



Department of  
Primary Industries

# Macadamia plant protection guide 2019–20

NSW DPI MANAGEMENT GUIDE



Jeremy Bright



# 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



## 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



## 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 Difenconazole

- 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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Department of  
Primary Industries

# Macadamia plant protection guide 2019–20

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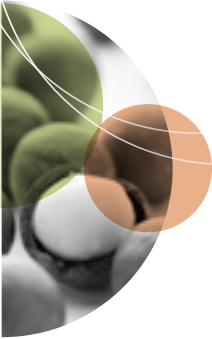
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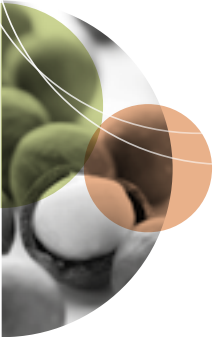


# Contents

- 3 About this guide**
  - 3 Feature article
  - 3 Vertebrate pests
  - 3 Pesticides
  - 3 Distribution
- 5 What's new?**
- 5 APVMA review continues**
  - 5 Phytophthora trunk canker in macadamia registration
  - 5 Controlling pests and diseases
  - 5 IPM project update: year 2
- 6 Macadamia development stages**
  - 6 Pre-flowering
  - 6 Early flowering
  - 7 Peak flowering
  - 7 Nut set
  - 7 Pea size nut and spring flush
  - 7 Shell hardening
- 8 IPM project: year 2 updates**
  - 9 New South Wales Department of Primary Industries
  - 10 Queensland Department of Agriculture and Fisheries
  - 11 Macadamia integrated disease management
  - 12 New promising and potential entomopathogenic fungi are on the way
  - 12 Macadamia lace bugs
  - 14 Managing vegetative diversity
- 16 Vertebrate pests in macadamia: rats**
  - 16 Background
  - 16 Rodents in orchards
  - 16 Rodent management
  - 18 References
  - 19 Further information
  - 19 Case study
- 20 Vertebrate pests in macadamia: pigs**
  - 20 Habitat and damage
  - 20 Breeding
  - 20 Monitoring
  - 21 Control
  - 22 Further reading
  - 22 Case study
- 23 Vertebrate pests in macadamia: deer**
  - 23 Habitat and damage
  - 23 Breeding
  - 23 Monitoring
  - 23 Control
  - 23 Further reading
  - 24 Case study
- 26 Vertebrate pests in macadamia: birds**
  - 26 Habitat and damage
  - 26 Monitoring
  - 26 Control
  - 27 Further reading
  - 27 Case study
- 27 The main message for vertebrate pest management**
- 28 Deterring birds from orchards**
  - 28 Introduction
  - 28 Research
  - 28 Results
  - 29 Conclusions
  - 29 Reference
- 31 Orchard pest and disease management priorities**
- 40 Fruit spotting bug**
  - 40 Life cycle
  - 41 Damage to macadamia nuts
  - 41 Monitoring
  - 42 Using a trap crop
  - 42 Control options
- 44 Macadamia seed weevil: a breakthrough for control**
  - 44 Current distribution
  - 45 Macadamia seed weevil control
  - 45 Further information
- 46 Controlling pests and diseases in macadamia**
- 46 Macadamia pests**
  - 46 Beetles (various)
  - 47 Fruit spotting bug
  - 48 Green vegetable bug
  - 48 Kernel grub
  - 49 Leptocoris bug
  - 49 Macadamia flower caterpillar
  - 49 Macadamia lace bug
  - 50 Macadamia nut borer
  - 50 Macadamia seed weevil
  - 50 Mites
  - 51 Red-shouldered leaf beetle
  - 51 Thrips
- 51 Macadamia diseases**
  - 51 Botrytis blight (grey mould)
  - 52 Branch dieback
  - 52 Flower blight
  - 52 Husk spot
  - 53 Phomopsis husk rot
  - 53 Phytophthora

- 53 Other**
  - 53 Lightning strike
- 55 Non-bearing and nursery trees**
- 56 Macadamia pesticides**
- 58 Pollination with native stingless bees**
- 59 Honeybee best practice management**
- 61 Biosecurity 'how to'**
  - 61 Biosecurity – a legal responsibility
  - 61 Farm biosecurity planning
  - 61 On-farm biosecurity risks
- 64 Managing spray drift**
  - 64 What is spray drift?
  - 64 Types of drift
  - 64 Minimising spray drift
  - 65 Minimising spray drift and achieving ideal coverage
  - 66 Weather conditions affecting spraying
  - 67 Where to find helpful meteorological information
- 69 Managing your legal responsibilities when applying pesticides**
  - 69 The Pesticides Act
  - 71 Pesticides and worker safety
  - 73 Pesticides and the environment
  - 75 Managing residues resulting from pesticide application
  - 75 Permits
- 76 Disposing of farm chemicals and their containers**
  - 76 drumMUSTER
  - 77 ChemClear
- 78 Timing, calibration and spray coverage**
- 79 Chemical compatibility**
  - 79 The importance of understanding tank mixing and compatibility
- 80 Avoiding pesticide resistance**
  - 80 Resistance management
  - 80 Case study: mites in macadamia
  - 80 Insecticides
  - 81 Fungicides
  - 82 Minimising glyphosate resistance in Australian orchards and vineyards
- 83 Macadamia growers' resources**
- 86 NSW DPI Agriculture – Horticulture Leaders and Development Officers**
- 89 Notes**





# About this guide

This 5th 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

Over the years there have been many requests for information relating to vertebrate pests of macadamia and their control. Rats appear to be the most damaging, although other vertebrate pests also cause significant damage. This year's feature article is by Dr David Elmoultie, the Australian and New Zealand Business Manager for BASF Professional and Speciality Solutions portfolio. David started his career as an ecologist with a primary research interest in vertebrate foraging ecology and population management within agricultural systems. Under the supervision of Dr John Wilson, David completed his Honours and PhD degrees, investigating the effects of nut removal from Australian macadamia orchards (Honours) whilst investigating small mammal foraging behaviour and ecology with tropical rainforests for his PhD.

## Vertebrate pests

Feedback from the annual pest consultants meeting indicated that pigs, birds (especially cockatoos) and deer are significant vertebrate pests for macadamia. The NSW DPI vertebrate pests unit have contributed useful control strategies for protecting your crop from these pests. They have also provided links to relevant organisations, such as the Office of Environment and Heritage, for obtaining permits for native bird control. Case studies by growers provide practical relevance.

## Pesticides

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

because there can be many product names for the same active ingredient and it would be impossible to list them all at each mention in the guide.

Under the pesticides registration system administered by the Australian Pesticides and Veterinary Medicines Authority (APVMA), individual products are registered for use in or on specific crops for specific weeds, pests or diseases. Also, there can be variations in use recommendations between states for the same crop; even differences in application times or treatment intervals.

Using common chemical names in recommendations is intended to simplify the advice. It means that at least one product containing that active ingredient is registered for the purpose given. The onus is on the pesticide user to ensure that their product use is consistent with the label or permit issued by the APVMA. Pesticide use is under constant scrutiny through residue surveys and reviews. It is vital that these valuable tools for nut production are not misused.

## Distribution

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

## Acknowledgements

We thank the officers of NSW DPI and other organisations who have helped to revise this issue of the guide.

## 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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# What's new?

## APVMA review continues

There have been no further updates to the APVMA review. The key point to note is that 19 chemicals have been prioritised for review. Chemicals relevant to the macadamia industry include:

- acephate
- carbamate
- methomyl
- triazole
- trichlorfon.

We still emphasise that it is imperative for this industry to continually search for different management options to be able to stay viable. With our most effective chemicals continually under review, we must look for other options such as:

- identifying new chemicals that are as effective as the old chemicals (and not under review)
- introducing new predatory pests
- adopting better systems for monitoring and managing trees so they are less desirable to pests.

Essentially, we need to be developing a sustainable integrated pest and disease management (IPDM) system for the industry.

## Phytophthora trunk canker in macadamia registration

The APVMA permit ([PER84766](#)) for using phosphorous acid as the active ingredient, either as a trunk (curative) or foliar (preventative) application for phytophthora root rot and trunk stem canker, has been replaced with a product label on Agri-Fos® 600.

## Controlling pests and diseases

The aim is to grow this section of the guide. It is hoped that a quick reference section of common pests and diseases for our industry will make it convenient for growers and workers in orchards to identify issues of concern. A new pest included this year is Leptocoris and a new disease is Branch dieback.

## IPM project update: year 2

The macadamia IPM project is now in its second year. Some of the partners have provided updates showing how their section of the project is progressing.

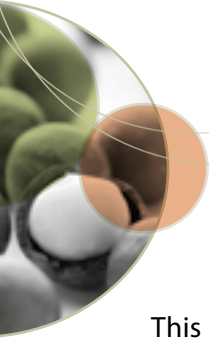
A key outcome of the IPM project this year is the identification of indoxacarb as a control for macadamia seed weevil (MSW). The product, applied to match head size nutlets will eliminate egg laying from the adult female weevil, thus avoiding the significant losses suffered previously. It will also help to eliminate several costly control sprays and there will be less requirement for hygiene clean ups as there will no longer be infected nuts on the ground.

Further activity in the past 12 months include:

- a northern lace bug species has increased its host range to move onto macadamia
- softer chemical products have been recognised to cover for heavy duty chemical products that can have detrimental effects on bees. These softer products may be registered soon and we will provide further information when it is available.

The macadamia industry will continue along the IPM path as we improve our understanding of the significance of cultural, biological and chemical practices.

**IPM is not an outcome, it is a journey.**



# Macadamia development stages

This section will help growers identify the macadamia growth stages that are mentioned in the pest and disease calendar. The growth stage is determined by when the majority of the plant is in a specific stage of development. These are:

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

## Pre-flowering



Figure 1. Pre-flowering.



Figure 2. Pre-flowering.

## Early flowering



Figure 3. Early flowering.



Figure 4. Early flowering.



## Peak flowering



Figure 5. Peak flowering.



Figure 6. Peak flowering.

## Nut set



Figure 7. Nut set.



Figure 8. Nut set (match head size).

## Pea size nut and spring flush



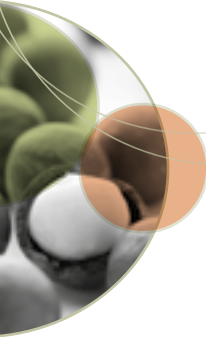
Figure 9. Pea size nut and spring flush.

## Shell hardening



Figure 10. Shell hardening.





# IPM project: year 2 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, focusing their efforts on developing sustainable pest management

practices for the macadamia industry (Figure 11). Combinations of biological, cultural and chemical controls are being tested on commercial farms and research stations as part of the program. This section of the guide features updates from some of the program components.



Figure 11. The IPM project team.

## New South Wales Department of Primary Industries

Ruth Huwer, Craig Maddox and Mark Hickey

Since the IPM program started in January 2017, a major trial has been conducted at the Centre for Tropical Horticulture (CTH) and baseline information on pest and beneficials presence has been recorded. The trial included a standard treatment and two IPM treatments involving IPM compatible chemicals, biological control releases and cultural controls. The third season of field trials has been set up, monitoring is completed and harvest has commenced. For this season, correct spray timing for fruit spotting bug (FSB) and strategic use of indoxacarb to prevent seed weevil laying were the main highlights.

Using yellow sticky traps (Figure 12) to monitor macadamia lace bug (MLB) showed that this pest can be well managed with targeted chemical control (including two new compounds), but in an unsprayed orchard with multiple varieties, MLB is present all year. Selected pests and beneficials in different treatments in the upper canopy were also recorded. The results from the first harvest assessment for the 2019 season are completed and the presence of pests on husk and kernel damage measured. The dry season had implications for many trunk and bark borers, which will most likely show up later this spring.

A highlight from the CTH trials was the successful management of macadamia seed weevil (MSW). A minor use permit for indoxacarb (PER86827) was issued by the APVMA in September 2018, and many Northern Rivers growers reported using the product. This season's trial looked at applying indoxacarb at different times and, when a strategic spray was applied based on monitoring results, the following results could be expected:

- applying indoxacarb early (in October) reduced weevil egg production by 100% between October and January
- applying indoxacarb later (e.g. in November) reduced weevil egg production by 78%
- where indoxacarb was not used, the egg production increased.

Our four collaborating consultants in the Mid North Coast, Northern Rivers, Sunshine Coast and Bundaberg area completed a second season of treatments and monitoring at the case study sites. In each of these regions, two contrasting

case study sites have been set up. One of these is using standard grower treatments (usually based on broad-spectrum pesticides) and the other is using IPM options including IPM compatible chemicals, biological and cultural controls. The monitoring data are being collated.

The IPM options and program strategies have been reviewed and once agreement is reached, it will be circulated to a wider audience for input and comment.



Figure 12. A yellow sticky trap used for monitoring thrips is also useful for monitoring macadamia lace bug.





## Queensland Department of Agriculture and Fisheries

Diana Leemon, Ian Newton, Shane Mulo and Grant Bignell

### The effectiveness of entomopathogenic fungi as an insect control agent

New *Beauveria* isolates were obtained from sample material provided by NSW DPI. The method for producing spores from these isolates was optimised to increase the spore yield so that small batches could be provided for field testing.

