasitised macadamia nut borer eggs appear black after about five days. Photo: Chris Fuller.

Larvae are legless grubs which appear pinkish (Figure 96) 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 97), which usually occurs within the nut. Pupae are light brown at first and darken with age. The whole life cycle takes around 5 weeks in summer.

Figure 96. Macadamia nut borer larvae.
Photo: Chris Fuller.

Figure 97. Macadamia nut borer larvae will develop cocoons before pupating. Photo: Craig Maddox.

Damage

Damage is easily identified as entry holes in the husk of nuts (Figure 98). These holes are usually close to the panicle and will have protruding frass (Figure 99). Infested nuts will drop prematurely. Greatest losses occur when the shell has not fully developed. Where thin-shelled varieties have been previously attacked and the shell compromised, MNB damage will be apparent.

Management

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

Cultural and physical

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

Biological

Until recently, MNB was the number one pest of the macadamia crop. It was not until the NSW DPI entomology team developed a system for mass-rearing and releasing *Trichogrammatoidea cryptophlebiae* (Figure 100) 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 after January specifically for MNB is no longer required. It should be noted the effectiveness of MacTrix may be compromised in temperatures over 35 °C.

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

Figure 98. A macadamia nut borer at an entry hole. Photo: Chris Fuller.

Figure 99. A macadamia nut borer entry hole with protruding frass. Photo: Chris Fuller.

Figure 100. A female *Trichogrammatoidea cryptophlebiae* investigating an egg. Photo: R Llewellyn.

Chemical

The control options for macadamia nut borer are listed in Table 28.

Table 28. Control options for macadamia nut borer in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (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 two sprays per season to avoid resistance. Dangerous to bees.
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High (10)	Do not use more than two sprays per season to avoid resistance. Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.
MacTrix release	0	0	0	Per release (-1)	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 four applications in any one season.
Tebufenozide (Mimic 700 WP)	S5	16A	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 Queensland, so strict on-farm biosecurity measures should be enforced when moving any machinery or other equipment from infested areas to non-seed weevil areas.

Risk period

Table 29. 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, about 6 mm long (Figure 101) and can be in the orchard all year. During winter they will often be found in groups on the ends of branches. As the weather warms, the weevils will wait until the nuts have reached a vulnerable size, approximately 8 mm in diameter, in which to lay their eggs (Figure 102). The fully grown larvae can be up to 10 mm long.

Figure 101. Macadamia seed weevil. Photo: Craig Maddox.

Figure 102. A macadamia seed weevil lays its egg on a chewed patch of husk. Photo: Craig Maddox.

Damage

The female weevil scarifies an area about 3–4 mm wide on the husk into which she lays a single egg. This will be obvious as a triangular lay mark at the stem end of the fallen nuts (Figure 103). 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 104), then pupate and exit the nut as an adult. Larva development depends on the period before shell hardening because once the shell hardens, the developed weevil is not able to exit. Damage after shell hardening will appear as grazing marks all over the husk, similar to a golf ball appearance (Figure 105).

Figure 103. Typical mark left by macadamia seed weevil that indicates egg-laying. Photo: Craig Maddox.

Management

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

Figure 104. Macadamia seed weevil larvae and pupae overwintering in nuts. Photo: Craig Maddox.

Figure 105. Macadamia seed weevil damage after shell hardening appears as grazing marks all over the husk, leaving a golf ball appearance. Photo: Craig Maddox.

To prevent MSW from thriving in your orchard:

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

Cultural and physical

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

Biological

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

Chemical

Best results for MSW control have been achieved with a combination of good hygiene (removing infested nuts) and targeted spraying with indoxacarb (PER86827) during spring when the nutlets are 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 30.

Table 30. Chemical control options for macadamia seed weevil in macadamia in NSW and Qld. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Indoxacarb (Avatar®) PER86827, expires 31.3.26	S6	22A	42	High (10)	Apply first when nuts are at pea size; best control is achieved when applied at match head size. Ensure thorough coverage. Sweep out affected nuts and expose to full sunlight. Mulch affected nuts. Do not exceed a maximum of 2 applications per crop with a 10-day retreatment interval.
Tetraniliprole (Vayego® 200 SC)	S5	28	10	Low (1)	Start applications when weevils are active and after petal fall. Do not apply more than three applications within a season.

Macadamia twig girdler

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

Risk period

Table 31. 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 itself is seen. The larvae emerge from the egg at 1–5 mm long and develop to about 23 mm long. The head is dark brown to black, the body is light brown with dark brown spots (Figure 106). The adult MTG is a silvery-white moth with yellow legs and a wingspan up to 26 mm. It is mostly active at night.

Figure 106. Macadamia twig girdler larva. Photo: Chris Fuller.

Damage

MTG larvae feed in webbed shelters that become cluttered with excrement (Figure 107). They can also reside in damaged foliage as larval development progresses (Figure 108). Numerous larvae at various stages will often be in one shelter, which can remain on the tree long after the life cycle is completed, giving it a ragged appearance (Figure 109). Twigs weakened by girdling readily snap off and this tends to induce bunched growth. Tunnelling in the husks and kernels causes damage similar to the macadamia nut borer.

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

Figure 107. A webbed shelter made by macadamia twig girdler larvae. Photo: Chris Fuller.

Figure 108. Macadamia twig girdler damage. Photo: Chris Fuller.

Figure 109. A young macadamia tree looking ragged from macadamia twig girdler damage. Photo: Chris Fuller.

Management

Monitoring is essential, especially for new plantings and nursery plants. The suggested threshold for action is 15% 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 management practices such as pruning and biological controls will also help.

Cultural and physical

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

Biological

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

Chemical

The chemical control options for MTG are listed in Table 32.

Table 32. Chemical control options for macadamia twig girdler in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Carbaryl (Bugmaster® Flowable)	S6	1A	0	High (10)	Do not use more than two sprays per season to avoid resistance. Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.
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 four 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 with the naked eye, we often see the damage they cause such as bronzing of nuts caused by flat mites and husk silvering caused by broad mites. Most mite damage is cosmetic, however high populations in March to May will prevent bud initiation. In most cases the 'normal' weather pattern will wash this population away in a usual wet season.

Risk period

Table 33. 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 mite

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

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

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

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

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

Flat mite

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

Signs of damage

Broad mite

Broad mites and *Scirtothrips* can destroy flower buds and eliminate any potential crop for the season (Maddox et al. 2014) Broad mites feed on flowers, young leaves and fruit (Figure 110 and Figure 111). Flower feeding symptoms include silver-bronze colouring and deformation. Broad mites will also attack the new leaf flush and will lay on the under-side of the leaf. Symptoms will present as cupping and distortion of the leaf (Figure 111). Recently, eriophyid mite has become more of an issue, particularly in the A series trees. It causes leaf stunting and branch dieback.

Figure 110. Broad mites on A16 macadamia. Photo: Craig Maddox.

Figure 111. Broad mite damage to A16 macadamia.

Figure 112. Eriophyid mite damage to A16 macadamia variety. Photo: Craig Maddox.

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

Flat mite

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

Management

Monitoring

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

Cultural and physical

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

Biological

The following biological controls are commercially available:

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

Chemical

A timely spray to protect autumn flush might be required. The chemical control option for mites is listed in Table 34.

Table 34. The chemical control option for mites in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Abamectin (Vertimec®) PER87510, expires 30.6.24	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 most commonly in spring and summer, particularly after rain.

Risk period

Table 35. 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 across the wing covers and a similarly coloured spot in the middle of each wing cover (Figure 113). The yellowish eggs are small and oval. Eggs are laid just below the soil surface, mainly in pasture such as ryegrass. The larvae feed on the grass roots and pupate in the soil. The larvae are white, slightly flattened with hard brown plates at both ends and reach 12 mm long before pupation.

Figure 113. Red-shouldered leaf beetle.

Damage

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

Management

Understanding the pest's life cycle is key to controlling red-shouldered leaf beetle. It takes approximately 2 months to complete and this will happen around summer. Adults will lay eggs after good rain. As with other swarming pests, it is often only noticed when there are swarms of beetles in a tree. Other trees are also likely to be infested with the beetles.

Cultural and physical

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

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

Biological

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

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

Chemical

Generally you can disregard individual beetles or groups fewer than 10. 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 36.

Controlling pests in macadamia

Table 36. 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) Qld, WA and NT only	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 two sprays per season to avoid resistance. Do not allow spray to drift off-target onto sensitive areas. Dangerous to bees.

Scale insects

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

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

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

Risk period

Table 37. The peak risk period for scales 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

The eggs are yellow and 0.15 mm long. The first instar (or crawler) is yellowish and 0.15 mm long. It moults after approximately 14 days. The second instar looks similar to the adult females, which are variable in colour and shape, measuring 1–2 mm in diameter. On leaves they are grey to white, circular and convex (Figure 114); on stems, they are brown and slightly convex. They lay their eggs under the body. Males are oval-shaped and elongate but are not always present. The adult male is a tiny insect with one pair of wings, no mouthparts and only lives for 24 to 48 hours.

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

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

Inspect branches, leaves and nuts to find the greyish-coloured scale insects (Figure 115).

Damage

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

Management

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

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

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

Cultural and physical

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

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

Biological

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

Chemical

Frequent or inappropriate application of broad-spectrum insecticides will disrupt natural enemy populations, allowing scale insect populations to increase. The chemical control option for scale insects is listed in Table 38.

Figure 114. Latania scale adult. Photo: Lorraine Graney, Bartlett Tree Experts, Bugwood.org.

Figure 115. Latania scale multiple life stages. Photo: United States National Collection of Scale Insects Photographs, USDA Agricultural Research Service, Bugwood.org.

Table 38. The chemical control option for scale insects in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Acetamiprid + pyriproxyfen (Trivor®)	S6	4A + 7C	14	High (10)	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 39. 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 (Figure 116). When they hatch they are small (1–3 mm long), but generally develop until they are about 25 mm long. Digging just below the soil surface near roots will reveal curled up larvae in a characteristic C-shape (Figure 117). They have three pairs of well-developed legs and usually a hard, brown, dark red or black head.

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

Adults are similar in size and shape to other scarab species including the African black beetle (Figure 119). They are tan coloured with striping on the outer wing cover (Figure 119). It is not until the larvae become adults that clear identification is possible. Most scarab beetles are approximately 8–25 mm long.

Figure 117. Argentinian scarab larva.

Figure 116. Argentinian scarab larvae in the soil.

Figure 118. African black beetle. Photo: Hanna Royals, Screening Aids, USDA APHIS PPQ, Bugwood.org.

Controlling pests in macadamia

Figure 119. 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 semi-shade environments.

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

The flights are the most obvious sign of activity as scarab beetles tend to swarm. They will be noticed especially at night when they are attracted to lights, similar to Christmas beetles which also belong to the scarab beetle family. Regular light trapping by NSW DPI entomology staff revealed the peak flight times were around November–December (Figure 120).

Management

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

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

Biological

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

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

Chemical

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

Figure 120. NSW DPI entomologists trialling different lights to see which is most effective at trapping beetles, especially scarabs.

Tea mosquito bug

The tea mosquito bug (*Helopeltis* spp.) is mostly a pest for north Queensland macadamia but has been reported as far south as Brisbane. It is a significant pest globally and in Vietnam macadamia. 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 40. 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 brown to reddish-brown but with an orange thorax (Figure 121). There is a dark pin-like protrusion from the centre of the thorax.

The legs are long and fragile, similar to mosquito legs. The eggs are white, elongated and about 1 mm long. Later instar nymphs appear similar to adults, although they are wingless and orange-brown. Antennae are longer than the body (George et al. 2015). Eggs are laid in plant tissue, mainly in stems and petioles of young leaves. Eggs take about 1 week to hatch. Nymphs will feed on young leaves and shoots. There are five nymph stages with a developing period of 10–16 days. Adults can live for several weeks and females can lay 30–50 eggs in this time.

Damage

Feeding by both nymph and adults will produce black necrotic lesions on soft leaves, young shoots, flower panicles and developing fruit. Damage could be mistaken for FSB or BSB damage.

Figure 121. Adult tea mosquito bug. Photo: QDAF.

Management

Cultural and physical

The tea mosquito bug prefers dense foliage within the plant (Figure 122) 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 are also prone to be a pest. Green tree ants are also not found south of Gladstone (Queensland Museum).

Chemical

No chemicals are registered for the control of tea mosquito bug in macadamia.

Figure 122. Adult tea mosquito bugs in custard apple. Photo: Phillip Banks.

Thrips

Flower thrips (*Scirtothrips dorsalis*), greenhouse thrips (*Heliothrips haemorrhoidalis*) and redbanded thrips (*Selenothrips rubrocinctus*) will all damage macadamia. Western flower thrips (*Frankliniella occidentalis*; Figure 123) is also becoming a problem in the Bundaberg region.

Risk period

Table 41. 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 0.5–2 mm long, making them hard to see with the naked eye. They are cylindrical, the head often being narrower than the prothorax or the rest of the body (Figure 124). Adult flower thrips are orange-brown while adult greenhouse and redbanded thrips are black. Redbanded thrips nymphs are light yellow with a bright orange band (Figure 125). Flower thrips can also affect leaves.

Figure 123. Western flower thrips. Photo: David Cappaert, Bugwood.org.

Damage

Damage on the outer husk is caused when the sticky excrement hardens and gives the fruit an uneven, reddish appearance. Over time it will become a uniformly brownish rust colour (Figure 126). 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 127). Continual attack on new flush is a concern as this can cause the plant to lose carbohydrates.

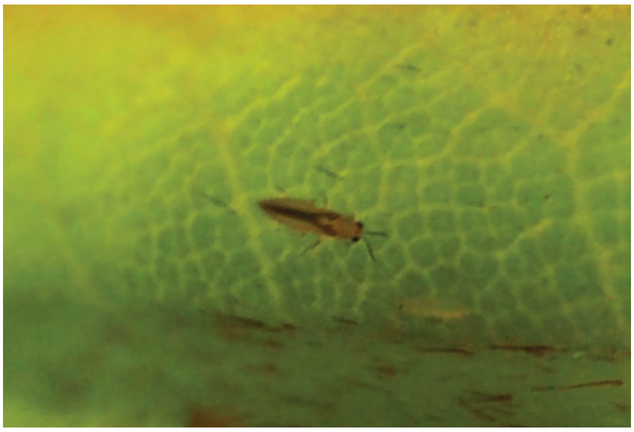

Figure 124. Adult thrips. Photo: Chris Fuller.