One of the *Beauveria* isolates obtained from a macadamia seed weevil was used to determine the endophytic potential of this fungus. Young nuts (match head stage) on trees at Alstonville were dipped in different formulations of *Beauveria* spores. *Beauveria* colonies grew from the pieces of surface sterilised nuts, suggesting that when nuts are treated with *Beauveria*, the fungus is capable of growing into the outer tissue of the young developing nuts where it could offer a second line of defence against seed weevils (Figure 13). Further work is investigating the effects of endophytically treated nuts on newly emerged seed weevils.



Figure 13. A macadamia seed weevil on a nut.

### Pheromone trap trials

Crop scouts, consultants and growers have reported mixed results using the banana spotting bug pheromone trap (Figure 14), sometimes catching high numbers of bugs and at other times catching very few, even when the bugs were observed in the field.

QDAF project staff are working with the manufacturer to improve trap design, longevity and reliability. The manufacturer is investigating changes to the chemical lure supply and manufacturing process, including loading the lures in Australia to improve reliability.



Figure 14. A banana spotting bug pheromone trap.

### Benchmark data

Yield, quality and planting data from the 2018 production season were analysed for the macadamia benchmark project (MC15005). Factory reject data from 2009 to 2018 showed that insect damage remains the most significant cause of reject kernel, and farms in the Mid North Coast of NSW had the highest average factory reject levels. Fruit spotting bug was the most significant pest in 2018, accounting for 37% of all responses, followed by macadamia seed weevil (27%) and rats (18%). Major diseases reported by benchmark participants included phytophthora (25%), husk spot (25%), flower diseases (14%) and branch or tree dieback (8%).





# Macadamia integrated disease management

Associate Professor Femi Akinsanmi

## Rationale

Significant economic losses from diseases that reduce orchard productivity in macadamia orchards are a major concern to growers. Potential production increases from recent plantings are threatened by endemic and emerging plant pathogens. Economic loss from decreased market access and market share due to the detrimental effects of plant pathogens is highly undesirable to all industry stakeholders.

## Aims

1. to deliver a holistic integrated disease management (IDM) program that is compatible with integrated pest management (IPM)
2. to increase productivity and profitability of growers and the Australian macadamia industry
3. safeguard the Australian industry from severe economic constraints to orchard productivity, threats from exotic pathogens and access to international markets.

## Structure

This project consists of:

- strong strategic and applied research for sustainable disease control
- training and extension to improve tree health
- capacity and resources for diagnostic capability
- tools for managing emerging and endemic priority diseases including husk spot, phomopsis husk rot, flower blight complex, phytophthora root rot and branch dieback.

## Results

Laboratory and field trials were established to determine the epidemiology and control measures for priority diseases in macadamia orchards. Preliminary results include:

### Flower blights

- pathogens (*Pestalotiopsis macadamiae*, *Neopestalotiopsis macadamiae*, *Cladosporium cladosporioides* and *Botrytis cinerea*) were confirmed in diseased raceme samples from commercial orchards in the Northern Rivers, Sunshine Coast and Bundaberg regions
- there are clear differences in the biology of the causal agents and this will underpin the disease risk assessment tool
- there was more nut set compared with the untreated control.

### Phomopsis husk rot

- the incidence was variable among orchards
- generally, the relatively drier conditions during the fruit maturation period (December–January) resulted in low disease incidence.



Figure 15. Phomopsis husk rot.

### Husk spot

- disease incidence was very low (<1%) in commercial orchards that used tree shakers in the preceding season
- wet conditions at match head to pea size stage were conducive for infection, but the relatively drier conditions during the oil accumulation period decreased disease severity (measured as a proportion of premature nut drop due to husk spot), thus, insignificant yield loss occurred.



Figure 16. Husk spot.

**Start clean:** nursery stock, new farm, every season

**Stay healthy:** farm biosecurity, holistic management, every stage

**Stay safe:** clean produce, profitable farming, every time

## New promising and potential entomopathogenic fungi are on the way

Kim Khuy Khun, Bree Wilson, Ruth Huwer, Mark Stevens and Gavin Ash

In 2018, some *Metarhizium anisopliae* and *Beauveria bassiana* isolates were identified as being able to successfully infect and kill the macadamia seed weevil under controlled temperature conditions. This year, after intensive bioassays in the laboratory, new, better performing isolates have been found. The *Metarhizium anisopliae* isolate was better than referenced virulent isolates by at least 17.5% and the new *Beauveria bassiana* potential isolate was greater than indigenous isolates and a commercial biopesticide product by 12.5–20% and 12.5%, respectively.

In addition to finding new promising and potential entomopathogens, *in vitro* compatibility studies of entomopathogens with registered pesticides were conducted. Unsurprisingly, all fungicides killed and inhibited entomopathogen growth, whereas a few insecticides appeared to be compatible with entomopathogens. This work will advance our understanding of the interactions between the chemicals and fungi to improve field-spraying regimes.



Figure 17. Investigating macadamia seed weevil mortality after spraying with entomopathogens.

## Macadamia lace bugs

Ryan Shofner; School of Biological, Earth, and Environmental Sciences, University of New South Wales

Macadamia lace bugs are insects native to northern New South Wales and southern Queensland. *Macadamia* species and other related plants are their natural hosts. To date, there have been four species recorded from macadamias that are crop pests: *Ulonemia concava*, *U. decoris*, *U. leai*, and a species that was previously unknown, but is currently being described and has no official name. Of these, *U. decoris* and the hitherto-unnamed species cause the most damage in NSW and southern QLD, while *U. leai* is a problem for growers in the Atherton region. *Ulonemia concava* has not been recorded since the late 1960s, and many recent field surveys have failed to locate this species.

This research focused on *U. decoris* using next generation genomic DNA sequencing techniques to analyse the species population structure across the Northern Rivers. All populations were similar in genetic structure, even those from opposite ends of the region. This suggests that either *U. decoris* are highly mobile and easily migrate from one orchard to the next, or that **they are carried from orchard to orchard, most likely on clothing or equipment.** Given that this species has been observed to be rather sedentary, perhaps they are unable to traverse extreme distances unaided.

Once established, population size can increase rapidly and become self-sustaining. Adopting appropriate orchard hygiene practices, especially cleaning of equipment and clothing when travelling between orchards, is highly recommended in order to curtail the spread of macadamia lace bugs to new locations.

This is further evidence for individual orchards to enforce good biosecurity measures to limit the spread of pests and diseases.

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](http://horticulture.com.au)



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## Managing vegetative diversity

**Dr Abigail Makim, Richard Llewellyn and Dr Christopher Carr; BioResources**

This study investigated different ways to manage vegetative diversity in macadamia orchards to increase the presence of desirable beneficial insects including pollinators, predators and parasitoids.

BioResources has been testing this idea with more than 10 growers located across all major growing areas since 2017. The objective was to develop simple and easily implemented strategies for reduced mowing. These strategies should promote more floral resources, vegetative bulk and height, and less overall disturbance as preferred by beneficials. Important farm-specific considerations include tree age and size, row width, direct sunlight and general light conditions in the inter-row, as well as existing machinery such as mowers, slashers and harvesters. The reduced mowing options being tested include alternate row mowing (Figure 18) and mohawks (Figure 19).

On each participating farm, direct comparisons are being made between the beneficials present in a regularly mown block compared with the lesser mown blocks. Early results are positive and indicate that reduced mowing could improve beneficial populations by:

- increasing arthropod species diversity and abundance consistently over time
- increasing parasitoids, specifically from the hymenopteran (superfamily Chalcidoidea). These are a highly diverse group of parasitoids, the majority of which are mostly unidentified
- decreasing aphids, leafhoppers and thrips.

At the same time, conventional, regular complete mowing could favour macadamia pests such as aphids and thrips.

The study is producing other hitherto unrecorded arthropod observations including the presence of beneficials important for young macadamia trees such as Corytophanidae (Diptera), which are larvae endoparasites of mealybugs, and Chamaeyiidae (Diptera) which are larval predators of coccids and psyllids. Being aware of these valuable beneficials can help to better inform major orchard management decisions.

BioResources has also been working with growers to evaluate the potential for invasive weeds, rat habitat, and arthropod pest reservoirs in reduced mowing. Conclusions so far include:

- it is low risk and the risk is underscored by appropriate management practices consistent with existing farm management including monitoring for:
  - undesirable weeds and applying mechanical or chemical removal as necessary



Figure 18. Alternate row mowing in a young orchard. This approach promotes retention of floral resources, vegetative bulk and height, and limited beneficial disturbance, with occasional slashing on a schedule that suits seasonal and orchard management demands on an alternate row basis. The row on the left has recently been slashed, while the row on the right will remain undisturbed until regrowth is well underway on the left.

- rats as per existing program, with occasional clean-up mowing/slashing of inter-row vegetation, particularly if rat activity is observed
- inter-row vegetation does not host macadamia arthropod pests when it consists of grasses and naturalised weeds common to most farms, with the possible exception of blackberry nightshade (*Solanum nigrum*) and lab lab (*Lablab purpureus*).

With these promising results, the next steps are being considered. Experience in a number of other industries and anecdotal information from the macadamia industry indicates that the benefits of carefully selected cover crops are more substantial than reduced mowing and include:

- a significantly more active and productive insectary timed specifically to the demands of the macadamia crop
- beneficials are most active leading into flowering, this is also when floral pests are major considerations
- identifying plant species suitable for the demands of the harvest period and harvest zone on the orchard floor
- a range of soil benefits, including erosion control, increased soil organic matter, improved nutrient cycling, reduced compaction, improved

water penetration and retention, improved orchard hydrology

- a major input for the orchard's composting system.

Little is currently known about cover crops in macadamias, for example the preferred species for establishment and management, desirable plant habit and floral characteristics, seed mixes, soil preparation, machinery, and life-cycle management systems; or potential risks including weeds, rats, and arthropod pest reservoirs. Consequently, BioResources has purchased a direct drill seeder and has commenced seed mix trials at a trial site in northern New South Wales.



Figure 19. A mohawk in a mature orchard. This approach allows for retention of vegetation for an insectary in the centre and away from the drip-line in the inter-row all year, including during harvest. This can support beneficial activity leading into flowering, while harvest operations continue as usual.



# Vertebrate pests in macadamia: rats

Dr David Elmoultie

Business Manager, BASF Professional and Specialty Solutions



## Background

Rodents are a significant concern for the Australian macadamia industry, accounting for up to 30% of crop losses (Figure 20) in high pressure years and additional losses from orchard floor nut removal (White et al. 1997; Elmoultie and Wilson 2005). During the past 20 years, significant research has been conducted within Australian orchards to identify the species responsible and to determine how the rodent populations interact with the broader orchard system to achieve high population numbers.



Figure 20. A macadamia branch damaged by rats.

## Rodents in orchards

Early studies identified a single rodent species, the common black rat (*Rattus rattus*; Figure 21), as being responsible for >95% of damage across the macadamia growing region (White et al. 1997; Horskins et al. 1998; White et al. 1998). Further studies show that rodents use resources based on availability, feeding within the trees (Figure 22) while macadamia is present and feeding and harbouring in non-crop habitats at other times (White et al. 1997; Horskins et al. 1998; White et al. 1998; Elmoultie and Wilson 2005).

Rodents also 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 (Elmoultie and Wilson 2005). This behaviour ensures the rodents maintain a stable food supply throughout the year and are feeding and residing in dense protected environments, thus reducing the risk of predation from birds (Elmoultie et al. 2009). Rodents never solely consume nor depend on macadamia resources, they supplement their diet with alternative non-crop resources throughout the year.



Figure 21. The common black rat (*Rattus rattus*). Photo: The Queensland Museum.

In recent years, rodent population dynamics within orchard systems have changed. Rodents are now nesting in trees, rather than foraging in non-crop habitats abutting the orchard edges. Changes in structure and resource availability are suspected as the causes, which have primarily been driven by introducing new cultivars that maintain nuts longer within the trees (Eldridge et al. 2012; Whitehouse et al. 2012) and modifying cultural practices to influence non-crop resources within the orchard.

## Rodent management

Managing rodents in macadamia orchards has relied on mortality based approaches (baiting, burrow fumigation and trapping). Although these tools are effective at killing the rodents, alone they do little to suppress populations and ultimately do not reduce crop losses.



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, such an approach results in cost-effective rodent management.



Figure 22. A rat caught foraging within the tree canopy early in the season.

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. The recommendations below might not be viable for all orchard systems or every year, however, they are presented as a guide for growers as strategies to implement for maximum success and minimal crop loss.

### Season-long strategy

It is imperative that adjacent non-crop habitats are 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 revegetated 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 (e.g. glufosinate-ammonium such as Basta® herbicide).

Cultural practices such as insect refuge strips (i.e. mohawks, Figure 23) 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 is over, refuges can be slashed and only re-established once required (prior to flowering).

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



Figure 23. An insect refuge strip (i.e. mohawk).

### Harvest

Harvest should be conducted regularly to minimise the amount of nuts on the ground. This is particularly important 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 (Eldridge et al. 2012). Although using these varieties is not being discouraged,

consider where these higher risk varieties will be planted and how rodents can be managed within those orchard blocks.

### Block design

Block design should also be contemplated, as the inability to harvest and manage blocks resulting from poor weather is often a precursor to high rodent damage.

### Baiting and burrow management

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

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

Using bait stations is imperative; they are a legal requirement of registered bait products and are essential to increase bait take and maintain bait freshness. Baits should be secured within bait stations ensuring they are kept off the base using the securing rods provided. In stations where securing rods are not provided, a wire tie should be used.

Where burrows are observed (Figure 24), rodents should be eradicated before the burrows are disturbed or ripped. Burrow fumigation (e.g. carbon dioxide) and baiting can be effective. When baiting, use baits that will not fill the burrow entrances as the block baits will be expelled from the burrows and thus made available to non-target species. Using appropriately registered dust or grain baits is considered the most suitable approach.



Figure 24. A rodent burrow in headlands adjacent to orchard blocks.

### Other methods

There are potentially other methods for rodent control and while perhaps not considered conventional, one grower in Queensland is using snakes to help (Figure 25).



Figure 25. Every little bit counts; snakes might contribute to rat control programs in a limited way. Photo: Paul Trollis.

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## Further information

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## Case study

### Phil Bevan – Dalwood, NSW

We have always had a rat control program but two years ago, a favourable season for rats caught us by surprise and caused significant crop loss. You could say that year opened our eyes to the potential damage from rats and the effort required to bring down a large population; we have been more vigilant with our program since.

A key part of our management program is regularly monitoring our orchard for rat activity using an electronic mapping system on our phones, which allows us to add points where we find nests so we can come back later and deal with them.

We aim to keep the grass down in the orchard and along headlands. This removes habitat for rats to hide in and makes spotting activity easier. It also gives predatory owls a better chance to catch prey.

We also have about 50 rat bait stations (Figure 26) on our 30 ha orchard that we locate in potential problem areas. We move them to areas of high activity based on monitoring results to focus more on potential hotspots than spreading stations over the orchard. We use only an approved rodenticide for the orchard, which is currently racumin. We mix the racumin and macadamia kernel, mindful to use stations that are inaccessible to pets and other animals, and only use baits that do not translocate. The baiting program is mainly useful in the period when nuts are not developed, mostly in the spring and early summer.

Based on our monitoring, we return to eradicate ground nests (burrows) with a small engine device (Cheetah) that produces carbon monoxide and blows it into the rat hole (Figure 27). This

system humanely euthanases the rats. We use newspaper and a bit of dirt to plug up the other holes in the same nest and run the machine for a bit over five minutes. We monitor the sites for a few days afterwards and rarely find subsequent rat activity. For the odd cases where we do, we re-treat the burrow.

We also harvest frequently to keep the food source low for rats.

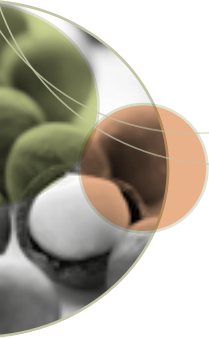
We have become vigilant against rats, as we know changes in weather conditions can bring on a significant increase in rats. This combination of activities has managed to keep rat activity to a minimum in our orchard – and has kept crop loss to rats down.



Figure 26. A rat bait station that is inaccessible to non-target species such as birds and uses baits that do not translocate.



Figure 27. A device used to fumigate a rat nest.



# Vertebrate pests in macadamia: pigs

Contributions by Les Gains and Brice Kaddatz; Suncoast Gold Macadamias

## Habitat and damage

Feral pigs are usually found within two kilometres of a water source, although they can cover much greater distances. Pig population densities depend on environmental conditions such as food and water sources. Pigs are most active in late afternoons and early mornings, but if they have been hunted will become nocturnal. They cause environmental damage such as wallowing and rooting up the ground causing erosion (Figure 28) and are a major biosecurity risk, potentially spreading weeds and pathogens. They can also destroy infrastructure on the farm, including water courses.

Pigs seem content in macadamia orchards (Figure 29) and can consume macadamia nuts in large quantities. Examining gut contents reveals multiple kilograms of kernel (Figure 30). A moderate size pig can consume up to six kilograms of nuts in shell per hour. A mature pig (90–100 kg) will consume 3% of its body weight per day; smaller pigs up to 5% of body weight. Ten pigs feeding in an orchard for ten days can destroy nearly 300 kilograms of nuts in shell.

## Breeding

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 31). In favourable conditions, up to three litters can be produced per year, leading to rapid population expansion.

## Monitoring

Monitoring should involve pig numbers before and after control measures, as well as identifying and quantifying the effects from their activity. Feral pigs consistently use trails (pads) from one area to another, such as from shelter to food supply or water, and marking of these trails is common.

Feral pigs will often root up the ground leaving depressions that make it difficult for finger wheels to harvest nuts. Conversely, the only sign might be small shell segments scattered about the foraged area. If pig damage to the crop is suspected, then a bright torch at night over the area will highlight the white inside the cracked shells. Also look for other signs such as pig prints on damp ground and

muddy rub marks on tree trunks. Game cameras can be placed on pads to identify the numbers and sizes of pigs, providing useful information for determining the best control options.



Figure 28. Pigs damage the orchard floor causing erosion and making it difficult to harvest.



Figure 29. Pigs making their way to macadamia trees.



Figure 30. Gut contents of a 70 kg sow containing approximately \$60 of macadamia kernel.





Figure 31. Pigs can produce up to three litters per year and can have up to 10 piglets.

## Control

### Exclusion

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

While the initial cost of an effective pig exclusion fence (Figure 32) 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, that is 33% of nut in shell (NIS), which equates to 7.5 kg of NIS lost
- the NIS value is \$5.50/kg, so in one night the pig consumed \$41 of nuts
- if there are 15 pigs in the orchard, then  $15 \times \$41 = \$615$  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 \$37,125 from pigs.
- the cost of effective fencing (mesh fencing with an electric stand out wire) is about \$9,000 per kilometre
- a 40 hectare orchard might only need 2.6 km of fencing (if a square block), costing \$23,400.

Therefore, you are saving almost \$14,000 in the first year and \$37,000 every year following.

### Trapping

There are a number of trap types for pigs including silo mesh traps, trigger traps (Figure 33) 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 32. An effective pig exclusion fence.



Figure 33. Pigs caught in a trap.

### Shooting

Shooting can contribute to pig control, however long sleepless nights during harvest are less than helpful. Ground shooting is usually opportunistic; either involving dogs to locate the pigs or patiently waiting in a hide for the pigs to appear. If trapping strategies are being used, avoid shooting near the trap as it will disrupt the regular pattern of pig intrusion and disperse them to other areas.

## Combining methods

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

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

## Further reading

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

## Case study

### Les Gains

Our farm is at Amamoor in the Mary Valley, about 20 km south of Gympie. We are surrounded by cattle properties and the general district contains many macadamia, avocado, stone fruit and small crop farms. The Amamoor State Forest is nearby.

From about 2000 to 2010, we experienced sporadic feral pig intrusions, with little damage or crop loss. On several occasions we had doggers come on to the property, and although they never caught a pig, they did seem to deter them.

In 2011 we had our first serious pig problem. We borrowed some game cameras to see where the pigs were entering and exiting. There were two separate sounders plus some individual boars, a total of about 25 pigs. We started by hunting (shooting) them in late evenings and early mornings, but the pigs soon reverted to night time visits. Then it became spotlight shooting and locating the pigs by listening for them cracking nuts. At night, and with no wind, this proved very difficult because the pigs often detected us before we could get close enough. We were not reducing pig numbers, with sows producing litters faster than we could cull them. The doggers were still coming but catching nothing.

In 2012 the pigs returned in greater numbers. We installed a pig trap in a corner of one block and loaded it with food. Unsurprisingly, the pigs ignored the trap to free range in the orchard. However, at the end of the season after harvesting, we caught seven pigs by providing a trail of nuts

from their entry point to the trap. Using night vision monocular made hunting easier but we were not making large inroads into their numbers.

A change in strategy was in order. We realised we needed patience to attract and get the pigs into a routine, but that that was not a good idea in the orchard while we were losing crop. So in 2013 we got agreement from two neighbours with cattle to place traps on their properties. We followed the pig pads (tracks) from our farm and found places on the pads that were quiet and had little human activity. Food (NIS) was placed there and soon vanished, so we then placed traps at these locations. Now we could hassle the pigs as much as possible in our orchard and force them to eat at the trap sites. This was successful and we were able to cull large numbers of pigs from the traps. The pigs were still coming to our orchard but we also now had a phone camera that would alert us when they arrived so we could quickly disturb them. The doggers were still coming and going away empty-handed, but making life hard for the pigs.

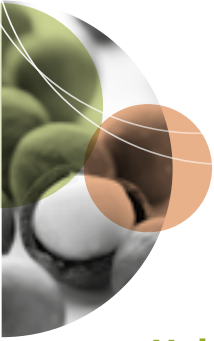
We used this strategy successfully for the next couple of years. The main problem was the time taken to check the trap sites and replenish the food supply. The phone camera was a great help here since it only needed to take one photo each morning to see if we needed to visit a site. Meanwhile, other macadamia and avocado growers were asking for assistance and we were quite successful at trapping large numbers of pigs.

About this time I teamed with a keen shooter from Brisbane, he had thermal gear, monocular and a rifle scope, which made night shooting much easier than my digital night vision. This allowed me to concentrate on the trapping while he cleaned up the trap-shy pigs or where it was not worth the time and effort to set up a trap.

Over a number of years we have gained access to over a dozen properties covering about 350 hectares. Landholders are very supportive and are continually on the lookout for pig activity. Three of them have their own traps and now pig numbers are very low.

Despite the very low incidence of pig activity on our property, we still want to keep them out completely for biosecurity reasons (crop contamination). We have started building pig-proof fencing around all the tree blocks. We are about half way through after about 18 months of building it ourselves. We started on the blocks that were most affected and since completing those areas, there has been no pig activity detected. We have used two fencing systems; a seven-wire electric only at \$6,000-8,000 per kilometre (internal) or a pest animal mesh with electric outrigger at \$8,000-10,000 per kilometre (boundaries).





# Vertebrate pests in macadamia: deer

## Habitat and damage

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

## Breeding

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

## Monitoring

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

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

## Control

### Exclusion

Fencing is the best alternative but deer can jump well and the installation of 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 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 the potential to fence out a number of small farms that are within the same area, thus sharing the costs of control
- tree guards to be used: usually plastic or poly mesh frames are placed around the bases of young trees. They can go to 1.2 m high and will prevent chewing by other vertebrate pests such as rabbits and wallabies.

### Shooting

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

Remember, if you are going to have others on your property to carry out deer control, you must consider a number of 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 judgment to kill deer with a single shot. Lactating females should not be shot, but if inadvertently shot, efforts must be made to find the young and humanely euthanase them.

### Repellents

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

## Further reading

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

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

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## Case study

### Colin Kemp, Bowraville

There are a number of options available for deer control, but in our experience, not many of them are completely effective. The most prevalent deer species we see is the Chital deer (*Axis axis*), also known as axis deer or Indian spotted deer (Figure 34). They are highly adaptable feeders; they will graze and browse, making the most of any feed available. However, deer have higher protein requirements and therefore will prefer the highest quality feeds available.



Figure 34. A Chital deer (*Axis axis*), also known as axis deer or Indian spotted deer. Photo: Paul Trollis.

The deer seem to like our place because of the lush green grass, plentiful water in our dams and lots of cover in the areas we have kept to encourage wildlife, birds and biodiversity. They do not appear to graze on the trees or eat the nuts, but the antlered-males rub on the trunks and remove large amounts of bark, break off branches or smash young trees to remove the velvet on the antlers and sharpen them for fighting other males. We see extensive puncture marks in the skins of males that have been shot.

In a recent tree count, we found that about 250 trees have been lost due to the damage done by deer over the last few years. That is about 7% of our plantings, so a significant loss. Replanting while the deer are still so active does not seem feasible, although we have recently acquired

a small number of trees and plan to replant in some blocks and try individual tree protection with stakes and covers.

The deer attack trees of all sizes; even 15-year-old trees sometimes receive a lot of damage in one night, mainly from trunk rubbing (Figure 35). The older trees usually survive, but they suffer from the damage. Many of the younger trees damaged in the last twelve months have recently died as the combination of the damage and the hot dry weather this summer was too much for them.



Figure 35. The result of trunk rubbing by deer. Photo: Colin Kemp

### Exclusion fencing

Chital deer can jump fences as high as 1.5 m and will also dive under them. A well-maintained netting fence, approximately 2.1 m high with solid strainer posts at less than 9 m apart should be effective. Gates must be of similar construction. The cost to establish exclusion fencing around our orchard is estimated to be approximately \$70,000.

### Trapping and yarding

Trapping and yarding was discussed at some local meetings, but deer are highly reactive animals and apparently get very agitated when trapped. This has raised animal welfare concerns, plus the cost of setting up a viable set of yards made this option not practical.



## **Sprays**

We have tried sprays (human urine) but that seemed to have limited effect.

## **Radios**

We put portable radios in strategic places and played various stations, including talkback programs, but that also seemed to have limited effect to the extent that a tree with a radio in it was severely damaged overnight.

## **Shooting**

We have a long history of people wanting to shoot, but they generally do not have the patience to do it for long. Deer and wild dogs sense people very easily although can be approached while on a tractor; but carrying around a high-powered rifle while driving the tractor is not a very good work practice. Recently the relaxed game shooting laws allowing spotlighting and other aids have meant a resurgence in interest but, as they are a game animal they can only be shot by someone with a hunters licence in NSW. We have been fortunate in finding a young fellow who visits the area here regularly on weekends. He now knows our place well and has worked out the trails the deer use and the times they are active. He has removed six stags over the last four months and the damage has reduced, although I think he will need to remove another 20 every year to have

any real effect. Our strategy is to only remove the large-antlered males, but we have also discussed removing young deer as well to try to manage both ends of the family cycle.