Management

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

Figure 125. Thrips nymphs. Photo: Chris Fuller.

Cultural and physical

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

Biological

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

Figure 126. Thrips damage to a macadamia nut. Photo: Chris Fuller.

Chemical

An effective control program for thrips should be based on strategic spraying informed by monitoring and observation. When spraying at or around bloom, be aware of any label warnings and recommendations for protecting bees and other off-target species. The chemical control options for thrips are listed in Table 42.

Figure 127. Thrips damage to macadamia leaves. Photo: Chris Fuller.

Table 42. Chemical control options for thrips in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Insecticide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Abamectin (Vertimec®) PER87510, expires 30.6.24	S6	6	28	High (10)	Only apply once per season. Dangerous to bees.
Acephate (Lancer® 970)	S6	1B	0	High (10)	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 four applications in any one season.

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Vertebrate pests in macadamia

Birds

Bird species that disrupt macadamia production directly by removing nuts or damaging plants (chewing) and infrastructure such as irrigation lines, include but are not limited to, sulphur-crested cockatoos (*Cacatua galerita,* Figure 128), galahs (*Eolophus roseicapilla*) little corellas (*Cacatua sanguinea*), black cockatoos (*Calyptorhynchus banksia* , Figure 129) and Australian ravens (*Corvus coronoides*). The mistletoe bird (*Dicaeum hirundinaceum*) disrupts macadamia growth by introducing mistletoe, which is a parasite to the plant. Each bird species has its own movement and distribution patterns, breeding seasons and feeding strategies.

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

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

Monitoring

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

Figure 128. A flock of cockatoos approaching a macadamia orchard.

Control

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

Bird scaring

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

Acoustics

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

Figure 129. A black cockatoo.

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

Shooting

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

Drones

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

Other techniques include:

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

Further information is provided in the references section.

Further reading

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Deer

Deer are usually found in fringe areas of bush, woodlands and riparian vegetation, preferring agricultural areas interspersed with forest vegetation (Figure 130). They can destroy young macadamia plants through defoliation and stripping bark from tree trunks when they rub their antlers on trunks (Figure 131) and lower limbs. Younger trees that are not yet established usually suffer the most severe damage.

Figure 130. A chital deer (also known as axis deer) on a Bowraville property. Photo: Paul Trollis.

Figure 131. The result of trunk rubbing by deer.

Breeding

Males are sexually mature at 17 months but do not usually breed until they are about 4 years old due to competition from dominant stags. Females are usually sexually mature at 16 months and will breed once a year thereafter. The mating season is in autumn and this is when males will become territorial. The gestation period is 8 months with a single fawn being produced. While they do not breed as prolifically as pigs, their population is still expanding.

Management

Monitoring

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

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

Control and physical control

Exclusion fencing

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

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

Shooting

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

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

Chemical

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

Further reading

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Pigs

Feral pigs (*Sus scrofa*) are usually found within 2 km of a water source, although they can cover much greater distances. Pig population densities depend on environmental conditions such as food and water sources. Pigs are most active in late afternoons and early mornings, but if they have been hunted, will become nocturnal.

Pest identification

Male pigs are sexually mature at around 18 months and they usually roam alone, seeking out new territories. Females travel in groups called sounders. They can breed from 7–12 months of age and will produce a litter of 2–10 piglets (Figure 132). In favourable conditions, they can produce up to three litters a year, leading to rapid population expansion.

Figure 132. Pigs can produce up to 3 litters per year and can have up to 10 piglets.

Damage

Pigs can cause environmental damage such as wallowing and rooting up the ground causing erosion and are a major biosecurity risk, potentially spreading weeds and pathogens. Pigs also destroy infrastructure on the farm, including water courses. The digging done by pigs leaves depressions in the ground that make it difficult for finger wheels to harvest nuts (Figure 133).

Figure 133. Pigs damage the orchard floor causing erosion and making it difficult to harvest.

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

Pigs seem content in macadamia orchards (Figure 134) and can consume macadamia nuts in large quantities. Examining gut contents reveals multiple kilograms of kernel (Figure 135). A moderate size pig can consume up to 6 kg of nuts in shell per hour. A mature pig (90–100 kg) will consume 3% of its body weight per day; smaller pigs up to 5% of body weight. Ten pigs feeding in an orchard for 10 days can destroy nearly 300 kg of nuts in shell.

Figure 134. Pigs making their way to macadamia trees.

Management

Monitoring

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

Figure 135. Gut contents of a 70 kg sow containing approximately $60 of macadamia kernel.

Exclusion

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

While the initial cost of an effective pig exclusion fence (Figure 136) might seem high, it is likely that it will be recouped in just one season based on the following example calculations:

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

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

Figure 136. An effective pig exclusion fence.

Trapping

There are several trap types for pigs including silo mesh traps, trigger traps (Figure 137) and remotely controlled traps. Traps are generally set along a well-worn pad or in an area known to be frequented by pigs. Free feeding for a time to get the pigs entering and leaving the trap is essential. It might take weeks before a trap can be set to keep pigs in. The benefit of remotely controlled trigger traps is that the pig population can be monitored from a remote camera and the door triggered with the press of a button when the full complement of pigs is inside the trap.

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

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

Figure 137. Pigs caught in a trigger trap.

Shooting

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

Combining methods

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

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

Further reading

Mitchell B and Balogh S. 2010. Monitoring techniques for vertebrate pests – feral pigs, https://pestsmart.org.au/toolkits/feral-pigs/

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

Rats

The common black rat (*Rattus rattus*; Figure 138) is a major concern for the Australian macadamia industry. Rodents use resources based on availability, feeding within the trees (Figure 139) while macadamia is present and feeding and harbouring in non-crop habitats at other times.

Risk period

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

Figure 138. The common black rat (*Rattus rattus*). Photo: The Queensland Museum.

Table 43. The peak risk period for rats is from 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

Despite its name, the black rat is usually brown or grey. A distinctive characteristic of rats that helps distinguish them from similarly sized carnivorous marsupials is their front teeth: they have a pair of chisel-shaped incisors with hard yellow enamel on the front surfaces. Their nests might be seen before the actual rat itself. Look for burrows within the orchard (Figure 140), thatched twigs (Figure 141) up in the canopy and the distinctively eaten out nuts.

Figure 140. A rodent burrow.

Figure 139. A trapped rat in the tree canopy.

Figure 141. A macadamia branch damaged by rats.

Damage

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

Management

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

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

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

Cultural and physical

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

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

Cultural practices such as insect refuge strips (i.e. mohawks, Figure 142) can be established to encourage beneficial insects and are compatible with rodent management strategies, although they should be maintained and limited to the areas required. If rodent activity is observed, baiting or trapping programs should be undertaken within these refuges. Once pollination

Figure 142. An insect refuge strip (i.e. a mohawk).

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

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

Harvest

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

New plantings

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

Biological

There are potentially other methods for rodent control and while perhaps not considered conventional, one grower in Queensland is using snakes to help (Figure 143). Many growers also use dogs for limiting rat numbers. Establishing owl boxes along the perimeter of the orchard will also assist in controlling the rat population.

Chemical

Bait strategically (Table 44), targeting areas known for rodent activity. Rather than spreading limited baiting resources around the entire orchard, focus on key blocks which have suffered rodent activity previously.

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

Figure 143. Snakes might contribute to rat control programs in a limited way. Photo: Paul Trollis.

Acknowledgement

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

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

Table 44. Chemical control options for rats in macadamia in NSW. Always read the label.

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

Table 45. 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 35
Fall armyworm									Page 40
Macadamia felted coccid									Page 55
Macadamia leaf miner									Page 58
Macadamia twig girdler									Page 65
Macadamia seed weevil									Page 63
Tea mosquito bug									Page 75
Black citrus aphid									Page 39
Macadamia flower caterpillar									Page 52
Macadamia lace bug									Page 55
Flower looper									Page 42
Banana fruit caterpillar									Page 33
Mites									Page 67
Red-shouldered leaf beetle									Page 69
Fruit spotting bug									Page 43
Green vegetable bug									Page 47
Leptocoris species									Page 55
Scale insects									Page 71
Scarab beetles									Page 73
Thrips									Page 73
Macadamia nut borer									Page 60
Macadamia kernel grub									Page 48
Rats									Page 84

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

Risk period

Table 46. 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 infection conditions. Diseased flowers appear dark brown and cluster together on the rachis with fungal strands and greyish fungal spores, hence the grey mould name. Complete destruction of the raceme can follow with grey fuzzy mould covering dead flowers (Figure 144).

Figure 144. Botrytis blight. Photo: Femi Akinsanmi.

Management

Cultural and physical

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

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

Chemical

If infection occurs in July flowering, be prepared to spray during later flowering as inoculum will be present. Temperature and moisture play an important role in deciding when to spray; the aim is to have fungicide in place before flower petals start to turn brown. The chemical control option for Botrytis blight is listed in Table 47.

Table 47. The chemical control option for Botrytis blight in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Iprodione (Rovral® Aquaflo)	S5	2	0	Low (1)	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.

Branch dieback

Cause

Branch dieback is caused by the fungus *Dothiorella ribis* (previously *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 48. Branch dieback can be present 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 healthy sheen. The plant parts become 'blighted' and start to die back (Figure 145). 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 146).

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

Figure 145. Branch dieback in macadamia. Photo: Femi Akinsanmi.

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

In some cases, before obvious dieback symptoms become apparent, the trees might appear to be suffering from a nutritional disorder as the leaf veins turn reddish. In other cases, particularly trees younger than 4 years, the leaves can appear a dull khaki green with the whole tree dying (Figure 147) within 3 to 4 weeks. This is

Figure 146. A discoloured cross-section typical of branch dieback.

common in diseases associated with the Botryosphaeriaceae group of fungi. Similar to Phytophthora, dieback can occur more commonly at the end of the rows where waterlogging can occur or on hilltops where soil is poorer or shallower. Generally, symptoms will appear from mid-summer to early autumn after prolonged warm, humid hot weather.

Management

Cultural and physical

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

Cut out dead branches until you identify a clean-cut cross-sectional area. Ensure the cut is made so that water does not pool on the cut surface. If discoloured cross-sections continue to the trunk, you will need to remove the tree. Paint large exposed branches with copper and water-based white paint.

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

Finely chipped dead and decaying timber can be incorporated into a composting pile where the temperature ranges 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, see NSW DPI Primefact 'How to compost on farm'.

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

Chemical

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

Figure 147. A macadamia tree with advanced branch dieback.

Flower blight

Cause

Flower blight, 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 and it resulted in total crop failure. The disease now occurs in all macadamia producing regions on the Australian east coast.

Risk period

Table 49. The peak risk period for flower blight 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 148). Infections can occur at any stage of raceme development but the 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 148. Rachis dieback and early dry flower from the tip. Photo: Femi Akinsanmi.

Management

Cultural and physical

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

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

Chemical

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

Green mould

Cause

Cladosporium gloeosporioides is a dark coloured mould that attacks the leaves and fruits 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, in Australia, green mould is emerging as a more common issue.

Risk period

Table 50. The peak risk period for green mould is from bud break to 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

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 149). The disease is most likely to appear at the end of pollination.

Management

Cultural and physical

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

Chemical

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

Figure 149. Cladosporium blight in macadamia raceme. Photo: Femi Akinsanmi.

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 after wet weather and warm temperatures. The prevalence of husk rot is increasing in macadamia orchards.

Risk period

Table 51. 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 diameter will appear on the green fruit pericarp (Figure 150). These lesions can form greasy decay of the entire fruit pericarp.

Figure 150. Husk rot on macadamia nuts.

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

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

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

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 developed on an injured husk, it cannot be cured, it can only be suppressed.

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

Where branches with *Phomopsis* canker are identified, they should be cut out of the tree. Ensure that the cut is at least 15 cm below the lesion/good wood intersection. Disinfect 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 cut.

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 52.

Table 52. The chemical control option for husk rot and canker in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (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 splash easily spreads fungal spores from diseased sticktights to developing nuts in the tree canopy. Macadamia husk spot can cause heavy premature nut shedding.

Risk period

Table 53. The peak risk period for macadamia husk spot 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

Early symptoms appear as pale yellow flecks with a diffuse halo on the husk. These spots become a darker yellow to tan-brown and expand to approximately 5–10 mm in diameter (Figure 151). The spots will appear later in the season on 3/4 to full-size nuts. Dry husk spots are woody and hard to cut through compared to an unaffected husk. While the shell and kernel are not affected, macadamia husk spot can result in nuts dropping 4–6 weeks early. These nuts will be immature, have low oil accumulation and will not be suitable for processing.

Management

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

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

Cultural and physical

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

Chemical

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

The chemical control options for husk spot are listed in Table 54.

Figure 151. Macadamia husk spot damage.

Table 54. Chemical control options for macadamia husk spot in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Azoxystrobin + tebuconazole (Custodia®)	S5	3 + 11	15	Low (1)	Beware of resistance, do not apply more than two consecutive sprays of either Group 3 or 11 fungicides.
Carbendazim (Spin Flo®)	S7	1	14	Medium (5)	Do not apply more than two 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.
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 to 28 days later, depending upon prevailing weather conditions. Do not apply more than two sequential applications of a Group 7 fungicide before rotating to a fungicide with a different mode of action.
Pyraclostrobin (Cabrio®)	S5	11	0	Low (1)	Do not apply more than two sprays per season as part of a complete disease control program. Start application at match head stage and a repeat application at 14 to 28 days later. Ensure that fungicides from an alternative chemical group are included in the spray program each season.
Pyraclostrobin + fluxapyroxad (Merivon®)	S5	7 + 11	21	Low (1)	Start applications at match head growth stage. Do not apply more than three applications a year and no more than two consecutive applications per year. Ensure that fungicides from an alternative chemical group are included in the spray program each season.

Phytophthora disease

Cause

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

Risk period

Table 55. 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 off. Trees can also be stunted.

Trunk canker mostly occurs on the main trunk but can also spread to the limbs of the tree. It appears as cracking up the length of the trunk from the ground. Red resin will often ooze from these vertical cracks (Figure 152). Over time, the bark will become corky and deeply furrowed, when it can be easily peeled away, revealing a reddish coloured wood. The affected trees often have healthy suckers sprouting from the rootstock at ground level. The death from trunk canker results from the cankers girdling the trunk.

Management

Unfortunately, the *Phytophthora* 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* pathogen is in the soil, it can never be eliminated.

Cultural and physical

Only use clean planting material. Nurseries supplying tree stocks should use sterile (steamed) material that will eliminate *Phytophthora* pathogens. Ensure new plants have a strong, well developed root system. Try to plant trees where you can achieve adequate drainage so that there is no waterlogging. In low lying areas, look at how this could be achieved with mounding and/or drainage in a way that will not compromise mechanical harvesting.

Compost, chicken manure and urea assist by improving soil health and inhibiting Phytophthora. However, be careful when adding fertilisers and uncomposted animal manures that can release ammonia and salts and damage young roots.

Trunk canker generally results from wounds near the base of the tree. Try to avoid cutting or wounding the tree near ground level. Place guards around the base to prevent 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 56.

Figure 152. Ooze sap from a severe case of Phytophthora. Photo: Femi Akinsanmi.

Table 56. Chemical control options for Phytophthora in macadamia in NSW. Always read the label.

Active constituent (example trade name)	Poison schedule	Fungicide group	WHP (days)	Effect on beneficials (IPDM score)	Remarks
Copper as cuprous oxide (various)	S6	M1	1	Low (1)	Preventative not curative. Do not use more than five 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

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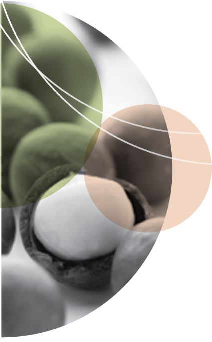
Table 57. The peak risk periods for macadamia diseases.

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 89
Phytophthora									Page 96
Flower blight									Page 91
Green mould									Page 92
Macadamia husk spot									Page 96
Botrytis blight (grey mould)									Page 88
Husk rot and canker									Page 93



Non-bearing and nursery trees

Young trees that are not bearing nuts (Figure 153) do not need the same intensive spray schedule as bearing trees, however, they still require continual monitoring for pests and disease. Below are the types of problems most likely to be encountered with young, non-bearing macadamia trees (Table 58).

Table 58. Problems most likely to be encountered with young non-bearing macadamia trees.

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

Figure 153. A young macadamia tree damaged by wallabies.

Nutrient disorders

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

Introduction

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

Good soil nutrition begins before planting so site preparation is vital. Before planting, soil testing should be conducted across the whole orchard, separating samples that might vary due to changes in soil characteristics. Sampling depths should be about 0–20 cm and 20–40 cm pre-planting. In well-drained red soils in higher rainfall areas, testing to 40–60 cm will determine subsoil acidity. In planted orchards, ideally try to include samples from different tree varieties and ages. Given the 2 year lead time from ordering plants to delivery, growers have plenty of opportunity to perform complete horticultural soil tests and act on the information received. This will allow the amendments enough time to be effective.

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

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

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

Nitrogen

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

Deficiency: lack of nitrogen reduces photosynthetic capacity and therefore growth. Nitrogen deficiency can cause reduced flowering and fruit set, therefore decreased production (Figure 154). It is quite mobile in plants so younger leaves recycle it from older leaves which then go yellow (Figure 155) and drop off prematurely.

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

Figure 154. Nitrogen deficiency in a macadamia tree. Photo: Andrew Sheard.

Figure 155. Older and younger leaves all show general yellowing, but it is worse on 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 phosphorus, making it unavailable to the plant. However, it is not the actual amount of P that might be low, but rather the availability of the P to the plant. This is further compounded when the tree has exposed roots (Figure 156). These roots indicate minimal proteoid roots and therefore an inability to extract available P, thus leading to deficiency.

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

Toxicity: soils high in P often induce iron deficiencies.

Figure 156. Exposed roots indicate decreased proteoid roots, creating an environment less able to absorb phosphorus. Photo: Andrew Sheard.

Potassium

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

Cation exchange capacity (CEC) and the amount of potassium available will influence whether plants will suffer from potassium deficiency. Ensure you have the correct CEC ratio and sufficient available potassium in the soil.

Deficiency: potassium is mobile in the plant so deficiency symptoms will appear on older mature leaves as light brown necrotic areas between the veins and along leaf margins (Figure 157).

Figure 157. Necrotic areas between the veins and along leaf margins are signs of potassium deficiency. Photo: Andrew Sheard.

Calcium

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

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

Deficiency: low levels of calcium can be associated with leached, low pH soils. Amendments for low pH will depend on the availability of other elements such as magnesium. Calcium is not very mobile in the plant so deficiencies appear on the new growing points and include yellowing of the leaf tips (Figure 158 and Figure 159).

Figure 158. Calcium deficient leaves. Photo: Andrew Sheard.

Figure 159. Yellowing leaf tips is a symptom of calcium deficiency. Photo: Theunis Smit.

Magnesium

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

Deficiency: magnesium is readily mobile in the plant, moving from older to newer plant tissues (Figure 160). Magnesium deficiency will appear as interveinal yellowing from the leaf tips and edges towards the central midrib areas (Figure 161). Exchangeability and the ratio of magnesium in relation to other nutrients such as calcium and potassium will influence its uptake. Deficiencies mainly occur in high rainfall areas with low pH sandstone soils and ferrosols. Heavy applications of potassium can also induce magnesium deficiency.

Figure 160. Magnesium deficiency in macadamia, note that older leaves are most affected as magnesium is quite mobile within the plant. Photo: Andrew Sheard.

Figure 161. Interveinal yellowing from leaf tips to the midrib is a symptom of magnesium deficiency. Note the leaf base area remains green. Photo: Andrew Sheard.

Iron

Iron (Fe) is required for chlorophyll production.

Deficiency: macadamia plants deficient in iron will display interveinal yellowing with the leaf veins remaining green (Figure 162). In severe cases, young leaves can turn almost white with dieback of the leaf tip and shoot growing point, and young nut husks will lose their green lustre to become pale yellow (Figure 163). As iron is not very mobile within the plant, these symptoms will be displayed on the younger leaves.

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

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

Figure 162. Yellowing of iron-deficient plants due to the lack of chlorophyll. Remember iron deficiencies can be induced through high levels of competing elements such as phosphorus. Photo: Andrew Sheard.

Figure 163. Iron deficiency in macadamia nutlets showing chlorosis due to lack of chlorophyll. Photo: Andrew Sheard.

Boron

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

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

Deficiency: as boron is not very mobile within the plant, younger leaves will display symptoms first, becoming leathery and having split veins. In severe cases, poor internodal growth and leaf dieback (Figure 135) become apparent. To rectify the deficiency, boron is best applied by spreading on the ground 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 for just before peak flowering.

Recent work showed that a foliar boron spray on boron-deficient plants gave clear benefits for first grade kernel yield and kernel recovery (Russ Stephenson, pers. comm.).

There is a fine line between boron deficiency (Figure 164) and boron toxicity (Figure 165).

Figure 164. Boron deficiency showing poor internode growth and leaf dieback. Photo: Andrew Sheard.

Figure 165. Marginal leaf burn from boron toxicity. Photo: Andrew Sheard.

Zinc

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

Deficiency: zinc is relatively immobile in the plant so symptoms will appear on younger shoots first, as rosetting of leaves at the end of shoots and stunted leaves with intercellular chlorosis (Figure 166 and Figure 167).

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

Figure 166. Distinct intercellular chlorosis which is typical with zinc deficiency. Little leaf or rosetting is also present. Photo: Andrew Sheard.

Figure 167. Intercellular chlorosis caused by zinc deficiency. Photo: Andrew Sheard.

Manganese

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

Deficiency: manganese is relatively immobile so deficiency symptoms will appear on young leaves as interveinal chlorosis close to the midrib (Figure 168). Leaves usually maintain a distinct band of darker green along the midrib and veins. High pH soils will reduce Mn availability and high organic matter can also tie up manganese.

Toxicity: in soils in the north coast of NSW, particularly where pH is low (< 5), we have seen many plants displaying manganese toxicity. Toxicity symptoms include interveinal brown spots along the outside edge of older leaves (Figure 169). Leaves may eventually brown off and die back. Ameliorating low soil pH and increasing organic matter in the soil will alleviate Mn toxicity.

Figure 168. Chlorosis due to manganese deficiency with dark green along the midrib. Photo: Andrew Sheard.

Figure 169. Manganese toxicity showing brown spots along the outer edges of the leaves. Photo: Alan Mason.

Nutrient disorders

Copper

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

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

Deficiency: as copper is key to lignin production, deficiencies will be displayed as twisted or distorted lateral branches. The most obvious indicator of copper deficiency is the appearance of a 90-degree branch angle of new flush (Figure 170); almost in the shape of a 'C'. Alkaline soils will inhibit copper uptake.

Further reading

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

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

Figure 170. A 90-degree branch angle of new flush is a typical sign of copper deficiency. Photo: Andrew Sheard.

Pollination with native stingless bees

Chris Fuller, Kin Kin Native Bees

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

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

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

An inventory of insects that visited macadamia flowers at the different trial sites was compiled. Stingless bees and honey bees were by far the most significant floral visitors during the trials, and of these, stingless bees were the most efficient pollinators. Consequently, growers could increase nut set by introducing hives of managed pollinators to their orchards.

There is a developing pollination industry based around using native stingless bees. Hives can either be rented or brought in for the flowering period, or alternatively, some growers are choosing to purchase their own hives (Figure 171). When hives are kept on the farm all year, growers should consider planting alternative forage from which the bees can collect nectar and pollen when the macadamias are not flowering (see Figure 172 for an example).

This is especially important in areas such as Bundaberg where many orchards have little surrounding natural forests. These forage areas also provide harbourage and food for beneficial predatory insects that help with pest insect control and add to the overall biodiversity on the orchard. Stingless bees are generalist foragers and are very good at finding feed, provided it is in reasonably close proximity. Weeds such as cobblers pegs or billy goat weed (also known as blue top) can provide pollen and nectar over winter when little else is available.

Figure 171. As hive numbers grow in orchards, stands are created for multiple hives. This stand will eventually house 20 hives.

Figure 172. A mohawk of alternative forage for bees.

For further information on the availability and use of native stingless bees in macadamia orchards, please contact Chris Fuller at info@nativebees.com.au.

Honey bee best practice management

Honey bees are vital in agriculture, pollinating countless food crops including macadamia (Figure 173). 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.

Figure 173. A honey bee pollinating a macadamia flower.

Communication to organise beehive placement timing and location before flowering is essential

Communication between beekeepers, growers, spray operators and neighbours is vital, especially as honey bees can easily fly 2 km from their hive to forage on flowers. In addition to word of mouth and written pollination contracts, the BeeConnected app (Figure 174) is a valuable tool for farmers who would like to be informed of, and connected with, beekeepers near their farm, contractors spraying the crop protection products and beekeepers who want to be informed of crop protection activities near their beehives (Figure 175). After registering as a user, farmers can enter the location of their property and if this is within 10 km from where a beekeeper registers the location of their beehives, then both parties will be notified, prompting a discussion about their activities. This can be done using the secure messaging service.

Figure 174. The BeeConnected app.
Source: CropLife Australia.

Farmers can register the time and location of their planned crop protection activities, such as pesticide spraying. Using a smart phone, farmers can find their paddock by exploring near their current location, a registered property, or searching GoogleMaps. Switching between street and satellite view makes it easier to find specific paddocks using nearby roads and geographical features. BeeConnected is optimised for Android and Apple smart phones (http://beeconnected.org.au/).

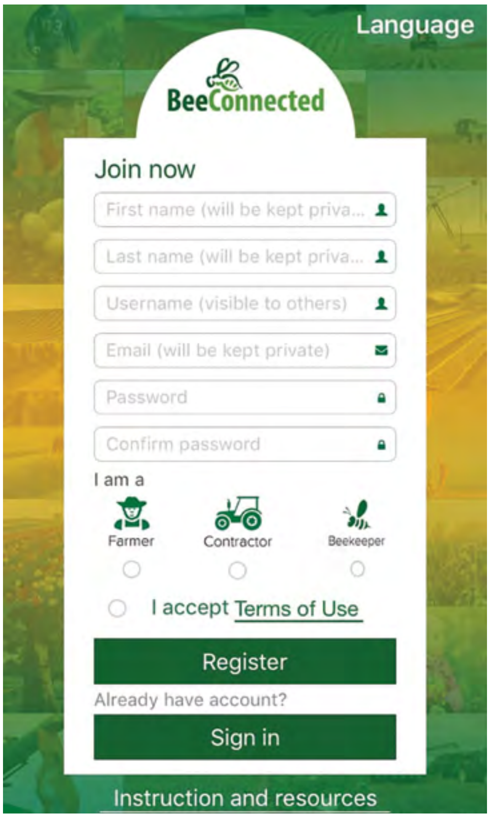


Figure 175. The BeeConnected app enables farmers, contractors and beekeepers to be connected.
Source: CropLife Canada.

Monitoring

Pre-flowering

Monitor crops and green racemes. If spraying is required, ensure it is completed before bees enter the orchard. Always check the chemistry you intend to use is not residual through to flowering.

During flowering

Ideally, if no pests were observed during pre-flower monitoring, then no further action should be required. 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 176) 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 (2 km) to find alternative food sources and can come in contact with insecticide treated crops).

Figure 176. A native bee in flight honing in on a macadamia flower. Photo: Chris Fuller.

Other ways to help bees

To ensure bees spend more time pollinating the crop than searching for water and to guard the bees from drinking pesticide-contaminated water, beekeepers and growers should provide clean water; a practice that includes covering or removing water sources for bees before a pest control treatment, or emptying and refilling water after a treatment is made. Water supplies will need to be cleaned and refreshed regularly (possibly daily).