## **Conclusions**

Prevention would be the ideal solution, however, it is not always possible. A combination of suitable fencing and shooting by a responsible marksperson will help.

Given the number of deer in the area, I doubt if we will ever see them completely eradicated. Many small landholders see them as lovely adornments to the landscape and will not allow shooters, some will even actively try to disrupt them (one of my neighbours verbally abuses my shooter if they see him). As I said to the LLS board when I made a presentation to them over a year ago – it would not be viable to establish this orchard today with the deer presence. Our activity is now focused on limiting the ongoing damage and the number of animals in the area.

# Vertebrate pests in macadamia: birds

## Habitat and damage

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 36), galahs (*Elophus cacatua*) little corellas (*Cacatua sanguinea*), black cockatoos (*Calyptorhynchus banksia*, Figure 36) and ravens (*Corvus coronoides*). The mistletoe bird (*Dicaeum hirundinaceum*) disrupts macadamia growth by introducing mistletoe, which is a deadly parasite to the plant. Each bird species has its own movement and distribution patterns, breeding seasons and feeding strategies.



Figure 36. A flock of cockatoos approaching a macadamia orchard.



Figure 37. A black cockatoo.

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

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

## Monitoring

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

## Control

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

## Bird scaring

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

## Acoustics

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



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

### Shooting

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

### Drones

Drones have provided some success in scaring away birds and best results are achieved if the drones are used with other deterrents. PhD candidate, Zihao Wang, from the University of Sydney (School of Aerospace, Mechanical and Mechatronic Engineering) is conducting interesting work using an unmanned aerial vehicle. See the article on page 28.

### Other techniques include:

- Agri-laser systems
- Baits
- Feeders
- GPS navigation (for autonomous drone flying)
- Industrial and commercial acoustics systems
- Networked gas cannons
- Night vision systems
- Radio activated cannons
- Strobe lighting systems
- Thermal 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, however, due to the number of commercial drone products available, we have purposely not mentioned any one in particular.

### Further reading

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

Office of Environment and Heritage destruction licence for native species: [www.environment.nsw.gov.au/wildlifelicences/OccupierLicences.htm](http://www.environment.nsw.gov.au/wildlifelicences/OccupierLicences.htm)

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

### Electronic bird repellents

Bird Beam (Laser): [www.birdbeam.com.au](http://www.birdbeam.com.au)

Bird Gard Australia: [www.birdgard.com.au](http://www.birdgard.com.au)

Birds Off™: [www.birdsoff.com.au](http://www.birdsoff.com.au)

### Case study

**Chris Searle, Bundaberg and Brice Kaddatz, Gympie**

The biggest frustration with cockatoos is the damage they do to irrigation infrastructure. One strategy might be to place grease on the irrigation line either side of sprinklers or drippers. For example, a very sticky moly grease might work but it is neither cheap nor quick to distribute throughout an orchard. However, given that up to 75% of sprinklers/drippers in a block can be destroyed in a few days, it might be more costly not to do so.

We found that with a serious focus, starting at the first bird sighting and using a range of scaring tactics, the birds did leave after about 10 days.

The most effective method for mobile scaring is the non-lethal 12 gauge cracker cartridges. These have a range of approximately 80 m and they explode over or near the birds. These have also been effective with other species in non-orchard environments i.e. wild ducks from dams.

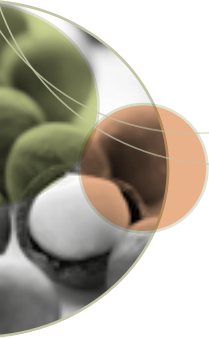
### The main message for vertebrate pest management

**Dean Chamberlain; Team Leader Operations – Invasive Pests  
North Coast Local Land Services  
w: [www.lls.nsw.gov.au/northcoast](http://www.lls.nsw.gov.au/northcoast)**

The main message we have for anyone suffering damage from vertebrate pests is to contact their LLS and discuss the matter with a Biosecurity Officer who can provide expert advice and best management practice techniques. LLS can also assist landholders to coordinate large scale control programs which are far more effective than individual producers working alone.

LLS currently works with a number of macadamia producers north of Lismore assisting with feral dog and pig control.

LLS is currently developing Local Pest Management Plans with stakeholders, so it is important that affected landholders contact LLS so that we can assist them. Deer are an emerging pest, so if affected landholders contact LLS, we can record the details and use this to guide future management and funding opportunities.



# Detering birds from orchards

Zihao Wang, Andrew Lucas, Andrea S. Griffin and KC Wong; University of Sydney

## Introduction

Pest bird damage to commercial crops is a significant global problem. Using unmanned aerial vehicles (UAVs, more commonly known as drones) is one of the emerging approaches to tackle this problem. Typically, these drones are made to look like natural predators. However, birds will habituate to scaring methods without the presence of a real threat. Therefore, we used a different approach in our research by trying to make the birds learn that the drone is a new predator in their community rather than an existing natural predator.

## Research

Decades of bird behaviour research shows that birds learn about novel threats by seeing it at the same time as hearing alarm responses from other birds. To capitalise on this way of learning, the prototype drone is equipped with a horn tweeter and a crow taxidermy as shown in Figure 38. The crow taxidermy is hanging upside down from the undercarriage of the drone. The idea is for it to look as though the drone has just caught the crow. The distress call coming from the horn tweeter signals to onlooking birds that the crow taxidermy is in real danger, an experience that should trigger social learning.

The drone was tested in four vineyards in New South Wales in 2018 (Wang et al., 2019). The main pest species encountered were the Australian Raven (*Corvus coronoides*), Common Starling (*Sturnus vulgaris*), Sulphur-crested Cockatoo (*Cacatua galerita*) and Silvereye (*Zosterops lateralis*). The drone was flown manually to deter the pest birds from the vineyards. For flocking birds (ravens, starlings and cockatoos), we observed and recorded the distance at which birds fled from the drone, and the time taken for the birds to return to their initial position. For the silvereyes, because they behave differently, we counted their activity for 15 minutes before and after the drone flights as a measure of effectiveness.



Figure 38. The unmanned aerial vehicles equipped with a horn tweeter (top left) and a crow taxidermy (bottom).

## Results

The drone successfully deterred all birds in all nine trials. On average, the birds fled from the drone when it was approximately 100 m away. In trials 1–6, the same raven flock was targeted, and while they did not leave the vineyard after the drone flight, they settled about 450 m away from their initial position. In contrast, the cockatoo and starling flocks left the vineyard after the drone flight. Only the starling flock in trial 9 returned to the vineyard after 5 minutes, however, they perched on powerlines briefly before flying away. The results from the nine trials are summarised in Table 1.

A total of three experiments were performed with silvereyes. The number of birds moving into and out of the vines after the drone flight was significantly less than before the drone flight (Figure 39). The relative reduction in bird activity in the 15 minutes after the UAV flight was 66%, 95% and 42% respectively (Figure 40).



The results indicate that the drone effectively deterred the birds. The drone had a minimum 50 m radius of influence on large birds. All birds left their initial location after the drone flight in all nine trials. Only one flock of starlings returned but did not forage in the vines. The effectiveness of the drone against silvereyes is evident in the reduction of silvereye activity after the flights.

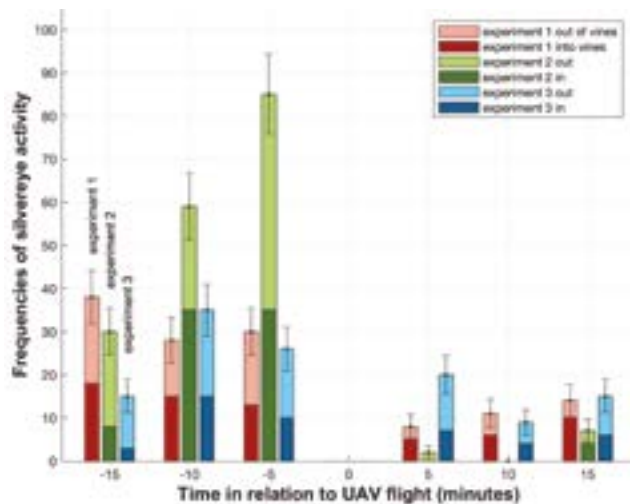


Figure 39. Silvereye responses to the drone flights.

mounts and vocalisations were more closely related to the target species (e.g. using a silvereye taxidermy against silvereyes rather than a crow taxidermy). In addition to such adjustments, future research will focus on developing autonomous technologies, so that more frequent flights and more precise targeting become possible.

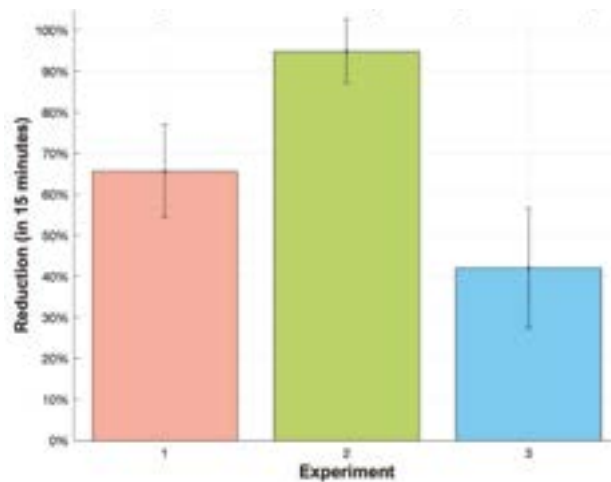


Figure 40. Reduction in silvereye activity during the 15 minutes after the drone flight.

## Conclusions

Incorporating bird behaviour theory into the drone design provides opportunities for new bird control methods. The drone can potentially reduce bird damage for all commercial crops. The effectiveness of the drone against each target species could improve if the drone was flown more frequently and if the taxidermy

## Reference

Wang Z, Griffin AS, Lucas A and Wong KC (2018). Psychological warfare in vineyard: using drones and bird psychology to control bird damage to wine grapes. *Crop Protection*, 120, 163–170.

Table 1. Birds' responses to the drone flights in nine trials.

Trial	Species	Time of UAV launch	Response distance (m)	Number of animals before UAV flight	Number of animals at initial position after UAV flight	Time taken to return to initial position (min)	Settle distance from initial position (m)
1	Raven	8.52 am	50	100	0	0	500
2	Raven	9.40 am	100	100	0	0	550
3	Raven	10.20 am	300	100	0	0	400
4	Raven	10.58 am	100	100	0	0	450
5	Raven	11.11 am	150	100	0	0	350
6	Raven	11.30 am	150	100	0	0	600
7	Cockatoo	6.10 pm	50	50	0	Not seen before dark	NA
8	Starling	5.30 pm	50	50	0	Not seen before dark	NA
9	Starling	5.57 pm	100	50	0	5 (perching on powerlines, flew away before dark)	NA



# ***SERIOUSLY LONG WEED CONTROL IN ORCHARDS AND VINEYARDS***

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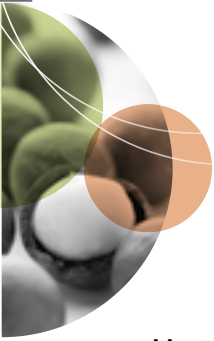
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# Orchard pest and disease management priorities

Most macadamia pests and diseases appear during specific crop growth stages. This guide lists the most common pests and diseases that growers should be monitoring for during a typical growing season (Table 2). It gives recommendations for control based on an integrated pest and disease management approach (IPDM). This approach assumes that orchard pest and disease monitoring has indicated thresholds that require treatment. Guidance of action level by a pest scout or consultant is strongly recommended.

## Resistance management

A fundamental aspect of any IPDM strategy is the pesticide used. The primary consideration is

to rotate applications so that the pest, disease or weed is not continually exposed to chemicals of the same group, thus reducing the risk of resistance to that chemical. To do this successfully, growers need to be able to identify chemical groups. You can do this by checking the activity group identification symbol, which all registered pesticides have on their labels, e.g. 1B, 11C, 18.

**Note:** the pesticide recommendations are based on NSW registrations, which are pest and crop specific. This is different from Queensland, where regulations are for crops only. The recommendations made in this guide are based on NSW regulations, however, they are relevant to the industry in Australia.

Table 2. Macadamia management guide (correct as at 10 May 2019).