Provide alternative pollen sources before and after macadamia flowering (for good colony strength and bee health) and always place hives away from areas prone to shade and flooding.

Biosecurity: how prepared are you?

How do you prepare for a biosecurity threat on your property? Some key things to be aware of include identifying the main pests, diseases and weeds to be aware of and developing a plan to manage these threats. Find out about the key pests and diseases, learn what you look for, how to identify them and what control options are available.

An essential part of managing biosecurity is to ensure employees are aware of their biosecurity obligations and key pests, diseases and weeds. Inducting staff before they start work should make them aware of your farm biosecurity plan, teach them what to look for and train them to report anything unusual immediately.

Reporting should be done by alerting a manager, contacting the Exotic Plant Pest Hotline on 1800 084 881 or by submitting a report online by visiting www.dpi.nsw.gov.au/biosecurity/report-a-pest-or-disease. A photo can be submitted as part of the report. Local Land Services (LLS) or NSW DPI staff can be contacted for advice and to assist with this reporting. Early detection and reporting are key to minimising the effect of an exotic pest or disease on the economy, environment or community.

On-farm biosecurity

The best way to start on-farm biosecurity is to create a Farm Biosecurity Plan. This does not have to be a huge document, but one that clearly outlines some simple steps you, your staff and visitors can take each day to minimise the risk of introducing and/or spreading unwanted pests and diseases on or off your property. It is likely that a plan is already in place, but is it documented? Assess the things you are already doing on-farm and use them where possible to start your plan; remember to keep it simple.

Figure 177. Biosecurity signage.

As mentioned, a great starting point is to induct new and existing staff or visitors onto your property. Discuss your biosecurity plans with them, let them know what your expectations are and remind them of their biosecurity obligations whilst working and to report anything unusual.

Having biosecurity signage (Figure 177) around the property is a constant reminder to all personnel to be vigilant in their hygiene, including hand tools, machinery, equipment and surveillance for anything unusual.

Please note: if you have one of the newer biosecurity farm signs that mention the *NSW Biosecurity Act 2015*, you must by law have a Farm Biosecurity Plan in place and be able to provide a copy of your plan if requested by a member of the public. Never put anything in your biosecurity plan that you are not actively implementing or cannot implement on your property as your plan can be audited at any time.

Using a sign-in/out register at the front office or workshop is useful for recording who has been on to the property and from where they came. It is also useful to keep a similar register for any machinery and vehicles; take note of the registration numbers. This detail can be very useful if tracing is required.

Another useful idea is to implement controlled traffic onto the property. This means minimising the property access points for staff and visitors by only using one or two key entrances that can be monitored. This also means that when you have consultants or other industry contractors/visitors coming on-site, ask them to book a time and day to meet you. Have them park their vehicles at the office and if they need to move around the property, this can be done using a specific farm vehicle. If this is not possible, it is always a good idea to get them to spray their vehicle wheels with an appropriate detergent/disinfectant before they enter the property and again when exiting.

A property map (Figure 178) identifying access points, evacuation points, check-in sites, wash down areas, amenities, chemical storage areas and no-go areas is ideal for staff and visitors so you can control where they go while on the farm.

Remember that biosecurity is a shared responsibility and we all have a biosecurity obligation to report anything unusual under the *Biosecurity Act 2015*. The key to managing exotic pests and diseases is to find out about them as quickly as possible so their effect on the economy, environment and community are minimised. If you have not started a biosecurity plan yet, what is one small step you can take today to make a change?

Bee aware when spraying during pollination

Many beekeepers place beehives on macadamia farms during flowering because of the pollination benefits the bees provide. This can be at the request of the farmer or beekeeper. Pollination services have mostly been provided at no cost to the farmer, 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, either 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 your chemical spraying can have on bee colonies located nearby (within 1–3 km). Please advise nearby farmers 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, which would be disappointing as bee pollination improves crop yield and profitability. This 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, see the NSW DPI Primefact Best Practice Bee Management in Macadamia.

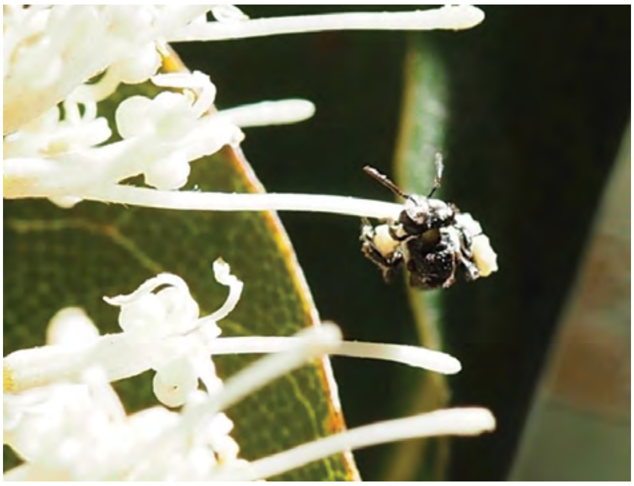


Figure 179. Native bee pollinating a macadamia flower. Photo: Chris Fuller.

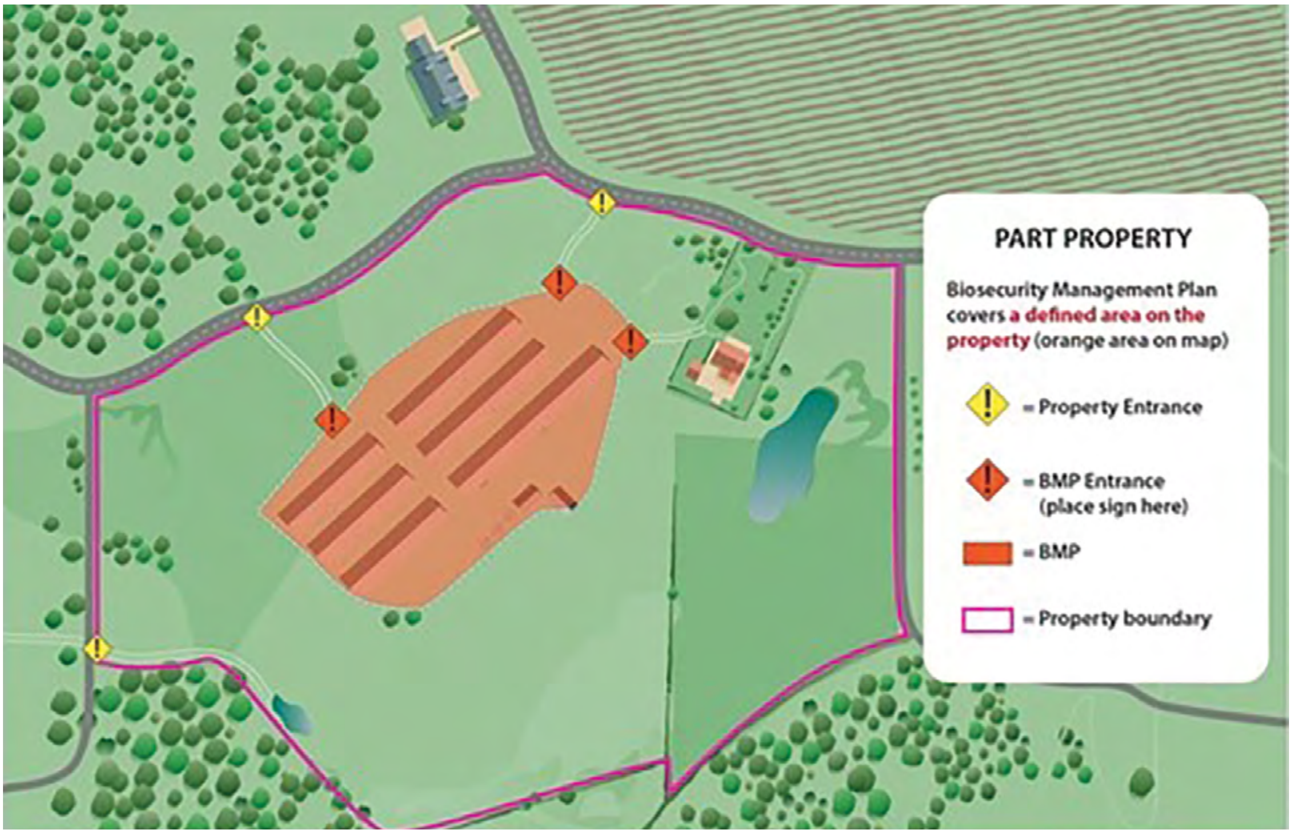
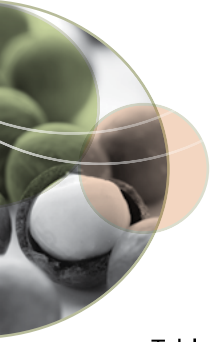


Figure 178. A property map example.

Biosecurity



Macadamia pesticides

Table 59. Chemicals registered[1] for managing macadamia pests. Always read the label.

For managing...	Active constituent	IPM rating	Comment[2,3]
Banana fruit caterpillar	Methomyl	High (10)	Systemic and contact insecticide, PER90592, expires 30.4.26, Qld only
Fall armyworm	Indoxacarb	High (10)	Contact insecticide with stomach action, PER89278, expires 31.3.23
	Methomyl	High (10)	Systemic and contact insecticide, PER89293, expires 30.4.23
	Spinetoram	Medium (5)	Insecticide with contact action, PER89241, expires 31.3.23
Fruit spotting bug	Acephate	High (10)	Contact insecticide with stomach action
	Acetamiprid + pyriproxyfen	High (10)	Contact and ingestion, targets insect central nervous system
	Beta-cyfluthrin	High (10)	Systemic and contact insecticide with stomach action
	Sulfoxaflor	Medium (5)	Systemic and contact insecticide with stomach action
	Trichlorfon	Low (1)	Insecticide and acaricide with contact and stomach action, PER13689, **expires 30.9.21**
Green vegetable bug	Trichlorfon	Low (1)	Insecticide and acaricide with contact and stomach action, PER13689, **expires 30.9.21**
Macadamia felted coccid	Diazinon	High (10)	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
	Petroleum oil	Low (1)	Insecticide and acaricide with ovicidal activity, PER11635, expires 30.6.25
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	Low (1)	Insecticide and acaricide with contact and stomach action
Macadamia lace bug	Diazinon	High (10)	Non-systemic insecticide, acaricide with contact, stomach and respiratory action PER14276, expires 30.11.22
	Pyrethrin	High (10)	Contact insecticide with stomach action
	Sulfoxaflor	Medium (5)	Systemic and contact insecticide with stomach action
	Trichlorfon	High (10)	Insecticide and acaricide with contact and stomach action, PER13689, **expires 30.9.21**
Macadamia leaf miner	Acephate	High (10)	Contact insecticide with stomach action
	Diazinon	High (10)	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
Macadamia nut borer	Acephate	High (10)	Contact insecticide with stomach action
	Beta-cyfluthrin	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	High (10)	Contact insecticide with stomach action, PER86827, expires 31.3.26
	Tetraniliprole	Low (1)	Anti-feedant with residual activity on all life stages

For managing...	Active constituent	IPM rating	Comment[2,3]
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 30.6.24
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	High (10)	Contact and ingestion, targets insect central nervous system
Thrips	Abamectin	High (10)	Acaricide with stomach action and translaminar movement PER87510, expires 30.6.24
	Acephate	High (10)	Contact insecticide with stomach action Qld, WA and NT only
	Spinetoram	Medium (5)	Insecticide with contact action

Table 60. Chemicals registered[1] for managing macadamia diseases in NSW. Always read the label.

For managing...	Active ingredient	IPM rating	Comment[2,3]
Botrytis blight (grey mould)	Iprodione	Low (1)	Contact fungicide with protective and curative action
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
	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 as cuprous oxide	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: InfoPest http://infopest.com.au and APVMA PubCRIS https://portal.apvma.gov.au/pubcris

IPM ratings:

Low (1) indicates that, when used with care, a chemical will have little impact on beneficials and is recommended in an IPM program.

Medium (5) indicates that this pesticide can be used with caution in an IPM program, but the chemical's effect on beneficials present should be assessed before application.

High (10) indicates that this chemical is likely to have a negative off-target effect including on beneficial arthropods.

[2] Adapted from *The Pesticide Manual*, 15th Edition, British Crop Protection Council 2009.

[3] The APVMA website https://portal.apvma.gov.au/permits

Managing spray drift

What is spray drift?

Spray drift is the air-borne movement of chemicals with the potential to cause injury or damage to humans, plants, animals, the environment or property, onto a non-target area. All pesticides are capable of drift. 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 a range of agricultural enterprises co-exist, conflicts can arise, particularly from pesticide use. Some labels now carry spray drift management instructions including buffer zones. Anyone using any chemicals must read and follow all label instructions.

Types of drift

Droplet drift is the easiest to control because, under good spraying conditions, droplets are carried down by air turbulence and gravity to collect on plant surfaces. Droplet drift is the most common cause of off-target damage from pesticide application.

Particle drift occurs when water and other pesticide carriers evaporate quickly from the droplet leaving tiny particles of concentrated pesticide. Particle drift has damaged susceptible crops up to 30 km from the source.

Vapour drift is confined to volatile herbicides such as 2,4-D ester. Vapours can arise directly from the spray or evaporation from the sprayed surfaces. Using 2,4-D ester in summer can lead to vapour drift damage to highly susceptible crops such as tomatoes, sunflowers, soybeans, cotton and grapes. This can occur hours after the herbicide has been applied.

Vapours and minute particles float in the airstream and are 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 when compared with the non-volatile amine, sodium salt and acid formulations. Some low-volatile ester formulations can contain high-volatile esters, so caution should be exercised when using these products.

Proximity of crops susceptible to the chemical being applied and their growth stage.

Application method and equipment used:

- aerial application releases spray at ~3 m above the target and uses relatively low application volumes
- ground rigs have lower release heights and generally higher application volumes, with a range of nozzle types
- misters produce very fine droplets that use wind to carry them to the target.