Month	Reason	Treatment	Group	WHP (days)	Remarks
<b>PRE-FLOWERING</b>					
July	Macadamia flower caterpillar	Acephate (S6)*	1B	NRD <sup>1</sup>	Monitor crop for hotspot areas. DO NOT SPRAY WHEN BEES ARE FORAGING. Apply in late evening when bees are not active or remove bees from orchard. Good coverage is essential for control. Apply Bt at first sign of activity. Bt is best used in a routine program, it is not suitable for emergency treatment. <b>Biological control</b> Wasps (larvae parasite) <i>Agathis rufithorax</i> , <i>Brachymeria</i> sp., <i>Phanerotoma</i> sp. Egg parasitoids <i>Trichogrammatoidea flava</i> Parasitic bug <i>Teratophylum</i> sp. Syrphid fly larva <i>Melanostoma agrolas</i>
		OR			
		<i>Bacillus thuringiensis</i> (Bt) (PS exempt)	11C	NRD <sup>1</sup>	
		OR			
		Methoxyfenozide (PS exempt)	18	28	
OR					
Tebufenozide (S5)	16A	28			
OR					
Trichlorfon (S6)	1B	2			

Month	Reason	Treatment	Group	WHP (days)	Remarks
July	Lace bug	Diazinon (S6) (See APVMA permit <a href="#">PER14276</a> , expires 30 November 2020) <b>OR</b> Pyrethrin (NA) (See APVMA permit <a href="#">PER14852</a> , expires 31 March 2022) <b>OR</b> Trichlorfon (S6) (See APVMA permit <a href="#">PER13689</a> , expires 30 September 2021)	1B  3A  1B	14  1  2	Lace bug is generally not an issue in central Queensland but is becoming so in south-eastern Queensland. Monitor crop for hotspot areas. DO NOT SPRAY WHEN BEES ARE FORAGING. Apply late evening when bees are not active or remove bees from orchard. Good coverage is essential. Apply diazinon at pre-flowering only due to residual and subsequent effect on bees. Diazinon residues on flowers can remain dangerous to bees for up to 7 days post application. Apply pyrethrin at first sign of infestation but before flowering, immediately before main flower opening. Repeat spray treatment (if required) before second flower opening, continuing to nut set if pressure persists. Apply a maximum of five applications of pyrethrin per crop with a minimum of 7 days between applications.
	Macadamia felted coccid	Diazinon (S6) <b>OR</b> Methidathion (S7) <b>OR</b> Petroleum oil (S5) (See APVMA Permit <a href="#">PER11635</a> , expires 30 June 2020)	1B  1B  Unspecified	14  21  NRD <sup>1</sup>	Beware of repeated methidathion applications as resistance may occur. Do not apply petroleum oil when temperatures exceed 32 °C or when soil is dry and trees are suffering from moisture stress. Products to be used are those referred to only as summer spray oils. <b>Biological control</b> Ladybird beetles and larvae <i>Midus pygmaeus</i> , <i>Rhizobius ventralis</i> , <i>Serangium maculigerum</i> Predatory moth <i>Batrachedra arenosella</i> Egg parasitoids <i>Aspidiophagus</i> sp., <i>Metaphcus</i> sp.
<b>EARLY FLOWERING</b>					
August	Macadamia flower caterpillar	Acephate (S6) <b>OR</b> <i>Bacillus thuringiensis</i> (Bt) (PS exempt) <b>OR</b> Methoxyfenozide (PS exempt) <b>OR</b> Spinetoram (S5) <b>OR</b> Tebufenozide (S5) <b>OR</b> Trichlorfon (S6)	1B  11C  18  5  16A  1B	NRD <sup>1</sup>  NRD <sup>1</sup>  28  7  28  2	Apply late August peak flowering for some varieties. <b>Biological control</b> Wasps (larvae parasite) <i>Agathis rufithorax</i> , <i>Brachymeria</i> sp, <i>Phanerotoma</i> sp. Egg parasitoid <i>Trichogrammatoidea flava</i> Parasitic bug <i>Teratophylum</i> sp. Syrphid fly larva <i>Melanostoma agrolas</i> .



Month	Reason	Treatment	Group	WHP (days)	Remarks
August	Lace bug	Pyrethrin (NA) (See APVMA permit <a href="#">PER14852</a> , expires 31 March 2022) <b>OR</b>	3A	1	An option is to not treat at early flowering and then target pest at peak flowering due to some varieties still being harvested and residue concerns.  Apply a maximum of five applications of pyrethrin per crop with a minimum of 7 days between applications.
		Trichlorfon (S6) (See APVMA permit <a href="#">PER13689</a> , expires 30 September 2021)	1B	2	
	Phytophthora	Copper as cuprous oxide (S6) <b>OR</b>	M1	1	<b>Maintenance</b> Foliar spray phosphorous acid. Apply at mature leaf flush during spring and autumn. Do not apply to young leaf flush as it can burn foliage. Apply to each leaf flush if disease persists during production period. Apply to point of run-off, ensuring all leaves and branches are covered. Do not apply to trees under severe water stress or during very hot weather (e.g. temperature > 28 °C). <b>Curative</b> Trunk application phosphorous acid. Apply to affected trees at root flush and 28 days after root flush. Dilute spray to point of run-off around trunk to approximately 1 metre above soil level, ensuring thorough coverage of trunk. Apply bark penetrant such as Pulse® at a rate of 2%.
		Metalaxyl (S5) <b>OR</b>	4	28	
		Metalaxyl (S5) + copper oxychloride (S6) <b>OR</b>	4/M1	28	
		Phosphorous acid	33	14	
<b>PEAK FLOWERING</b>					
September	Lace bug	Pyrethrin (NA) (See APVMA permit <a href="#">PER14852</a> , expires 31 March 2022) <b>OR</b>	3A	1	Monitor crop for hotspot areas. Apply in the evening when bees are not active or remove bees from orchard. Thorough coverage is essential.  Apply a maximum of five applications of pyrethrin per crop with a minimum of 7 days between applications.
		Trichlorfon (S6) (See APVMA permit <a href="#">PER13689</a> , expires 30 September 2021)	1B	2	
	Macadamia flower caterpillar	Acephate (S6) <b>OR</b>	1B	NRD <sup>1</sup>	Monitor for eggs and very small larvae on flowers and apply control at threshold of 50–80% infested racemes.  <b>Biological control</b> Wasps (larvae parasite) <i>Agathis rufithorax</i> , <i>Brachymeria</i> sp., <i>Phanerotoma</i> sp. Egg parasitoid <i>Trichogrammatoidea flava</i> Parasitic bug <i>Teratophylum</i> sp. Syrphid fly larva <i>Melanostoma agrolas</i> .
		<i>Bacillus thuringiensis</i> (Bt) (PS exempt) <b>OR</b>	11C	NRD <sup>1</sup>	
		Methoxyfenozide (PS exempt) <b>OR</b>	18	28	
		Spinetoram (S5) <b>OR</b>	5	7	
		Tebufenozide (S5) <b>OR</b>	16A	28	
Trichlorfon (S6)	1B	2			

Month	Reason	Treatment	Group	WHP (days)	Remarks
September	Botrytis blight	Iprodione (S5)	2	0	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.
<b>NUT SET</b>					
September–November	Husk spot	Carbendazim (S7)	1	14	Apply first spray when nuts are at match head size.
		OR Copper hydroxide (S6)	M1	1	Do not apply more than two consecutive sprays of the same group.
		OR Difenoconazole (S5)	3	NRD <sup>1</sup>	At least two sprays 14–28 days apart and more sprays if: <ul style="list-style-type: none"> <li>• weather is conducive for husk spot</li> <li>• variety is susceptible</li> <li>• infestation was severe in previous years.</li> </ul>
		OR Pyraclostrobin (S5)	11	NRD <sup>1</sup>	Remove sticktight from trees to reduce inoculum.
	Macadamia twig girdler	Carbaryl (S6)	1A	NRD <sup>1</sup>	Monitor for leaf clumping and twig damage, particularly on young trees.
	OR Methidathion (S7)	1B	21	<b>Biological control</b> Parasitic wasp <i>Elachertus</i> sp.	
	OR Spinetoram (S5)	5	7		
	Green vegetable bug (GVB)	Trichlorfon (S6) (See APVMA permit <a href="#">PER13689</a> , expires 30 September 2021)	1B	2	Damage appears similar to that from FSB, although GVB will usually make more stings and they will be shallower than FSB stings. <b>Biological control</b> Parasitic wasp <i>Trissolcus basilis</i> and parasitic fly <i>Tricopoda giacomellii</i> .
	Banana fruit caterpillar	Methomyl (S7) (See APVMA permit <a href="#">PER12796</a> , expires 30 June 2021)	1A	NRD <sup>1</sup>	A problem only in Queensland. Blow out leaf litter before spraying. Use as ground surface treatment only, using spray boom or equivalent equipment. Apply one application only during late flowering–early fruit development. Time spray to coincide with initial observation of larvae activity. Ensure thorough coverage of all leaf litter and soil surface along tree line. Use higher rate when large larvae or higher numbers are present. Do not spray tree foliage, flowers or developing nutlets.
September–November	Macadamia seed weevil ( <i>Kuschelorrhynchus macadamiae</i> )	Acephate (S6) (See APVMA permit <a href="#">PER81463</a> , expires 31 January 2021)  OR	1B	NRD <sup>1</sup>	Apply a maximum of three applications per season using an air-blast sprayer with a minimum re-treatment interval of 14–21 days.



Month	Reason	Treatment	Group	WHP (days)	Remarks
September–November	Macadamia seed weevil ( <i>Kuschelorrhynchus macadamiae</i> )	Indoxacarb (S6) (See APVMA permit <a href="#">PER86827</a> expires 30 September 2021)	22A	42	Apply first when nuts are at pea size using a spray volume of 500–1,000 L/ha.  Ideally apply indoxacarb at match head size for best control.  Ensure thorough coverage.  Sweep out affected nuts and expose to full sunlight.  Mulch affected nuts.  See NSW DPI factsheets: <a href="#">Macadamia seed weevil pest information and management options</a> and <a href="#">Macadamia seed weevil life cycle and monitoring</a> .
<b>PEA-SIZE NUT AND SPRING FLUSH</b>					
November–December	Fruit spotting bug (FSB)	Acephate (S6) <b>OR</b>	1B	NRD <sup>1</sup>	Monitor crop for fallen nuts.
		Azinphos-methyl (S7) <b>OR</b>	1B	7	Trap crops of <i>Murraya paniculata</i> are good indicator plants for FSB presence and can help determine pressure levels. Using chicken wire enclosures to prevent wildlife spreading berries is recommended.
		Beta-cyfluthrin (S6) <b>OR</b>	3A	7	Monitor orchard boundaries, particularly if backing onto FSB host species. Use previous year's incidence to help predict incursion.
		Methidathion (S7) <b>OR</b>	1B	21	Avoid applying more than two consecutive sprays of the same active to prevent resistance. Only apply beta-cyfluthrin once as it has been known to create mite and thrips flare ups.
		Trichlorfon (S6) (See APVMA permit <a href="#">PER13689</a> , expires 30 September 2021) <b>OR</b>	1B	2	Monitor crop to prevent late FSB damage from mid-December onwards.  <b>Biological control</b> Egg parasitoids <i>Centrodora darwini</i> , <i>Anastatus</i> sp., <i>Ooencyrtus cauru</i> , <i>Gryon</i> sp.  Nymph and adult parasites <i>Pentatomophaga bicinta</i> (tachnid fly), <i>Pheidole megacephala</i> (coastal brown ants – beware of aphids), <i>Pristhesancus papuensis</i> (assassin bug).
	Sulfoxaflor (S5)	4C	NRD <sup>1</sup>	<b>For Sulfoxaflor</b> <b>DO NOT SPRAY WHEN BEES ARE FORAGING.</b>  Do not use more than two applications to a crop in any one season. If making repeat applications, do not reapply within 21 days. Apply as part of a season-long spray program targeting pests when they are active in the crop. Using Transform® early in the fruiting/flowering stage will conserve beneficials when used in an IPM system. Complete spray coverage is essential. Concentrate sprays are not suitable for this pest. Adding an adjuvant, although not critical, might improve control. Apply to the point of run-off.	

Month	Reason	Treatment	Group	WHP (days)	Remarks
November–December	Macadamia nut borer (MNB)	Acephate (S6)	1B	NRD <sup>1</sup>	<p>**Wasp release starting date will depend on region; early November for Bundaberg, mid-December for NSW.</p> <p>Wasps work well as an area-wide approach i.e. surrounding farms should also incorporate wasps into their program as a control method.</p> <p><b>Biological control</b> Parasitic wasps: <i>Trichogrammatoidea cryptophlebiae</i>, <i>Apanteles briareus</i>, <i>Nixon</i>, <i>Bracon</i> sp., <i>Gotra bimaculatus</i> Parasitic fly.</p>
		OR			
		Azinphos-methyl (S7)	1B	7	
		OR			
		Beta-cyfluthrin (S6)	3A	7	
		OR			
		Cabaryl (S6)	1A	NRD <sup>1</sup>	
		OR			
		Methidathion (S7)	1B	21	
		OR			
		Methoxyfenozide (PS exempt)	18	28	
		OR			
		Spinetoram (S5)	5	7	
		OR			
		Tebufenozide (S5)	16A	28	
		OR			
		Trichogramma wasp**	NA	NA	
	Flower thrips ( <i>Scirtothrip</i> spp.)	Abamectin (S6) (See APVMA permit PER81162, expires 30 April 2020)	6	28	<b>Biological control</b> Predatory thrips <i>Scolothrips sexmaculatus</i> .
		OR			
		Acephate (S6)	1B	NRD <sup>1</sup>	
	Flower thrips ( <i>Scirtothrip</i> spp.) Broad mites ( <i>Brevipalpus</i> spp.) Flat mites ( <i>Polyphagotarsonemus</i> spp.)	Abamectin (S6) (See APVMA permit PER81162, expires 30 April 2020)	6	28	<p>No more than one application per season.</p> <p>Do not apply in consecutive seasons without using a chemical from a different mode of action in between.</p> <p>Dangerous to bees.</p>
	Macadamia mussel scale, long soft scale and white scale	Methidathion (S7)	1B	21	<p>Not yet found in Bundaberg.</p> <p><b>Biological control</b> Lacewings <i>Mallada signata</i> (larva) and <i>Cryptolaemus</i>.</p>
	Macadamia leafminer	Acephate (S6)	1B	NRD <sup>1</sup>	<p>Not yet found in Bundaberg and generally does not warrant control elsewhere.</p> <p>Beware of repeating methidathion applications as resistance can occur.</p>
		OR			
		Diazinon (S6)	1B	14	
		OR			
		Methidathion (S7)	1B	21	