Amount of active ingredient applied: the more applied per hectare the greater amount available to drift or volatilise.

Efficiency of droplet capture: 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 cause severe damage to highly sensitive plants.***

Minimising spray drift

Successfully managing spray drift will require a range of complementary strategies to be adopted, including:

Before spraying

- Always check for susceptible crops and sensitive areas such as houses, schools and riparian areas
- Notify neighbours of your spraying intentions
- Under the Records Regulation of the *Pesticides Regulation Act 1999* it is essential that weather and relevant spray details are recorded. An example spray record form is provided in Table 61 on page 122.

Identify sensitive areas

Sensitive areas are those where spray drift is likely to have the greatest adverse effects, such as:

- lakes, ponds and waterways
- wildlife habitats and wetlands
- neighbouring houses
- public roads (e.g. those used by school buses)
- schools and other public amenities
- travelling stock routes and reserves
- organic and alternative farming systems.

The potential adverse effect will depend on the exact nature of the sensitive area in relation to the toxicity and formulation of the chemical.

Establish appropriate buffer zones

Buffer zones help to minimise drift into sensitive areas. A buffer zone can consist of fallow, pasture, a non-sprayed strip of the crop or purpose-planted vegetation. Vegetative buffer zones should be sufficiently open to allow the spray to penetrate and of sufficient depth to trap the bulk of any drift.

Property planning

Property plans are a tool for communicating to others, such as spray contractors and neighbours, the factors that need to be considered when applying chemicals on the property. A property plan would include:

- houses and farm buildings
- neighbouring properties
- sensitive areas
- roads and access points
- public roads and public places
- watercourses and storage
- cropping and grazing paddocks
- powerlines and other hazards to aircraft.

Communication

Communicating with adjoining land users is critical in avoiding the conflict that can ensue from drift incidents. Communication can embrace:

- pre-season discussions with neighbours to identify the chemicals to be used and potential adverse effects on neighbours' activities
- notifying neighbours before applying chemicals
- an agreement on the conditions in which chemical application will not proceed or will be discontinued
- a clearly defined process and timetable for resolving any conflict that might arise
- an agreed process for recourse to regulatory action, if required.

During spraying

- always monitor meteorological conditions and understand their effect on drift hazard
- do not spray if conditions are not suitable, and stop spraying if conditions change and become unsuitable
- record weather conditions (especially temperature and relative humidity), wind speed and direction, pesticide and water rates, and operating details for each paddock. It is highly recommended that all macadamia farms have a weather station installed on-farm for monitoring conditions during spray application.
- do not spray when temperatures exceed 28 °C
- supervise all spraying, even when a contractor is employed. Provide a map marking the areas to be sprayed, buffers to be observed, sensitive crops and areas
- use the largest droplets that will give adequate spray coverage. Where droplet size is mentioned on the label, follow the label instructions
- always use the least-volatile pesticide formulation available
- maintain a down-wind buffer that could be in-crop. Where buffer zones are mentioned on the label, follow label instructions.

Minimising spray drift and achieving ideal coverage

A significant part of minimising spray drift is selecting the right equipment to reduce the number of small droplets produced. However, this can affect target coverage and the possible effectiveness of the pesticide application. This needs to be carefully considered when planning to spray. As the number of smaller droplets decreases, so does the spray coverage. The water rate might also need to be increased to compensate for coverage.

Use appropriate nozzles: nozzles at the top of an air-blast sprayer should be delivering coarse droplets that have less chance of spray drift. These can include air-induction nozzles or cannons. Lower nozzles would have finer droplet delivery when required. Coverage should be checked for the appropriate nozzle selection with the correct spray rates applied.

Pressure: always operate within the pressure range recommended by the nozzle manufacturer. Fine droplet production increases with increased operating pressure. Lower volumes produce a higher percentage of fine droplets than higher spray volumes at the same pressure and nozzle design.

Consider the size of the area treated: when large areas are treated, large amounts of pesticide are applied and the total spraying time is increased. This increases off-target risks and the likelihood that conditions such as temperature, humidity and wind direction will fluctuate during spraying. Applying volatile formulations to large areas also increases the chances of vapour drift damage to susceptible crops and pastures.

For information on managing chemical application to avoid and minimise spray drift, farmers and applicators should read label directions carefully.

Weather conditions affecting spraying

Midday turbulence: updraughts during the heat of the day cause rapidly shifting wind directions. Spraying should usually stop by 11.00 am during summer.

High temperatures: avoid spraying when temperatures exceed 28 °C.

Humidity: avoid spraying when relative humidity is low i.e. when Delta T (the difference between wet and dry thermometers; Figure 180) exceeds 10 °C. Spraying when Delta T is between 8–10 °C is considered high risk. High humidity extends droplet life and can greatly increase the drift hazard from fine droplets under inversion conditions. This results from an increased life of droplets smaller than 100 microns.

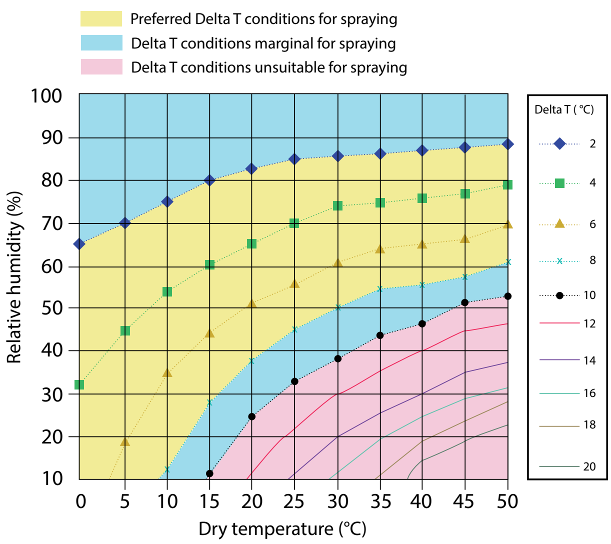


Figure 180. Delta T conditions for spraying. Source: Bureau of Meteorology.

Wind: avoid spraying during calm or still conditions as this is when droplets are more likely to remain suspended in the air. The ideal safe wind speed is 7–10 km/h. Leaves and twigs are in constant motion (a light breeze). Wind speeds of 11–14 km/h (moderate breeze) are suitable for spraying if you are using low drift nozzles or higher volume application. Small branches move, dust is raised and loose paper is moving. When wind speed is greater than 15 km/h, avoid spraying. For detailed information on wind speeds, see the Beaufort scale (www.bom.gov.au/lam/glossary/beaufort.shtml).

Surface inversions

What are surface inversions?

Surface inversions are layers of the atmosphere at the earth's surface in which temperature increases with height (Figure 181). This is the opposite (inverse) of the normal temperature decrease with height.

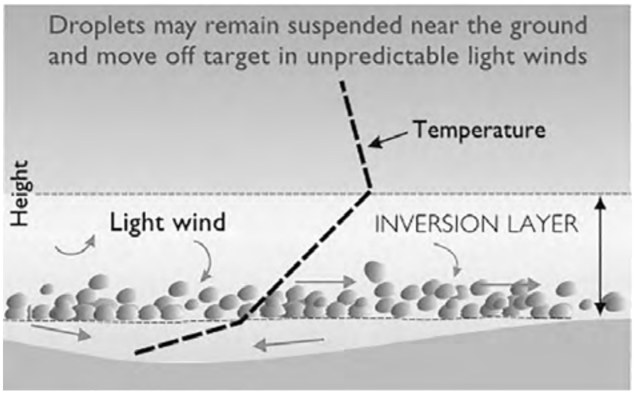


Figure 181. Surface inversion layer. Source: Bureau of Meteorology.

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 into low lying regions
- be transported, often in unpredictable directions.

Radiation inversions – the most hazardous

Surface inversions usually begin to occur near sunset after heat energy through infrared radiation moves upward into space and causes the ground to cool. That radiation passes through clear air with little effect. As the ground cools, the air in contact with the ground begins to cool directly through conduction, leading to the lowest layer of air being cooler than higher layers. This is radiation cooling or a radiation inversion.

Inversions caused by radiation cooling are the most hazardous to pesticide applications because they can severely restrict dispersion and promote transport (drift) of the 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 in Northern River valleys to cotton crops and to vineyards in the Murray Valley.

How to anticipate and recognise radiation inversions

The potential for inversions to occur and to adversely hold high concentrations of 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 factsheet on temperature inversions (www.cottonmap.com.au/Content/documents/Temperature%20Inversions.pdf)
- the GRDC factsheet on inversions and spraying (https://grdc.com.au/Resources/Factsheets/2014/08/Surface-temperature-inversions-and-spraying)
- the Bureau of Meteorology (BOM) factsheet: Weather for pesticide spraying (www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf).

Never spray during a surface inversion.

Where to find helpful meteorological information

Ideally, real time data should be collected in the 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 a number of websites. Data from the Bureau of Meteorology (BOM) weather stations for the previous 72 hours can help with planning spray activities and is useful for developing an understanding of the current daily patterns of meteorological conditions.

However, if the closest weather station being used for the information is many kilometres from the spray site, the information might not be as accurate as required. Therefore growers would benefit from investing in a weather station (Figure 182) 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 would be to install windsocks throughout the orchard. You can take a video (on your mobile) of the current conditions and compare the video to the Beaufort wind scale. This will give you an accurate account of conditions throughout the orchard on the day of spraying. To see the Beaufort scale, visit http://www.bom.gov.au/lam/glossary/beaufort.shtml.

Meteograms

Meteograms are very helpful in planning spray programs for periods of lowest drift risk and highest pesticide efficacy. They are mostly available by subscription. Some examples can be found at Weatherwise (www.weatherzone.com.au/models/meteogramdrill.jsp), or Spraywise decisions (www.spraywisedecisions.com.au). Meteograms provide 7-day forecasts of:

- temperature
- relative humidity
- Delta T
- rainfall
- wind speed and direction.

Source: M Scott, former Agricultural Chemicals Officer, NSW DPI, Orange.

Further reading

Further information about weather conditions and spraying can be found at:

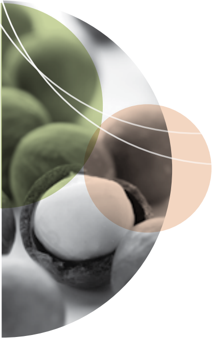
Cook T. 2015. Reducing herbicide spray drift (originally written by Andrew Storrie). NSW DPI, https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift

Gordon B. 2014. Practical tips for spraying. *GRDC Fact Sheet*, https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/08/practical-tips-for-spraying

Primary Industries Standing Committee. 2002. *Spray drift management principles, strategies and supporting information*. CSIRO Publishing, www.publish.csiro.au/book/3452

Tepper G. 2017. Weather essentials for pesticide application. *GRDC Fact Sheet*, https://grdc.com.au/__data/assets/pdf_file/0024/248181/GRDC-Weather-Essentials-for-Pesticide-Application-2017.pdf

Figure 182. A weather station in a macadamia orchard. Photo: Graham Wessling.



Your responsibilities when applying pesticides

Farm Chemicals Unit, Biosecurity and Food Safety, NSW DPI

The Australian Pesticides and Veterinary Medicines Authority (APVMA), NSW Environment Protection Authority (EPA), SafeWork Australia and SafeWork NSW are 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 of pesticides. States and territories regulate the use of pesticides.

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 at https://portal.apvma.gov.au/pubcris.

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

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 three of the 10 schedules in the Poisons Standard. All pesticides carry a signal heading. Signal headings for pesticides include:

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

Re-entry intervals

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

Pesticides and the environment

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

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

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

Withholding periods

The withholding period (WHP) is the minimum time that must elapse between the last application of a pesticide and harvest, grazing or cutting the crop or pasture for fodder. The 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, consult the label and the Safety Data Sheet (SDS) for safety directions.

Applying pesticides by aircraft

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

More information on the legal requirements for aerial application is available on the EPA website (www.epa.nsw.gov.au/pesticides/aerialapplicators.htm).

Pesticides Act 1999 (NSW)

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 risk 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 bearing an approved label
- prevent damage to people, property, non-target plants and animals, the environment and trade when applying pesticides.

Training

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

Record keeping

All people who use pesticides for commercial or occupational purposes must make a record of their pesticide use. Records must be made within 24 hours of applying a 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
- weather conditions at the time of spraying and weather conditions specified on the label
- changes to wind and weather conditions during application
- records must be made in English and kept for 3 years.

An example spray record from SMARTtrain is provided in Table 61.

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 you will need, including *Labelling of workplace hazardous chemicals* and another for *Preparation of safety data sheets for hazardous chemicals* to provide industry with guidance on how to comply with the GHS.

Work Health and Safety Act 2011 (Commonwealth)

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

The Act defines the responsibilities of employers or the person conducting a business or undertaking (PCBU) and the responsibilities of workers.

The Regulation covers hazardous substances and dangerous goods, including applying the GHS in Australia.

SafeWork Australia has published several Codes of Practice for different industries and situations to provide guidance for industries.

Work Health and Safety Act 2011 (NSW)

SafeWork NSW administers the *Work Health and Safety Act 2011* (WHS Act; https://www.legislation.nsw. gov.au/#/view/act/2011/10) and the Work Health and Safety Regulation 2017.

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

The WHS Regulation 2017 addresses management of hazardous substances (i.e. most pesticides). It covers identifying hazardous substances in the workplace, 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 to be kept on site
- SDS for chemicals kept on site
- controlling ignition sources and accumulation of flammable and combustible materials
- provision of fire protection, firefighting equipment, emergency and safety equipment
- 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 Farm Mechanisation

Bruce Browne, Farm Chemicals Officer, Biosecurity and Food Safety

Natalie O'Leary, Profarm Trainer.

Analytical laboratories

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

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

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

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

Information sources

APVMA www.apvma.gov.au

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

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 61. An example spray record form.

Chemical application record							
Property address:						Date:	
Owner:			Address:			Phone:	
Person applying chemical:			Address:			Phone:	
Spray application area				**Situation of use**			
Spray map including sensitive areas, wind direction, order of treatment				Area sprayed and order of spraying			
				Block name/ number	Area (ha)	Crop	Growth stage
				Pest(s)		Pest growth stage	Pest density
GPS reference: S E				**Application equipment**			
Comments (including risk control measures for sensitive areas):				Equipment type	Nozzle	Pressure	Speed
No-spray zone (metres):				Water quality (eg. pH, hardness)	Droplet size	Boom height (above target)	Other
Chemical details							
Full product name (including additives)	Chemical rate	Water rate	Total amount of concentrate	Total amount of chemical mix used	Mixing order	Re-entry period	WHP (days)
Weather details							
Rainfall (amount and time from spraying)	Before: mm		During: mm		After: mm		
Time of spraying:	Temperature ºC	Relative humidity%	Delta T	Wind direction from	Wind speed	Variability e.g. gusting speed and direction	
Start:							
Finish:							
Start:							
Finish:							
Clean up							
Disposal of rinsate:				Decontamination of sprayer:			

Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Avoiding pesticide resistance

Resistance in an insect, mite or disease to a specific chemical has occurred when the chemical no longer provides the control it did previously. Populations of pests and diseases that are repeatedly sprayed with a particular chemical group can develop resistance to that chemical. All populations contain a small number of individuals that are resistant to a given pesticide. Continuing to use that pesticide will kill susceptible individuals, but it will also promote resistant forms. Once a critical proportion of a population is resistant, the chemical will be ineffective.

Preventing resistance

Avoiding resistance for all pesticides is now an important consideration when choosing a control strategy. One strategy used is to rotate the chemical groups so that the weed, fungus, insect or mite is not being continually treated with the same type of chemical. Repeated treatment with the same chemical group could lead to the organism developing resistance to that group.

In the past, it has often been difficult for growers to distinguish between chemical groups and their different modes of action; a factor important in successful rotation. An identification scheme now exists for both herbicides and fungicides.

All registered pesticides have an activity group identification symbol on the label. This helps growers to choose a product from a different chemical activity group when seeking to rotate chemicals in a program.

Case study: mites in macadamia

Other industries have shown that mites are particularly successful in developing pesticide resistance and have overcome almost every miticide produced since the 1950s. This is certainly the case for macadamia where mites have recently become an issue due to certain effective broad-spectrum chemicals becoming unavailable.

The NSW DPI, funded by Hort Innovation, has successfully obtained a permit for the active ingredient abamectin, which has a different mode of action (6) from other chemicals used for mite control. To achieve control and long-term value of abamectin, chemical rotation of products used for other pests must be used, i.e. regularly changing the mode of action.

The macadamia industry has limited choices for miticides, which means that growers need to be more strategic about when to apply the product. Decisions such as:

- which flush would be most useful to protect?
- how bad is the damage?
- what are the other pests that might be targeted?

become important options when considering long-term effective control.

Insecticides

Unfortunately the macadamia industry relies heavily on a limited number of chemicals from the same groups, mainly 1A and 1B, limiting our options. However, there are options 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 at the later stages of nut development to use the available alternative options to 1B chemicals.

A typical scenario could be to spray macadamia lace bug early with a 4C product. Continue monitoring regularly for pests at this critical stage; there could be a requirement for a 1B product to be used around later flowering. Then at premature nut drop, continue monitoring for fruit spotting bug. This is when there is an opportunity to use a different chemical group, being 3A or 4A + 7C.

The chemical tables for each of the pests and diseases should help growers decide how to rotate their chemicals to avoid resistance. Ideally the industry needs to use available researchers to continually screen new chemical formulations as they become available. Not only will this screen the effectiveness of new formulations but will also identify ways that new chemicals can be incorporated into the spray program system to achieve better IPM strategies.

Fungicides

Fungicide resistance arises because most of the newer fungicides are very specific in their effects on fungal cells. In any collection of spores, a very low number will be resistant to a particular fungicide. If we use the same fungicide repeatedly, we allow these spores to multiply, while killing those which are susceptible to the chemical, until almost all the spores are resistant to, and unaffected by, the fungicide. If we then use a fungicide with a different mode of action, we can control the new strain but damage to the crop is already done.

Avoiding fungicide resistance

Generally horticultural crops have a variety of fungicides from different chemical groups to prevent resistance occurring. Unfortunately, in macadamia there are limited options to prevent husk spot, which is the industry's main fungal concern.

Management strategies for husk spot control, including which chemicals should be used when to maintain resistance, have been developed by Associate Professor Olufemi Akinsanmi, plant pathologist at the University of Queensland. These strategies are outlined in Table 62.

The clear message is that there should be no more than two consecutive applications of the same chemical group. This includes within season sprays one to four, and between season e.g. 4th spray to 1st spray the following year. Also, never rely solely on one type of fungicide for whole of season disease control, no matter how effective it seems; use at least two fungicides with different modes of action.

Specific recommendations for avoiding fungicide resistance are now shown on many labels and chemicals are now classified into groups. The principal groups adopted by the agrochemical industry through the APVMA and CropLife Australia are shown in Table 63 and Table 64. Only fungicides referred to in this guide are shown.

Table 62. 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 63. 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®
		Diazinon	Diazinon®
		Trichlorfon	Dipterex® 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	Acermectin	Abamectin	Vertimec®
11C	Microbial	*Bacillus thuringiensis*	Bacchus®

Group	Chemical class	Common name	Example trade name*
16A	Hydrazide	Tubufenozide	Mimic®
18	Diacylhydrazine	Methoxyfenozide	Prodigy®
22A	Oxadiazine	Indoxacarb	Avatar®
28	Anthranilamide	Tetraniliprole	Vayego® 200 SC

Table 64. Fungicide groups[1,2.] Always read the label.

Group	Chemical class	Common name	Example trade name*
1	Benzimidazole	Carbendazim	Spin Flo®
2	Dicarboximide	Iprodione	Rovral®
3	Triazole	Difenoconazole	Score®
3 + 11	Triazole + strobilurin	Azoxystrobin + tebuconazole	Custodia®
4	Phenylamide	Metalaxyl	Ridomil Gold®
4 + M1	Phenylamide + inorganic	Metalaxyl + copper oxychloride	Axiom® Plus
7	Pyrazole carboxamide	Penthiopyrad	DuPont™ Fontelis®
7 + 11	Pyrazole carboxamide + strobilurin	Penthiopyrad + fluxapyroxad	Merivon®
11	Strobilurin	Pyroclostrobin	Cabrio®
33	Ethyl phosphonate	Phosphorous acid	Agri-fos®
M1	Inorganic	Copper fungicides	Kocide®

[1] Trade names which include the common name are not listed. Source: www.apvma.gov.au and CropLife Australia.

[2] The information in the table shows insecticide and fungicide groups based on mode of action only. For a chemical's compatibility with IPM, please see the chemical listings for individual crops.

* Example only. Other products are registered.

Minimising glyphosate resistance in Australian orchards and vineyards

This information (Table 65) on glyphosate resistance has been produced by the Australian Glyphosate Sustainability Working Group, a collaborative initiative aimed at promoting the sustainable use of glyphosate in Australian agriculture. The AGSWG gratefully acknowledges the financial support of the GRDC.

Table 65. 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 tree or under vine	Strategic use of alternative knockdown groups
Not using alternative herbicide mode of action groups, including residual herbicides	Using alternative mode of action herbicides including residual herbicides
Relying on herbicides for weed control instead of other means e.g. mowing, mulching, tillage or grazing	Adopting non-herbicide practices for weed control e.g. mowing, mulching, tillage or grazing
Allowing weed control escapes to set seed	Preventing weed control escapes 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 farm) which leads to movement of resistant seed	Ensuring that all machinery and stock coming onto the farm are 'clean'
Lack of crop competition on weeds	Using cover crops to compete with weeds
All Group M herbicides are glyphosate herbicides	Using a double knock technique: full glyphosate rate followed by tillage or a full label rate of paraquat (Group L)

Timing, calibration and spray coverage

Achieving effective pest and disease control requires an understanding of the significance and interaction of calibration, coverage and timing. Each of these is individually essential and if any one of these is missing, the pest and disease control strategy will fail.

Calibration is making sure you get the right amount of product hitting the target.

Coverage is ensuring that your spray application covers the whole target area, including the high production front at the tops of the trees.

Timing is understanding the life cycle of the pest and identifying the correct time to spray in order to achieve maximum efficiency and the least amount of product loss.

Where all three elements align, we achieve effective control (Figure 183).

We need to physically check our coverage to ensure it is reaching the tops of the trees. This is where our production front predominates and therefore needs to be covered.

Inspect your orchard regularly and look for pests and diseases. No-one knows the orchard better than the person working the orchard. A pest scout or consultant will also complement this knowledge.

Finally we need to ensure we calibrate the spray equipment. Just as we check other machinery, (e.g. your car every 10,000 km and tractor every 1,000 hours) we also need to check our sprayer every year. When we calibrate, we can be sure that the right amount of chemical is hitting our target pest or disease.

Figure 183. The three components needed to interact to achieve good control and production.

Chemical compatibility

Scott Herd, Northern AgriServices Casino

The importance of understanding tank mixing and compatibility

Effectively controlling pests and diseases can mean the difference between producing a valuable, successful crop or a mediocre, disappointing outcome. Applying pesticides effectively requires some understanding of the pest, the product you are applying and the sprayer's ability to hit the target.

Many growers believe they can save money by applying a number of products in the one tank mix. However, this can present problems if the products are not compatible or compromise the efficacy of the products applied. For instance, a chemical applied to control macadamia lace bug can be compromised by adding fungicides and foliar fertilisers (which defeats the purpose of applying the insecticide in the first place).

If you are a farm manager, contractor or advisor, the grower will not measure your success by the number of products you have applied; they want a protected crop that produces a good yield.

It is critical that all growers and contractors read the label of the products they apply. Be aware that over time the instructions on product labels can change.

Checking spray tank water:

- what is the water source?
- is the pH (the measure of acidity/alkalinity) of the water stable?
- do you check it regularly? (simple pool test kits or pH test strips can be used)
- do you have adequate agitation in your spray tank?

When mixing products, a series of steps should be followed in order (Table 66) and remember 'dilution is the solution'. Always:

- add the product to water under agitation
- never add water to the product
- never mix products before adding to water.

If you are unsure about the compatibility of products (can they be mixed together and in what order should you put them in) you should read the label, ask your chemical supplier or contact the manufacturer.

A simple jar test (Table 67) can give some indication of whether products are physically compatible, but does not guarantee that you will not cause injury to the plant or that the mix will be effective against the desired targets. Once again, chemical suppliers, consultants or manufacturers might need to be contacted.

To conclude, remember to always read product labels and adhere to the instructions, prepare well and understand:

- the target pest
- your equipment
- your use of products and techniques.

Table 66. Multiple tank mix solutions guide.

Step	Action
Step 1	Fill the spray tank to at least 70% full, run agitation
Step 2	Add any water conditioners e.g. acidifier
Step 3	Add any water-dispersable granular products and allow 10 minutes or more for complete dispersion
Step 4	Add any suspension concentrate products
Step 5	Add any emulsifiable concentrate products
Step 6	Add any soluble liquid products
Step 7	Fill the spray tank to nearly full
Step 8	Add any adjuvants
Step 9	Fill the tank

Table 67. A simple jar test to check for compatibility.

	Final quantity	Option one	Option two	Option three	Option four
Tank mix	50 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	160 mL	400 mL	10 mL	0.8 mL
Tank mix	100 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	80 mL	200 mL	5 mL	0.4 mL
Tank mix	200 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	40 mL	100 mL	2.5 mL	0.2 mL
Tank mix	500 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	16 mL	40 mL	1 mL	0.08 mL
Tank mix	1000 L	8 L	20 L	500 mL	40 mL
Jar test	1 L	8 mL	20 mL	0.5 mL	0.04 mL

Tank mixing chemicals

Mark Whitten, Marquis Macadamias, Agricultural Liaison

Introduction

Mixing different chemicals into a single spray application is a common way for growers to increase efficiencies and reduce costs. When done correctly, tank mixing is an effective way of reducing the number of spray operations needed. Done incorrectly, incompatibility issues can lead to poor results and/or a big mess to clean out of your tank, filters, screens, nozzles and lines.

Top tank mixing tips

1. Keep mixes simple i.e. only 2–3 products
2. Know your water quality and pH
3. Know the product formulation
4. Follow the correct mixing order
5. Have enough water in the tank before mixing
6. Ensure you have adequate agitation (determined by the chemicals being thoroughly mixed)
7. Allow plenty of time between additions (3–5 minutes)

If you are unsure about compatibility, ask your crop protection consultant or reseller.

Pesticide spraying is an unfortunate necessity of modern-day agriculture and it is an operation that is rarely viewed with much excitement or enthusiasm. To increase efficiencies and reduce costs, often multiple agricultural chemicals will be combined into a single spray application. These chemicals include crop protection products, adjuvants, fertilisers, plant growth regulators and bio-stimulants.

This article aims to provide a general guide on correct tank mixing to ensure your spray operations are both efficient and effective. The information is of a general nature only. If in doubt about the compatibility of certain products, first check the label. If the information you need is not on the label, either conduct a jar compatibility test (Table 67) or contact the reseller or manufacturer.

Spray tank incompatibility

There are two basic types of tank-mix incompatibility: physical and chemical.

Physical incompatibility prevents products from properly dispersing or suspending within the tank. These are visible and usually identified by separation of products into layers, or the formation of gels, crystals or solids (Figure 184).

Figure 184. Physical incompatibilities in tank mixes are evident when the chemicals fail to mix thoroughly. Photos: Purdue University.

Chemical incompatibility can be invisible in the spray tank and will often only become apparent after spraying, showing up as crop burn (phytotoxicity) and/or reduced efficacy of the spray application.

To reduce the potential for spray tank incompatibilities, it is important to consider:

- product formulation
- tank mixing order
- time between additions
- water quality and volume
- agitation.

Product formulation

Pesticides come in many different formulations. The solubility of the active ingredient (AI) and its intended use will generally determine the product formulation. It is important to note that the same AI can be manufactured in different formulations. A recent example for the macadamia industry is indoxacarb, which is available in solid (e.g. Avatar®) and liquid (e.g. Steward® EC) formulations. Table 68 lists registered pesticides used in macadamia management, the active ingredient, an example trade name and formulation. Regardless of the product you use, you should always check the label for any comments about mixing and compatibility.