Month	Reason	Treatment	Group	WHP (days)	Remarks
November–December	Macadamia felted coccid	Diazinon (S6) OR	1B	14	Beware of repeating methidathion applications as resistance can occur.  Do not apply petroleum oil when temperatures exceed 32 °C or when soil is dry and trees are suffering from moisture stress.  Products to be used are those referred to only as summer spray oils.  <b>Biological control</b> Ladybird beetles and larvae <i>Midus pygmaeus</i> , <i>Rhizobius ventralis</i> , <i>Serangium maculigerum</i>  Predatory moth <i>Batrachedra arenosella</i>  Egg parasitoids <i>Aspidiophagus</i> sp., <i>Metaphcus</i> sp.
		Methidathion (S7) OR	1B	21	
		Petroleum oil (S5) (See APVMA permit PER11635, expires 30 June 2020)	Unspecified	NRD <sup>1</sup>	
<b>PEA-SIZE NUT AND SPRING FLUSH</b>					
November–December	Macadamia kernel grub	See remarks	NA	NA	Can be an issue where variety has open micropyle.  Control for MNB and FSB will prevent most kernel grub damage.
	Macadamia seed weevil ( <i>Kuschelorrhynchus macadamiae</i> )	Acephate (S6) (See APVMA permit PER81463, expires 31 January 2021) OR	1B	NRD <sup>1</sup>	Apply a maximum of three applications per season using an air-blast sprayer with a minimum re-treatment interval of 14–21 days.  See NSW DPI factsheets: <a href="#">Macadamia seed weevil pest information and management options</a> and <a href="#">Macadamia seed weevil life cycle and monitoring</a> .
		Indoxacarb (S6) (See APVMA permit PER86827, expires 30 September 2021)	22A	42	Apply first when nuts are at pea size.  Ensure thorough coverage.  Sweep out affected nuts and expose to full sunlight.  Mulch affected nuts.  Spraying for FSB should control exposed adult weevil, however, larvae and egg in nuts will not be affected.
<b>SHELL HARDENING AND OIL ACCUMULATION</b>					
January–February	Fruit spotting bug (FSB)	Acephate (S6) OR	1B	NRD <sup>1</sup>	Late season damage results in blind stings to nuts that are not easily visible from the outside. Monitoring for FSB damage after December is difficult, as damaged nuts do not drop. A useful guide for the likelihood of pest pressure at this time is last season's factory results.  Ensure adequate coverage of the whole tree as the chemical must contact the insect to kill it.  <b>Biological control</b> Egg parasitoids <i>Centrodora darwini</i> , <i>Anastatus</i> sp., <i>Ooencyrtus caurus</i> Nymph and adult parasites <i>Pentatomophaga bicinta</i> (tachnid fly), <i>Pheidole megacephala</i> (coastal brown ants – beware of aphids), <i>Pristhesancus papuensis</i> (assassin bug).
		Azinphos-methyl (S7) OR	1B	7	
		Beta-cyfluthrin (S6) OR	3A	7	
		Methidathion (S7) OR	1B	21	
		Sulfoxaflo (S5) OR	4C	7	
		Trichlorfon (S6) (See APVMA permit PER13689, expires 30 September 2021)	1B	2	

Month	Reason	Treatment	Group	WHP (days)	Remarks
January–February	Macadamia nut borer (MNB)	Acephate (S6)	1B	NRD <sup>1</sup>	<p>Late January spray for FSB will require more wasps to be re-introduced into the orchard.</p> <p>Although other products are registered, an effective area-wide management approach of wasp releases should eliminate the need for sprays unless a further FSB spray is required in January–February.</p> <p><b>Biological control</b></p> <p>Parasitic wasps <i>Trichogrammatoidea cryptophlebiae</i>, <i>Apanteles briareus</i>, <i>Nixon</i>, <i>Bracon</i> sp., <i>Gotra bimaculatus</i></p> <p>Parasitic fly.</p>
		OR			
		Azinphos-methyl (S7)	1B	7	
		OR			
		Beta-cyfluthrin (S6)	3A	7	
		OR			
		Cabaryl (S6)	1A	NRD <sup>1</sup>	
		OR			
		Methidathion (S7)	1B	28	
		OR			
	Methoxyfenozide (PS exempt)	18	28		
	OR				
	Spinetoram (S5)	5	7		
OR					
Tebufenozide (S5)	16A	28			
OR					
Wasps	NA	NA			
Phytophthora	Copper as cuprous oxide (S6)		M1	1	<p><b>Maintenance</b></p> <p>Foliar spray phosphorous acid.</p> <p>Apply at mature leaf flush during spring and autumn.</p> <p>Do not apply to young leaf flush as it can burn foliage.</p> <p>Apply to each leaf flush if disease persists during production period.</p> <p>Apply to point of run-off, ensuring all leaves and branches are covered.</p> <p>Do not apply to trees under severe water stress or during hot weather (e.g. temperatures &gt; 28 °C).</p> <p><b>Curative</b></p> <p>Trunk application phosphorous acid.</p> <p>Apply to affected macadamia trees at root flush and 28 days after root flush.</p> <p>Dilute spray to point of run-off around trunk to approximately 1 metre above soil level, ensuring thorough coverage of trunk. Apply bark penetrant such as Pulse® at a rate of 2%.</p>
		OR			
		Metalaxyl (S5)	4	28	
		OR			
Phosphorous acid	Metalaxyl (S5) + Copper oxychloride (S6)		4/M1	28	
		OR			
Phomopsis husk rot	Copper as cuprous oxide (S6)		33	28	
		OR			
			M1	1	Injury to the macadamia fruit pericarp predisposes it to infection.



Month	Reason	Treatment	Group	WHP (days)	Remarks
<b>NUT MATURITY AND HARVEST</b>					
March–July	Rats	Coumatetralyl (S6)	NA	NA	Monitor rodent levels before baiting. Regularly check traps and top up bait. Remove nests. Concentrate baiting in outer three rows closest to scrubby habitat. Maintain ground cover at a low height. Promote owl boxes. Rat control program should continue all year round, clearing nests in trees and identifying burrows within the orchard. Bait when nuts are available.
<b>EMERGING</b>					
As required	Bark beetle	No registration exists for macadamia in NSW	NA	NA	Declining trees are most susceptible. Remove and destroy affected limbs and trees from the orchard. Maintain soil and tree health.
	Branch dieback	No registration exists for macadamia in NSW	NA	NA	Recently becoming more prevalent in trees > 15 years old. Bark beetle is often seen as secondary to branch dieback infestation.
	Dry flower	No registration exists for macadamia in NSW	NA	NA	Expressed as flower blight. Causes raceme dieback and subsequent yield loss.
	Leptocoris	No registration exists for macadamia in NSW	NA	NA	FSB control should assist in controlling leptocoris. Ensure no host plants such as soapbark are near the orchard.
	Pinhole borer	No registration exists for macadamia in NSW	NA	NA	More likely in drier areas. Several species have been observed from Bundaberg to the Mid North Coast of NSW. The borer will be a problem if an infected nut gets into a storage silo, so ensure careful belt sorting.

\*Poison schedule: the second set of brackets. On the product label this will be seen as a signal heading whereby:

- Poison Schedule exempt (PS exempt)
- Schedule 5 (S5) Caution
- Schedule 6 (S6) Poison
- Schedule 7 (S7) Dangerous Poison.

The higher the number the greater the hazard and stricter labelling and regulatory requirements.

NRD<sup>1</sup>: Not required when used as directed.

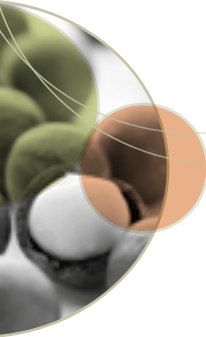
Always refer to product label and Safety Data Sheet (SDS).

Resistance strategies: No more than two consecutive sprays of a product within the same category e.g. Pyraclostrobin is category 11. So no more than two consecutive sprays with category 11. See Avoiding pesticide resistance on page 80.

Refer to the AMS Communication [Best practice guidelines for the application of chemicals in macadamia orchards](#) when planning the spraying of your orchard.

Calibrate your spray machinery at least annually and before the season starts.

Ensure you are obtaining good coverage for complete crop protection.



# Fruit spotting bug

Fruit spotting bug (FSB) has become the most significant macadamia pest since an effective biological control option was established for macadamia nut borer. Research shows that late FSB insect damage is consistently the primary reason for nuts being rejected at factory stage.

Two types of FSB are known in Australia; *Amblypelta nitida* Stål (*A. nitida*) and *Amblypelta lutescens lutescens* (*A. lutescens*). Both feed on macadamia fruit and flowers and have multiple host plant species (Table 3). *A. nitida* is prevalent in Northern NSW and South East Queensland, while *Amblypelta lutescens* can be found from the Queensland border through to Cape York (Figure 41).

Table 3. Types of FSB in Australia.

Species	<i>Amblypelta nitida</i> Stål ( <i>A. nitida</i> )	<i>Amblypelta lutescens lutescens</i> ( <i>A. lutescens</i> )
Distribution	From 17°S to 35°S (Figure 41)	From 11°S to 27°S (Figure 41)
Number of host plant species	56	111
Diet	Feeds only on fruit and flowers	Generally feeds on fruit, shoots and flowers, although rarely on macadamia shoots
Days to develop from egg to adult at 20 °C	63	79
Days to develop from egg to adult at 25 °C	45	50



Figure 41. Fruit spotting bug distribution in Australia.

## Life cycle

Fruit spotting bugs pass through 3–4 generations a year; one in spring, one or two in summer and one in autumn (Figure 42–Figure 46). Adults from the autumn generation survive the winter, to begin a new generation in spring.



Figure 42. *Amblypelta nitida* 1st instar stage.



Figure 43. *Amblypelta nitida* 4th instar stage.



Figure 44. *Amblypelta lutescens* 4th instar stage.



Figure 45. *Amblypelta nitida* 5th instar stage.



Figure 46. *Amblypelta nitida* adult stage.

### Damage to macadamia nuts

Very young fruit falls within a few days of an FSB attack, some with visible external symptoms such as slightly sunken black spots. Dissecting the fruit will confirm the lesions are from FSB feeding. Fallen nutlet counts in October–November is the key monitoring tool crop scouts use to inform spray recommendations; the spray threshold is 3% of nuts falling.

As the nuts mature later in the season (December onwards), they are less likely to fall once stung, but they will be unmarketable. Nuts of all sizes

and maturity levels can be damaged, although less frequently after shell hardening in January. Damage is visible as dark, slightly sunken spots on the husk, collapsed testa while it is soft, and misshapen, brown and shrivelled translucent kernels. Further damage can be caused by secondary disease from organisms spread by FSB (Ironsides 1981; Fay 2002).

### Monitoring

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

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

Key steps in effective monitoring include:

- identifying FSB entry points and natural harbours
- monitoring bordering vegetation
- identifying hotspots in the crop (FSB often return to a damaged tree repeatedly)

Identifying hotspots in monitoring:

- 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 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 47)
  - identify other insect damage e.g. macadamia nut borer and macadamia seed weevil (Figure 48)
  - repeat fortnightly until nut drop stops in December
  - late damage is difficult to detect as the nuts remain in trees.

Fallen nuts need to be checked for fresh damage from early in the season until mid-December.

This ceases to be an accurate indicator of recent activity the further into the season you measure. Activity after the shell hardens from January onwards, particularly on the thinner shelled varieties (e.g. A4, 849), is hard to detect from the ground and if unchecked, can be very costly.

When monitoring nut drop in spring, it is important to recognise and distinguish the common causes of nut drop, including macadamia seed weevil, macadamia nut borer and fruit spotting bug feeding (Figure 48).





Figure 47. Checking for sting lesions in husk and shell.



Figure 48. Common causes of nut drop include macadamia seed weevil (top left), macadamia nut borer (top right) and fruit spotting bug feeding (bottom).

## Using a trap crop

Trap crop hedges are being used commercially for FSB monitoring. A trap crop is a species planted in a hedge next to the macadamia crop that also attracts FSB. One of the best trap crop species is *Murraya paniculata*, or mock orange. Other proven species include *Macadamia ternifolia* and *Macadamia longan*. These species are now being trialled for their effectiveness in predicting FSB 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 better times.

During spring, a FSB hotspot will appear in the trap crop before the macadamia crop. The FSB stay in the hedge once feeding starts and monitoring should detect a build-up of large 5th instar nymphs (Figure 45). These are almost adult size, with black antennae, black 'knees' and only wing buds rather than fully expanded wings.

Adult FSB (Figure 46) fly from the trap crop to the macadamia crop approximately 10–14 days

after 30% of the bugs reach the 5th instar nymph stage. This is the optimal time to spray for the first FSB wave of the season. The hedge should be continually monitored for the next generation to emerge.

## Control options

### Cultural controls

To reduce the risk and damage from FSB:

- select appropriate varieties (avoiding thin-shelled macadamia varieties)
- reduce tree heights 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 effects
- use cover crops in the inter-row
- improve bordering alternate FSB host vegetation management.

### Biological controls

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

- Egg parasitoids: *Anastatus* sp. near *pentatomivorius* (Eupelmidae), *Ooencyrtus caurus* (Encyrtidae), *Gryon* sp. (Scelionidae) and *Centrodora darwini* (Aphelinidae). Nymph and adult parasitoids include the tachinid fly, *Trichopoda giacomellii*.
- Predators: spiders, e.g. *Ocrusiona* sp., ants, e.g. green tree ant *Oecophylla smaragdina*, *Pheidole* sp., predatory bugs, e.g. assassin bug *Pristhesancus papuensis*, and lacewings, e.g. brown lacewing *Micromus tasmaniae*.