Dry or solid formulations include

- **wettable powders (WP) and water-dispersible granules (WG)** typically use fine clay as a carrier in combination with wetting and dispersing agents. Importantly, these products do not dissolve but are dispersed through the water to form a suspension. They require constant agitation to remain dispersed in the spray tank.
- **water-soluble powders (SP)** and **water-soluble granules (SG)** dissolve in the spray tank and, once dissolved, do not require agitation.

Wet or liquid formulations include

- **suspension concentrates (SC)** are essentially solid products that have been pre-mixed in a slurry. These will settle out in both the drum and the spray tank. Ensure you shake the drum before use and maintain agitation when in the tank.
- **emulsifiable concentrates (EC)** consist of an oil-soluble AI in a solvent. To stop these products from separating in water, EC formulations include an emulsifying agent, which gives a milky appearance and requires agitation to remain dispersed in the tank.
- **soluble concentrates/liquids (SL)** are true solutions and once fully mixed, do not require agitation.

If you are unsure about the product formulation, check the label, or you can look it up on the Australian Pesticides and Veterinary Medicines Authority (APVMA) PubCRIS database.

Tank mixing order

When you are looking to add multiple products to the spray tank, these products must be added in a specific order to ensure they can be properly mixed. The order that products are added to the spray tank relates to their solubility and formulation type. If products are added in the incorrect order, there is a risk that they will interact and this can reduce their efficacy or affect their stability in the tank mix.

As a general rule, add dry products first and wet products second. This is especially important when using oil-based products and/or adjuvants because when dry products are added after wet products, the oils and adjuvants already in the mix can coat the dry formulation and reduce its ability to properly disperse. The undispersed product will often form clumps or a layer of precipitate that can clog nozzles and filters.

Macadamia tank mixing guide

Step 1
- Fill the tank to about 70% full with water
- Run agitation

↓

Step 2
- Add dry products
  - water conditioners, e.g. LI-700®, Companion surfactant (do not mix with coppers)
  - wettable powders (WP), e.g. some coppers
  - water-dispersible granules (WG), e.g. Avatar®
  - water-soluble granules (SG) or granules (GR), e.g. Lancer®

↓

Step 3
- Allow adequate agitation and mixing (determined by the chemicals being thoroughly mixed)

↓

Step 4
- Add wet products
  - suspension concentrates (SC), e.g. Spin Flo®
  - dispersible concentrates (DC), e.g. Trivor®
  - emulsifiable concentrates (EC), e.g. Bulldock®
  - solutions or soluble concentrates (SL), e.g. Agri-fos® 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.

- Do not add oils, surfactants or ECs before dry formulations because they can prevent adequate wetting and dispersion of the dry products.
- Always ensure there is plenty of time and water between tank additions.
- Due to the huge range of foliar fertilisers and variation in formulations, you should contact the manufacturer or reseller to determine where the product should be added in the tank mixing order.

Table 68. Registered chemicals used in macadamia management, their active ingredient, an example trade name, its formulation and chemical group (mode of action). Always read the label.

Active ingredient (AI)	Example product	Formulation*	Chemical group
Insecticides			
Abamectin (PER87510)	Vertimec®	EC	6
Acetamiprid + pyriproxyfen	Trivor®	DC	4A + 7C
Bacillus thuringiensis	Bacchus® WG	Various	11C
Beta-cyfluthrin	Bulldock® 25	EC	3A
Carbaryl	Bugmaster® Flowable	SC	1A
Diazinon (PER14276)	Diazol® 800	EC	1B
Indoxacarb (PER86827)	DuPont™ Steward®	EC, WG	22A
Methomyl (PER12796, Queensland only)	DuPont™ Marlin®	SL	1A
Methoxyfenozide	Prodigy®	SC	18
Petroleum oil (PER11635)	Summer Oil	Oil miscible liquid	Insecticide, spreader
Spinetoram	Success® Neo	SC	5
Sulfoxaflor	Transform® Isoclast™	SC	4C
Tebufenozide	Mimic 700 WP	WP	16A
Tetraniliprole	Vayego® 200	SC	28
Trichlorfon (PER13689)	Dipterex® 500	SL	1B
Fungicides			
Carbendazim	Spin Flo®	SC	1
Copper ammonium acetate	Cop-IT®	SL	M1
Copper hydroxide	Kocide® Opti™	WG	M1
Copper oxychloride	Coppox	WP, WG	Y
Copper sulphate (tribasic)	Tri-base Blue®	SL	M1
Cuprous oxide	Nordox™ 75	WG	M1
Difenoconazole	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 be spending extra time filling tanks for spraying, it is important to allow enough time between each product addition to ensure products are fully dispersed in the spray tank. If you add products too quickly, even in the correct order, you might end up with physical incompatibility. This is particularly important when the AI is suspended and does not dissolve in water (like many copper fungicides). You should allow at least 3–5 minutes between tank additions and ensure adequate agitation so the products properly disperse/mix throughout the spray tank.

Water temperature will also influence tank mixing; the colder the water, the longer it will take for products to properly dissolve, disperse, emulsify and flow. This is especially important for dry formulations and liquid flowables.

Water quality

Water quality will affect pesticide efficacy. Herbicides typically have the highest requirement for good quality water and, as a rule, you should always use tank water when mixing herbicides, especially glyphosate (e.g. Roundup®), as hard or muddy water will reduce its performance.

Water pH affects the breakdown (hydrolysis) of many pesticides. Generally, the target pH for most tank mixes should be near neutral or slightly acidic (pH 6–7). Some organophosphates (Group 1B) are especially sensitive to high water pH. For example, trichlorfon (e.g. Dipterex®) has a half-life of 3.7 days at pH 6, and a half-life of only 63 minutes at pH 8. So if your spray-tank water has a pH of 8, half of the AI is inactive after 63 minutes.

The risk of alkaline hydrolysis means it is important to know not only the initial pH of your water source, but also the pH of the products being added. Table 69 compares two different water sources and their pH as well as the effect of various products. Seasol® for example, has a pH of 10.4–11.4 and when used at rates of 250 mL/100 L of water (5 L/2,000 L) can increase the pH above 7. However, if this influence is known it can be easily adjusted with a buffer. The influence that LI-700 (buffer/acidifier) has on tank pH with and without the addition of Seasol® for the two different water sources is shown in Table 69. Note the dramatic change only 50 mL/100 L of LI-700 has on tank pH when combined with 250 mL/100 L of Seasol®.

Both the initial water pH and its buffering capacity (i.e. the water's resistance to change) will vary depending on the water source. Therefore, it is important to measure the starting water pH and tank pH after product additions using either pH strips or a calibrated pH pen. If your starting pH is above 7 and you are using products that are likely to increase the pH, consider using a buffer.

Water volume

The amount of water used directly affects the concentration of the products in a spray tank. The more concentrated the mix, the higher the chance of an incompatibility problem. This can be an issue when concentrate spraying and/or not having enough water in the tank before beginning to add any product. This is particularly important for WG formulations as they first need to absorb water before they can properly breakdown and disperse. If these products are not surrounded by enough water, their wetting and dispersing agents will not work. As a result, they can form clumps, gels and/or can settle to the bottom of the tank. This is why you do not pre-mix WG formulations (e.g. Avatar® or Kocide®) in a slurry. Instead, with thorough agitation, slowly add them directly to the tank.

Ensure your pest consultant writes out spray recommendation combinations in the order of mixing. Information about the correct mixing order can often be found on the product label. However, for some tank mix combinations, further information may be required from the reseller, manufacturer or through technical notes and product guides.

Table 69. The effect of buffers on different water sources and product combinations.

Product	Rate (mL/100 L)	Dam water (pH)	Change	Rain water (pH)	Change
Initial water pH		**7.7**		**5.6**	
LI-700®	100	5.1	−2.6	3.8	−1.8
LI-700®	200	4.6	−3.1	3.7	−1.9
Seasol®	250	9.1	+1.4	10.1	+4.5
Seasol® + LI-700®	250 + 50	6.1	−3.0	5.0	−5.1
Seasol® + LI-700®	250 + 100	5.2	−3.9	4.5	−5.6

Note: these water sources are examples only and will differ across time and location.

To avoid issues with water volume, always ensure spray tanks are 70% full before adding products. Additionally, when concentrate spraying, look to simplify tank mixes to reduce the chance of adverse product interactions and do not go over 5× the concentration.

Do not mix copper fungicides and acidifiers as the low tank pH created will spike the release of elemental copper ions, which can burn plant tissue.

Agitation

Adequate agitation is essential. Poor agitation will inhibit thorough mixing of products within the spray tank and create pockets of higher and lower concentrations. High product concentration can lead to incompatibilities when tank mixing and/ or crop damage while lower concentrations will reduce the efficacy of spray products.

A good example of this is when using products such as ethephon (e.g. K-ethephon) or 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 185). Generally, 10% of the pump's capacity is required for agitation, so this must be considered when calibrating the spray unit.

Figure 185. Copper fungicide that has settled due to inadequate agitation.

Take home message

Tank mixing mistakes cost you time and money, but they can easily be avoided if you follow the basic principles of correct tank mixing. This will improve your orchard efficiencies and ensure your spray applications are effective.

Further reading

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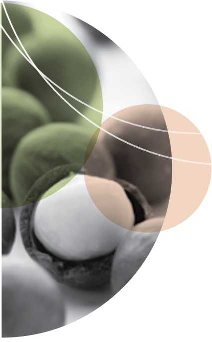


Disposing of farm chemicals and their containers

After chemicals have been applied according to the label directions, empty chemical containers and any unused chemicals must be disposed of in an environmentally responsible manner. Containers can be recycled through drumMUSTER while chemicals can be disposed of through ChemClear®.

drumMUSTER

drumMUSTER provides Australian agricultural and veterinary (agvet) chemical users with a recycling pathway for eligible empty agvet chemical containers. Developed with the environment in mind, the drumMUSTER program collects and recycles eligible, clean agvet containers.

Working with local councils and other collection agencies, drumMUSTER has established collection facilities all over Australia. Since its inception in 1998, 32 million containers have been recycled.

Once containers are collected, they are recycled into re-usable products such as wheelie bins, road signs, fence posts and bollards.

The drumMUSTER service benefits users, the environment, industry and the wider community by providing a reliable, cost-effective and sustainable option for recycling empty eligible agvet chemical containers.

Disposing of these containers in the right way is crucial to the reputation and sustainability of the agricultural industry in Australia. By using the drumMUSTER recycling program you can turn your unwanted containers into useful, sustainable products rather than having them placed into landfill or building up on-farm.

Only containers with 'drumMUSTER eligible container' printed on the label, as a sticker or embossed on the container are accepted (Figure 186). To contact drumMUSTER, visit the drumMUSTER website (www.drummuster.org.au) or phone 1800 008 707 or 02 6230 6712.

Cleaning containers for collection

When rinsing chemical containers, the personal protective equipment (PPE) specified on the label for application, mixing or loading the pesticide should be worn. This is because the chemical remaining in a container is the concentrate, which is the most toxic form of the chemical, even though it is diluted during rinsing.

Rinsing is the most effective method while the containers are still moist inside. The longer the residues have to dry and cake on the inside of containers, the more difficult they are to remove. This is the reason for rinsing during mixing and loading because the rinsate can be emptied into the spray or mixing tank of the application equipment. Using the rinsate this way avoids the necessity for having to dispose of the container residues separately.

To **triple rinse** a container up to 20 L to meet drumMUSTER standards:

1. remove the cap, invert the container and allow it to drip drain into the mixing tank for 30 seconds
2. add rinse water – 20% of container volume (e.g. 1 L per 5 L)
3. replace the cap and shake vigorously for 1 minute
4. remove the cap, invert and drip drain into mixing tank for 30 seconds
5. repeat twice
6. wash the cap separately and replace on the container.

Note: Triple rinsing is only suitable for small containers, up to 20 L.

Alternatively, use a pressure nozzle to triple rinse small containers. There are two main types of nozzle. One has a rotating spray head which can be used either to rinse an inverted container in the induction hopper or directly over the tank. The other type has a hardened, pointed shaft to pierce drums and the hollow shaft itself has four holes at 90° to spray the water around the container.

To **pressure rinse** a container up to 20 L:

1. remove the cap, invert the container and allow it to drip drain into the mixing tank for 30 seconds
2. ensure clean rinse water is at 35 – 60 psi pressure
3. insert the pressure rinsing probe either into the container opening or through the pierced base of the container (depending on type of nozzle)
4. invert the container over the mixing tank and rinse for 30 seconds or longer if the water coming from the container is not clear, moving the probe about to ensure all inner surfaces are rinsed
5. wash the cap in clear rinse water
6. turn off the water, remove the probe and drip drain the container into the mixing tank for 30 seconds
7. replace the lid on the container.

Large containers, e.g. 200 L, are best rinsed with a chemical transfer probe that has a flushing cycle as well as the primary suction cycle. Such probes are standard on many boom sprays, and options on most others. The drums might have to be slightly inclined to ensure all rinsate is removed. Typical rinse time for a 200 L drum would be 3–5 minutes.

Non-rigid containers, i.e. bags and cartons, have to be buried. Plastic bags should be rinsed first, and paper bags punctured or shredded. Cartons also have to be punctured or shredded before burial.

Burning is specifically prohibited.

For more information, visit www.drummuster.org.au or call 1800 008 707.

ChemClear®

ChemClear® provides Australian agvet chemical users with a collection and disposal pathway for their unwanted chemicals. ChemClear® complements drumMUSTER by providing agvet chemical users with a recycling and disposal option. Both programs are funded by AgStewardship Australia Limited through a 6 cents per litre levy placed on participating manufacturers' products and passed on to consumers at the point of sale.

ChemClear® collects two categories of agvet chemicals:

Group 1 chemicals are those currently registered products manufactured by participating companies signed into the Industry Waste Reduction Agreement. These products are collected free of charge.