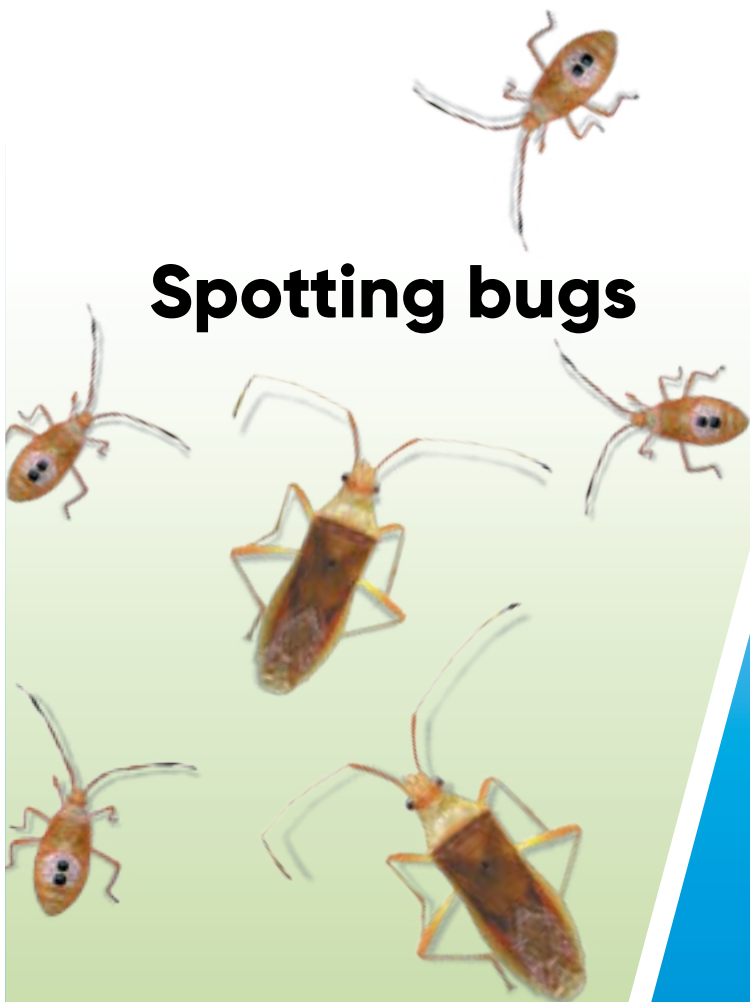
### Chemical control

Future strategies will incorporate an integrated pest management (IPM) approach, using cultural, biological and chemical controls based on monitoring using trap cropping and pheromone traps. Eventually area-wide management programs that reduce populations on a district basis might be developed.

The transition to IPM approaches will reshape chemical control practices through:

- using chemicals appropriately to reduce off-target effects
- using less broad-spectrum chemicals that are safer on beneficial insects
- spraying hotspots to target problem areas
- leaving unsprayed refuges in the crop
- improving timing to minimise the need for repeat sprays.

## Spotting bugs



## Stopping bugs

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# Macadamia seed weevil: a breakthrough for control

A key outcome from the IPM project is the identification of indoxacarb ([PER86827](#)) to control macadamia seed weevil (MSW). When applied to match head-size nutlets, indoxacarb will eliminate egg laying from the adult female weevil, thus avoiding the significant losses suffered previously. It will also help to eliminate several costly control sprays and there will be less requirement for hygiene clean ups as the nuts will no longer be infected by the weevil and therefore will not be on the ground.

NSW DPI entomologists have been studying macadamia seed weevil for many years, tracking its habits and investigating control methods. Here is an update on this serious pest.

## Current distribution

Macadamia seed weevil is spread throughout the Northern Rivers area of NSW and the Atherton area of Far North Queensland. There have been isolated incidences of MSW in the Gympie area, but it has not yet been reported in Bundaberg, the Glasshouse Mountains or the Mid North Coast of NSW. Where MSW is observed thriving, we generally see a number of elements that allow it to do so. These include:

## Extended flowering and out of season nut set

Just as extended flowering supports higher lace bug levels, it also supports MSW. It is not just the flowering, but the following small, soft shell, out of season nut that allows the weevil to lay its egg (Figure 49) and increase in numbers (Figure 50).

Natural disasters (e.g. from extreme weather) can create higher pest pressure from multiple flowerings and nut set. Growers need to be aware that out of season flowering will create a very high base population of not only MSW, but also other insect pests. This means that growers need to ensure their spray coverage and rates are adequate for what will be a very high pressure season.

Key points to consider include:

- **calibrate** your sprayer now
- **slow down**: place a target in the tree and check the coverage when travelling at your normal speed. In most cases spray operators are going too fast to achieve adequate coverage

- **timing**: you need to be protecting your crop at the most efficient time. Delays will cause losses in production.



Figure 49. Macadamia seed weevil lays its egg on a chewed patch of husk.



Figure 50. Typical mark left by macadamia seed weevil that indicates egg laying.



Figure 51. Macadamia seed weevil larvae and pupae overwintering in nuts.



## Neglected orchards

Neglected areas are ideal breeding grounds for many pests, including MSW. While the crop is there for the weevil, there is no reason for it to move into neighbouring orchards. However, when the crop is limited, the weevil will migrate to other areas to sustain reproduction.

## Orchard floor

Old, damaged nuts left on the orchard floor will allow weevil populations to develop and increase, resulting in further damage to your crop and income. Figure 51 shows damage to the nuts caused by MSW overwintering in them.

Case studies showing effective MSW control all included regular orchard floor clean up, nut mulching, and, in some cases, eliminating infested nuts from the orchard altogether.

Treatment should be similar to a pre-harvest orchard floor clean up to ensure that developing larva within the dropped nuts are controlled. Start early to avoid pest build up. Before fruit spotting bug causes early nut drop, growers need to make sure that their orchard floor is clean. Generally, growers can concentrate on hotspots in the orchard to maintain a clean floor. Start early to avoid pest build up.

## Follow recommended control programs

The APVMA has provided the macadamia industry with approval to use indoxacarb to control MSW ([PER86827](#)). Indoxacarb is best applied at match head stage and will prevent the adult weevil laying eggs into the nut for up to 13 weeks. Indoxacarb should be used with a hygiene clean up and effective monitoring to ensure durability of the product.

## Macadamia seed weevil control

### Pre-flowering

Out of season flowering means that in season flowering will have high pressure from built-up populations that were supported by the early crop. The MSW life cycle is influenced by degree days; cold, wet weather will slow their progress but diligence at pre-flowering is critical for effective control.

Out of season flowering will also not have indoxacarb treatment and therefore will be a good source of future weevil infestations.

## Pre-harvest clean up

Clean up generally occurs from January onwards and is especially important for orchards with macadamia seed weevil. If done thoroughly, it will minimise weevil populations. We are seeing good results where a combination of good hygiene (removing infested nuts) and targeted spraying during spring (with the registered minor use permit chemical acephate) effectively manages macadamia seed weevil.

## Chemical control

Indoxacarb applied to match head-size nutlets will eliminate egg laying from the adult female weevil for up to 13 weeks.

Best results for MSW control have been achieved with a combination of good hygiene (removing infested nuts) and targeted spraying during spring at match head with indoxacarb.

## Take photos

If you see macadamia seed weevil on other vegetation, take a photograph, record the GPS location and report it to NSW DPI development officer Jeremy Bright. Previous literature has reported macadamia seed weevil using *Ficus* spp. as a place to breed. To date, there are no other reports of macadamia seed weevil breeding in any crop other than macadamia.

## Further information

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# 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 use of pesticides.

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

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

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

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

Trees are more vulnerable to damage from pests and diseases when they are stressed. Tree health

can be supported by maintaining good soil health, which includes erosion control, adequate soil pH, maintaining high levels of organic matter to cover exposed roots, and ensuring adequate nutrients are available to the tree. The following is an overview of the pests and diseases of macadamia in NSW and QLD.

## Macadamia pests

### Beetles (various)

Many beetles have become more prevalent within the macadamia industry. Since certain effective broad-spectrum pesticides are no longer available, these beetles have become a major concern around the world, particularly in the forestry industry. The generalised term 'beetle' represents a number of species that can damage macadamia in different ways. The NSW DPI is working towards obtaining an accurate morphological taxonomy 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.

*Hypothenemus eruditus* (predominantly NSW) and *H. seriatus* (predominantly Bundaberg) is a type of bark beetle that infects the nut in shell (Figure 52). Damage will be influenced by shell thickness, how long the fallen nuts have been left on the ground between harvests, and orchard cleanliness. Areas of Queensland have *H. birmanus*, which feeds on avocado trunks as well as macadamia.



Figure 52. *Hypothenemus seriatus* (bark beetle) damage, Bundaberg, QLD.

The ambrosia beetles (Figure 53) feed solely on fungus and use sick and dying trees to cultivate their fungal garden. Once the tunnel is created, they release the fungal spores into the xylem and feed there. This fungus can further contribute to plant dieback. In 2016-17, we saw a number of single trees being destroyed through lightning strike. Secondary to the lightning strike was the appearance of *Euwallacea*, *Cnestus solidis* and *Xyleborus ambrosia* (forms spaghetti-like masses).



Figure 53. An ambrosia beetle damaging a macadamia trunk.

The classic bark beetle, *Cryphalus subcompactus*, feeds on the cambium layer and can potentially ring-bark branches, causing significant dieback (Figure 54). In many cases, these trees are also suffering from other problems.



Figure 54. *Cryphalus subcompactus* damage on dead trees at Bundaberg, QLD.

The carpophilus beetle (Figure 55) 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 55. Adult carpophilus beetle.

Further reading on beetle taxonomy includes:

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

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

### Fruit spotting bug

Two types of fruit spotting bug (FSB) are known in Australia; *Amblypelta nitida* Stål (*A. nitida*; Figure 56) and *Amblypelta lutescens lutescens* (*A. lutescens*; Figure 57). Fruit spotting bug damages nuts from pea size until harvest. It has a strong preference for thin-shelled varieties such as A4 later in the season. Early damaged nuts fall, but later damaged nuts remain in the tree, although they will be unmarketable once sent to a processor. Reviewing factory results for insect damage is a good way to determine how much FSB pressure the orchard has had, and how effective controls were.

Monitoring is the key to FSB control. Using a pest scout early and regularly throughout the production season is recommended. Later in the season, trap hedges can be used to predict FSB movement. Fruit spotting bug form hotspots rather than being spread evenly through an orchard. Hotspots are often on the borders of the orchard, especially where it is next to a forest or a neglected orchard. Two or three well-timed chemical sprays can limit the damage from FSB.





Figure 56. *Amblypelta nitida* nymph.



Figure 57. *Amblypelta lutescens lutescens* nymph.

### Green vegetable bug

Green vegetable bug (*Nezara viridula*; Figure 58) adults and nymphs will feed on macadamia nuts at all stages and the damage can look similar to that caused by FSB. Damage from the green vegetable bug (GVB) does not reveal any symptoms on the shell and it is not until the kernel is extracted that the damage becomes apparent. Generally, the control program for FSB and banana spotting bug will also control GVB. Monitor for the full season. GVB eggs are frequently parasitised by a wasp, *Trissolus basalis* and the 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*.



Figure 58. Green vegetable bug.

### Kernel grub

Eggs are laid on the outside of the nut, then through an open micropyle, or from damage caused by boring insects such as nut borer or FSB, the grub is able to enter the nut (Figure 59). Kernel 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.

Unfortunately, the biological control for macadamia nut borer does not predate on kernel grub. Monitoring is the key to controlling this pest; using navel orange weevil traps can be helpful. No product is registered to control this pest, but as it coincides with FSB and MSW, it should be an off-target control.



Figure 59. Kernel grub.

## Leptocoris bug

*Leptocoris* species bugs (commonly called soapberry bugs, family Rhopalidae), are widely distributed throughout NSW and Queensland. They will leave their native host and attack cultivated plants like macadamia. The adult is reddish-brown, has a narrow body, is winged and about 12 mm long (Figure 60). Underneath the body is dull red with a dark green area in the middle of the abdomen. Legs and antennae are black.



Figure 60. *Leptocoris* sp. on a macadamia.

Ideally the native host plants such as foambark (*Jagera pseudorhus*) and golden rain tree (*Koelreuteria elegans*) will carry leptocoris while macadamia are susceptible. If however, the native host has no crop, leptocoris will seek out macadamia. An incursion will generally be a large aggregation of leptocoris onto the macadamia crop. Damage will be similar to fruit spotting bug and green vegetable bug damage.

There is currently no product registered for control of leptocoris in macadamia, but as it can coincide with FSB, it should be an off-target control.

## Macadamia flower caterpillar

The adult moth is most active during the main flowering period, i.e. July to October. Eggs are laid on flower buds and can be confused with immature scale insects. Larval feeding destroys buds and flowers, leaving the raceme covered by webbing. Flower caterpillars (Figure 61) can severely reduce a nut crop if not controlled. Macadamia lace bug spray treatments should also control flower caterpillar.



Figure 61. Flower eating caterpillar.