Group 2 chemicals are those products manufactured by non-participating companies, or, deregistered, unknown, mixed or out-of-date products (by 2 years). A per litre/kilogram fee for disposal applies.

For more information or to register for the program, visit www.chemclear.org.au or call 1800 008 182.

Disposal of rinsate or dilute chemical

Labels contain a prohibition on disposing of concentrate on-site or on-farm, as per state environmental legislation. Unused chemical has first to be diluted and, if not applied in terms of the label use pattern, has to be disposed of in an environmentally responsible manner, such as an evaporation pit. This pit should be 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.

Figure 186. A chemical container (closest one) with a 'drumMUSTER eligible container' printed on the label.

Macadamia growers' resources

NSW DPI Primefacts are available free from NSW Department of Primary Industries website (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

NSW Macadamia plant protection guide (this book) can be collected from the NSW DPI Wollongbar office and from processors. It is available for free download (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

Macadamia integrated orchard management practice guide introduces canopy, orchard floor and drainage management as the three pillars of integrated orchard management. It also introduces stages of orchard development and provides a framework for assessing orchard blocks across the three pillars. The guide encourages growers to recognise important 'red flags'; signs that production decline is imminent. It describes currently used management practices (Toolkits) in the macadamia industry and the appropriate circumstances for their use. This book can be collected from the NSW DPI office at Wollongbar or processors, and can also be downloaded free at (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management).

Macadamia integrated orchard management case studies 2016 is a companion to the ***Macadamia integrated orchard management guide 2016***. Where the guide details the 'what to do' and 'when to do it', the case study booklet details the 'how to do'. It is designed to give growers considering integrated orchard management (IOM) the confidence to start planning. It involves ten orchard case studies (two from each of the Australian macadamia growing regions). The book can be collected from the NSW DPI Wollongbar office, from processors and can also be downloaded free at (www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/667812/macadamia-iom-case-studies-2016.pdf).

Macadamia integrated orchard management drainage 2017. This book is available for free download (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts). It is regarded as the best resource for planning IOM strategies and its popularity meant that the first print run was quickly depleted.

Spray Sense a publication providing information on pesticide use, including sprayer calibration, testing for residues, storing pesticides, disposal of empty containers, how to read a label and a number of other topics. The *Spray Sense* series of leaflets can be downloaded free (www.dpi.nsw.gov.au/agriculture/farm/chemicals/general/spray-sense-leaflet-series).

macSmart a range of more than 50 short and informative YouTube video interviews with growers and researchers covering topics including canopy management, innovative farm practices, orchard floor management, top performing farms, the latest research and other interesting topics. Go to www.macsmart.com.au.

Macadamia grower's handbook This publication (2004) details what is involved from establishing a new planting right through to harvesting the crop. It gives useful technical information, key points and commonly asked questions. Download free here http//era.daf.qld.gov.au/id/eprint/1964/4/mac-growing_guide_Part4.pdf

Macadamia problem solver and bug identifier An excellent reference for pest and disease identification. The book is available for purchase or can be downloaded free with the grower's handbook in several sections (http://era.daf.qld.gov.au/id/eprint/1964/).

Macadamia variety identifier A useful resource that helps with identifying 24 specific macadamia varieties. The publication is free to download (http//era.deedi.qld.gov.au/1964/14/mac-varieties.pdf).

Macadamia culture in NSW a useful introductory resource for growing macadamias. It is available for free download (www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-culture-nsw).

Australian Macadamia Society Grower Resources, an up-to-date industry resource library containing fact sheets, grower case studies and manuals, research reports and updates, videos and more. Compiled by the Australian Macadamia Society with the assistance of industry experts. Can be downloaded free (to members) www.

australianmacadamias.org/industry/resources

Establishing and managing smother grass on macadamia orchard floors, 2008 A guide on how to establish smother grass, including costs and management. Download for free (www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/establishing-managing-smothergrass).

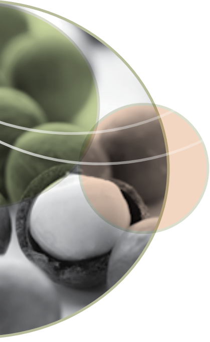
Reducing erosion and other soil degradation in macadamia orchards describes methods for reducing erosion. Download for free (https//www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/soil-macadamia).

The good bug book (second edition) is a valuable reference of the beneficial organisms commercially available for biological control in Australia. It includes illustrations of many of the beneficials as well as tables of information on their susceptibility to pesticides. It is published by Integrated Pest Management Pty Ltd for the Australasian Biological Control Association Inc. and can be purchased from Bugs for Bugs (www.goodbugs.org.au).

Internet sites for macadamia growers

Agricultural industry organisations	
Australian Macadamia Society	www.australianmacadamias.org/industry
Australian Nut Industry Council	www.nutindustry.org.au
Horticulture Innovation	www.horticulture.com.au
International Nut and Dried Fruit Council Foundation	www.nutfruit.org
macSmart	www.macsmart.com.au
National Farmers' Federation	www.nff.org.au
NSW Farmers' Association	www.nswfarmers.org.au
Alternative systems (organics)	
Australian Certified Organic	www.aco.net.au
Australian Organic	www.austorganic.com
Australian Organic Certification and Grower Groups	www.nasaa.com.au
Organic Federation of Australia	www.ofa.org.au
Climate	
Climate Outlook BOM	www.bom.gov.au/climate/ahead
Commonwealth Bureau of Meteorology	www.bom.gov.au
National Centres for Environmental Prediction	wxmaps.org/pix/aus.vv.html
The Long Paddock	www.longpaddock.qld.gov.au
Economic information	
Australian Bureau of Statistics	www.abs.gov.au
Department of Agriculture and Water Resources	www.agriculture.gov.au
Environment	
Department of the Environment and Energy	www.environment.gov.au
NSW Environment Protection Authority	www.epa.nsw.gov.au
Office of Environment and Heritage	www.environment.nsw.gov.au
Qld Department of Environment and Heritage Protection	www.ehp.qld.gov.au
Federal government	
ABC Rural Department	www.abc.net.au/rural
Australian Pesticides and Veterinary Medicines Authority	www.apvma.gov.au
Australian Trade Commission	www.austrade.gov.au
Department of Agriculture and Water Resources	www.agriculture.gov.au

Land and Water Australia	www.lwa.gov.au
Plant Health Australia	www.planthealthaustralia.com.au
Grower services	
Suncoast Gold Macadamia (Aust) Ltd	www.suncoastgold.com.au
Integrated pest management	
Australasian Biological Control Association Inc.	www.goodbugs.org.au
Bugs for Bugs	www.bugsforbugs.com.au
BioResources	www.bioresources.com.au
Processors	
CL Macs	www.clmacs.com
Freshcare Australia	www.freshcare.com.au
GB-Commtrade Pty Ltd	www.gbcommtrade.com.au
Macadamia Direct	www.macnut.com.au
Macadamias Australia	www.macadamiasaustralia.net
Marquis Macadamias	www.mpcmacs.com.au
MWT Foods	www.mwtfoods.com
Nambucca Macnuts	www.macnuts.com.au
Nutworks	www.nutworks.com.au
Pacific Farm Services	www.macadamia.com.au
Proteco Gold Pty Ltd	www.proteco.com.au
Stahmann Farms	www.stahmann.com.au
Suncoast Gold Macadamia (Aust) Ltd	www.suncoastgold.com.au
Swiss Gourmet	www.swissgourmet.com
Waliz Nuts	www.waliznuts.com
Rural assistance	
Centrelink	www.centrelink.gov.au
Health NSW	www.health.nsw.gov.au
Qld Health	www.health.qld.gov.au
NSW Rural Assistance Authority	www.raa.nsw.gov.au
Qld Rural Assistance Authority	www.qraa.qld.gov.au
Rural Skills Australia	www.ruralskills.com.au
State government	
Department of Agriculture and Fisheries (Qld)	www.daf.qld.gov.au
Local Land Services NSW	www.lls.nsw.gov.au
NSW Department of Primary Industries	www.dpi.nsw.gov.au
WorkCover Authority of NSW	www.workcover.nsw.gov.au
WorkCover Queensland	www.worksafe.qld.gov.au
Biosecurity	
Farm Biosecurity	www.farmbiosecurity.com.au/crops/fruit-nuts/fruit-nut-pests/nut-pests/
NSW DPI Plant Biosecurity	www.dpi.nsw.gov.au/biosecurity/plant



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NSW Local Land Services (Horticulture)

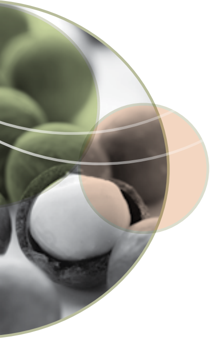
Local Land Services (LLS), launched in January 2014, delivers quality, customer-focused services to farmers, landholders and the community across rural and regional New South Wales. LLS bring together agricultural production advice, biosecurity, natural resource management and emergency management into a single organisation. LLS horticulture officers help producers address the challenges they face today and take advantage of future opportunities to achieve improvements in crop yields, orchard management and market access.

Producers can contact their nearest LLS office by phoning 1300 795 299 or the website: https://www.lls.nsw.gov.au/

NSW DPI Biosecurity and Food Safety

NSW DPI Biosecurity and Food Safety is the contact point in this state for anyone who requires advice on intrastate or interstate movement of fruit or plants and other issues of a biosecurity nature. In previous editions of this guide, we published contact details for regulatory officers at various locations across New South Wales. The method of contacting NSW DPI Biosecurity and Food Safety has changed, and all enquiries should now be directed via Plant Health Australia's Domestic Quarantine Line 1800 084 881. This phone number will connect you with an automated system to allow you to choose the state or territory that your report or enquiry relates to.

EXOTIC PLANT PEST HOTLINE
1800 084 881



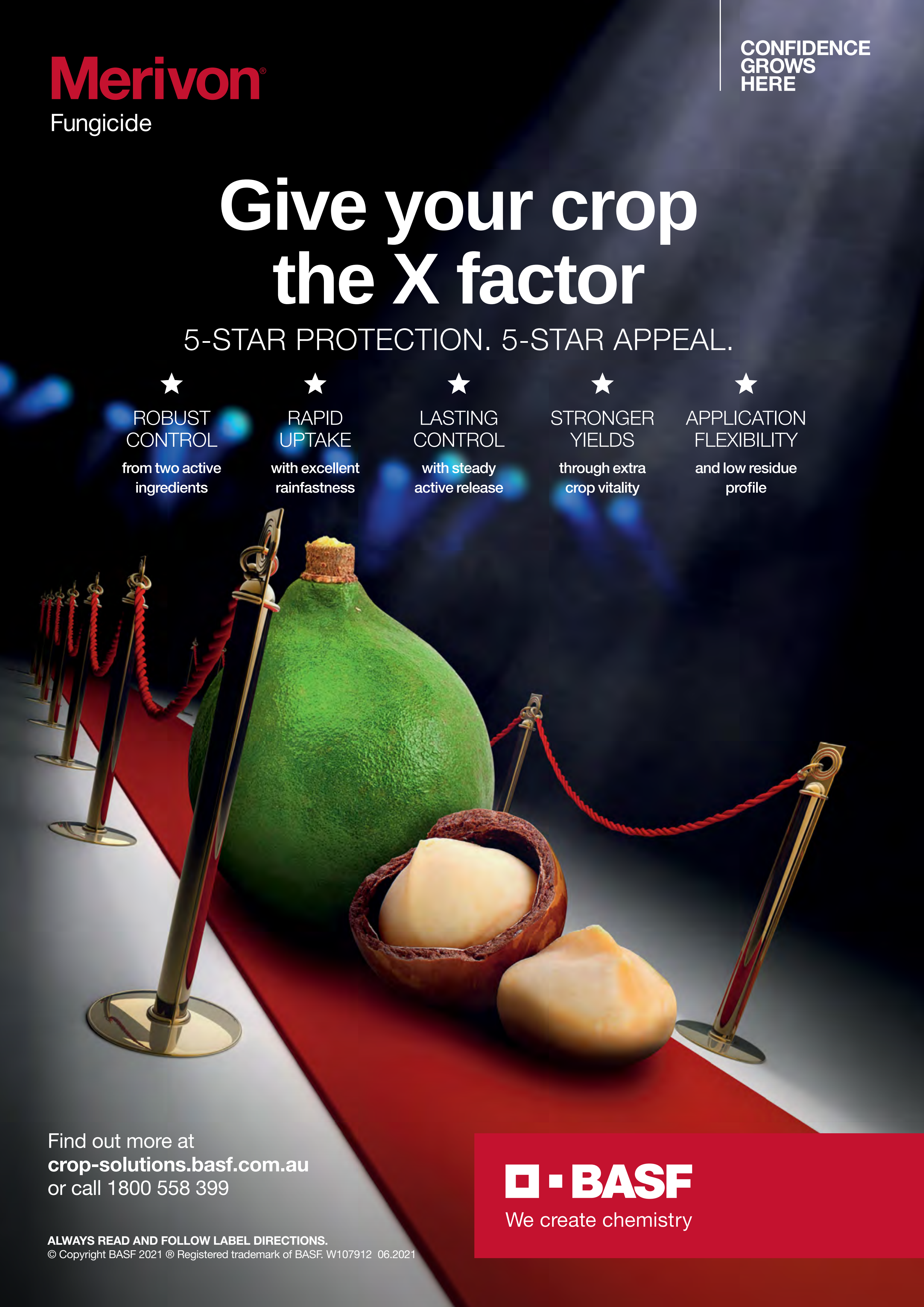
IPDM Scorecard

Instructions:

- Record the pest or disease, chemical and IPDM score in the table
- Insert beneficial releases under IPDM sub total
- At the end of the season, tally up the IPDM score
- Insert production in tonnes of NIS @ 10% in bottom corner
- Scan document and send to jeremy.bright@dpi.nsw.gov.au
- See 'Integrated pest and disease management score card' on page 30 for an example.

Pest	Product used	IPDM score
E.g. Macadamia lace bug	Sulfoxaflor	1
IPDM sub total		
E.g. Macadamia nut borer	8 wasp releases	-8
Total		

Production t/ha (NIS@10%) ______________



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