## Macadamia lace bug

There are three macadamia lace bug (MLB) species, with *Ulonemia decoris* found in NSW. MLB (Figure 62) damages the flowers, starting at the tips where they appear blackened (Figure 63). Left unchecked, the whole flower blackens and dies. Shaking the head of infested flowers reveals the lace bug. Nut set is prevented when lace bugs are not treated, causing > 90% production losses in later varieties.

Lace bug numbers build up over successive seasons as they overwinter on the bark of trees. Monitoring should start when the flower raceme is green and unopened, particularly if lace bug was a problem the previous year. Taking action early will mean less damage later.

Lace bug damage worsens when multiple flowerings extend throughout the season. Lace bug can trigger out of season flowering when the main flower set is destroyed. Ethrel has been used successfully to promote nut drop and return trees to synchronised flowering where out of season flowering has occurred.



Figure 62. Lace bug attacking macadamia florets.





Figure 63. Florets damaged by lace bug.

### Macadamia nut borer

The nut borer lays its eggs on the husk, and the larvae burrow through the nut shell to eat out the kernel (Figure 64). Nut borer continues to cause problems such as premature nut drop after shell hardening.

Cleaning up old nuts reduces carry over populations between seasons. Biocontrol with parasitoid wasps is effective against nut borer and best coordinated in an area wide approach.



Figure 64. Macadamia nut borer in developing nut.

### Macadamia seed weevil

Macadamia seed weevil (Figure 65) relies on out of season flowering and small soft-shell nuts for egg laying (Figure 66). Nuts might fall once the female has laid its egg inside the husk. These nuts should be mulched and destroyed to break the cycle. Hotspot areas should be noted and controlled. Ethrel has been used successfully to promote nut

drop and a return to synchronised flowering where out of season flowering has occurred.

For effective control of MSW, it is critical that match head sized nuts are treated with indoxacarb to prevent the seed weevil from egg laying.



Figure 65. Macadamia seed weevil.



Figure 66. Typical macadamia seed weevil egg lay signature triangle on a nut.

### Mites

Mite damage appears similar to thrips damage (Figure 67). Mites are becoming a problem due to overuse of 3A chemistry (synthetic pyrethroids including beta-cyfluthrin). Hot, dry weather is ideal for mite infestation. They are often seen on rows next to a dirt road. Ideally, introducing predatory mites would be a good control strategy, with consideration that later sprays for other pests would eliminate these biocontrol predators.





Figure 67. Broad mite on A16.

### Red-shouldered leaf beetle

Red-shouldered leaf beetles (*Monolepta australis*) are 6 mm long and yellow with a dark red band across the shoulder (Figure 68). The flaccid yellow eggs are small and oval. The larvae are white, slightly flattened with hard brown plates at both ends and can reach 10 mm long. The adult beetles will attack flowers and young leaves, often leaving just a network of veins. The leaves then desiccate and leave a scorched appearance to the shoot. These beetles are swarming pests, i.e. they will come in a swarm generally after a period of rain in spring and summer. Their duration is only a few days but their effect can be devastating, particularly for younger trees. Monitor frequently and if observed in large numbers, spray directly on the hotspot areas. Other hosts include legumes, avocado, corn, eucalypts, mango and kikuyu pastures.



Figure 68. Red-shouldered leaf beetle.

### Thrips

Thrips attack flowers, new flush (Figure 69) and nuts. Damaged nuts and flowers can appear bronzed. Leaf rosetting will appear on damaged new flush. Continual attacks on new flush is a concern as this leads to carbohydrate loss in the plant. It is important to protect at least one critical flush within the season. Yellow sticky traps, placed within the orchard, are useful for monitoring.



Figure 69. Witches broom growth created by thrips damage.

## Macadamia diseases

### Botrytis blight (grey mould)

Caused by the fungus *Botrytis cinerea*, botrytis blight (Figure 70) occurs mostly in mature flowers, especially during periods of wet, humid weather with temperatures between 18–22 °C. Diseased flowers appear dark brown and cluster together on the rachis with mycelial strands and greyish fungal spores, hence the grey mould appearance. Botrytis blight is more likely when flowering peaks coincide with optimal infection conditions. Dense canopies can increase botrytis blight risk, therefore ventilating the tree through opening up the canopy for better air movement will reduce infection risk.



Figure 70. Botrytis blight.

### Branch dieback

Branch dieback is caused by fungal species *Neofusicocum* and *Lasidipolodia*. Where a branch or part of the main trunk are affected, a point of gummosis (bleeding) occurs and the leaves above this point turn brown, with purplish blotches. The plant parts become 'blighted' and start to dieback (Figure 71). It is a slow process whereby the leaves can retain colour while the disease spreads down the branch.

A branch cross-section will show dark discoloration (often in wedge shape). The disease can appear where the tree has been stressed, such as water logging, extreme dry weather, or a poor growing environment. However, it can also appear in orchards with good soil, perhaps through physical damage to the wood.

Control by cutting out dead branches until you identify a clean cut cross sectional area; this should be covered with white paint.



Figure 71. Branch dieback in macadamia.

### Flower blight

Flower blight (Figure 72), also called dry flower or Raceme blight, is caused by fungal species in the *Pestalotiopsis* and *Neopestalotiopsis* complex. Not to be confused with botrytis blight, symptoms appear from green raceme through all flowering stages. Diseased flowers appear brown–dark brown and remain attached to the green rachis that later turns dark brown. The conditions necessary for infection and disease development are being investigated. Flower blight control might be required in orchards with recent history of occurrence. Cultural practices to prevent this disease are also being investigated, however, an open, well ventilated canopy is generally less prone to infection.

Ideally a prediction tool could be developed, given that there are certain climatic conditions involved and varietal susceptibilities.



Figure 72. Rachis dieback and early dry flower from tip.

### Husk spot

Husk spot is caused by the fungal pathogen *Pseudocercospora macadamiae*. Most varieties of macadamia are prone to husk spot (Figure 73), but it is more prevalent in specific varieties with sticktight husks. Rain splash easily spreads fungal spores from diseased sticktight to developing nuts in the tree canopy.

Cultural practices are important in limiting husk spot damage. Growing varieties that do not support sticktight 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 sticktight limits infection. Avoid moving husks with husk spot between farms as this can introduce husk spot to new orchards.





Figure 73. A husk spot-damaged nut.

### Phomopsis husk rot

Husk rot appears to be increasing in macadamia orchards. It is caused by the fungi *Diaporthe* spp., which are more prevalent after wet weather and warm temperatures. Husk rot symptoms include soft and spongy black lesions up to 10 mm diameter on the green fruit pericarp (Figure 74). The lesions can form greasy decay of the entire fruit pericarp. 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 could predispose the husk to infection or hail damage splits. Good orchard hygiene and insect control will help prevent husk rot.



Figure 74. Phomopsis husk rot.

### Phytophthora

Phytophthora disease (Figure 75) is caused by the fungus *Phytophthora cinnamomi*, a soil-borne water mould. Phytophthora will often appear at the bottom of slopes where water can pond, as well as on drainage lines and at the very tops of slopes where soil has been eroded.

Phytophthora appears to be worse where trees are suffering, e.g. nutritional or moisture stress. Generally, improving soil health and ensuring healthy root systems will help trees resist and recover from pest and diseases.



Figure 75. Ooze sap from a severe case of phytophthora. Photo: Olufemi Akinsanmi, University of Queensland.

## Other

### Lightning strike

Lightning strikes have been more frequent in the past five years. In nearly all cases the actual lightning strike has not been a direct hit, which would result in immediate damage to the tree, but rather a ground hit near the affected tree. Classic symptoms will not always be immediate, in most cases taking 3–6 months to show. However, if conditions are dry after the strike, symptoms can appear sooner. Classic symptoms are usually a centre tree with branch dieback throughout and the bordering trees having dieback on the side of the centre tree (Figure 76). In nearly all cases, bark beetle infests the trees at a later stage due to the reduced sap flow which



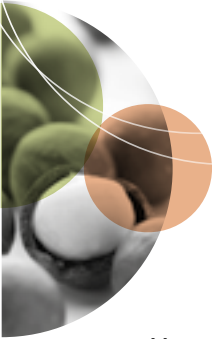
creates an opportunity for entry. Symptoms of Xyleborus bark beetle include spaghetti-like formations along the trunk (Figure 77).



Figure 76. Lightning strike in a macadamia orchard.



Figure 77. Symptoms of Xyleborus bark beetle include spaghetti-like formations along the trunk.



# Non-bearing and nursery trees

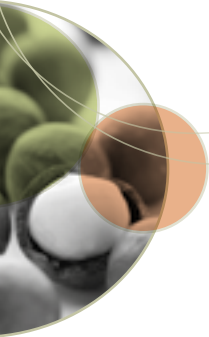
Young trees that are not bearing nuts (Figure 78) do not need the same intensive spray schedule as bearing trees, however, they still require continual monitoring for pests and disease. Below are the types of problems most likely to be encountered with young, non-bearing macadamia trees (Table 4).

Table 4. 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 is the most reliable means of preventing an attack.
Macadamia felted coccid	Can cause severe setback to developing young trees. Can enter through infested nursery stock. Heavy infestation will stunt and distort growth.	Inspect nursery stock thoroughly before planting into the orchard. Spray infested trees and look at promoting natural enemies.
Macadamia leafminer	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.
Macadamia twig girdler	Damage to branch forks and leaf whorls. Leaves skeletonised and webbed together.	Inspect and spray only affected plants. There are many natural enemies to twig girdler.
Phytophthora	Leaves will appear yellowish. In severe cases, ooze sap will exude from the trunk.	Ensure effective soil preparation before planting.
Red-shouldered leaf beetle	Generally will swarm orchard. The affected leaves will appear scorched, causing premature leaf drop and poor tree establishment.	Monitor trees, especially after rain in spring and summer. Treat only affected trees.
Scale	A number of scale can affect macadamia. Check nursery stock prior to planting. Look carefully along leaf stems and undersides. Also look for sooty mould.	Treat infected nursery stock but only treat infested plants as blanket spraying will reduce beneficials within the orchard.



Figure 78. Young trees require continual monitoring for pests and disease.



# Macadamia pesticides

Table 5. Pesticides – Chemicals registered<sup>1</sup> for managing macadamia pests and crop regulation in NSW.

For managing...	IPM rating	Pesticide common name	Comment <sup>2</sup>
Banana fruit caterpillar	3	Methomyl	Systemic and contact insecticide
Botrytis blight	1	Iprodione	Contact fungicide with protective and curative action
Broad mites, flat mites, flower thrips	3	Abamectin	Acaricide with stomach action and translaminar movement
	3	Acephate	Contact insecticide with stomach action
Fruit spotting bug	3	Acephate	Contact insecticide with stomach action
	3	Azinphos-methyl	Insecticide with contact and stomach action, moderate persistence
	3	Beta-cyfluthrin	Systemic and contact insecticide with stomach action
	3	Methidathion	Non-systemic insecticide, acaricide with contact and stomach action
	2	Sulfoxaflor	Systemic and contact insecticide with stomach action
	3	Trichlorfon	Insecticide and acaricide with contact and stomach action
Green vegetable bug	3	Trichlorfon	Insecticide and acaricide with contact and stomach action
Lace bug	3	Diazinon	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
	3	Pyrethrin	Contact insecticide with stomach action
	3	Trichlorfon	Insecticide and acaricide with contact and stomach action
Macadamia feltid coccid	3	Diazinon	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
	3	Methidathion	Non-systemic insecticide, acaricide with contact and stomach action
	1	Petroleum oil	Insecticide and acaricide with ovicidal activity
Macadamia flower caterpillar	3	Acephate	Contact insecticide with stomach action
	1	<i>Bacillus thuringiensis</i>	Stomach poison
	1	Methoxyfenozide	Insecticide that lethally accelerates the moulting process
	2	Spinetoram	Insecticide with contact action
	1	Tebufenozide	Insecticide that lethally creates unsuccessful moulting process
	3	Trichlorfon	Insecticide and acaricide with contact and stomach action
Macadamia husk rot	1	Copper as cuprous oxide	Protective fungicide
Macadamia husk spot	2	Carbendazim	Protective fungicide
	2	Copper hydroxide	Protective fungicide
	1	Difenoconazole	Systemic fungicide with protective and curative action
	1	Pyraclostrobin	Protective and curative fungicide



For managing...	IPM rating	Pesticide common name	Comment <sup>2</sup>
Macadamia leaf miner	③	Acephate	Contact insecticide with stomach action
	③	Diazinon	Non-systemic insecticide, acaricide with contact, stomach and respiratory action
	③	Methidathion	Non-systemic insecticide, acaricide with contact and stomach action
Macadamia mussel scale and white scale	③	Methidathion	Non-systemic insecticide, acaricide with contact and stomach action
Macadamia nut borer	③	Acephate	Contact insecticide with stomach action
	③	Azinphos-methyl	Insecticide with contact and stomach action, moderate persistence
	③	Beta-cyfluthrin	Systemic and contact insecticide with stomach action
	③	Carbaryl	Contact insecticide with stomach action
	③	Methidathion	Non-systemic insecticide, acaricide with contact and stomach action
	①	Methoxyfenozide	Insecticide that lethally accelerates the moulting process
	②	Spinetoram	Insecticide with contact action
	①	Tebufenozide	Insecticide that lethally creates unsuccessful moulting process
Macadamia seed weevil	③	Acephate	Contact insecticide with stomach action
	①	Indoxacarb	Contact insecticide with stomach action
Macadamia twig girdler	③	Carbaryl	Contact insecticide with stomach action
	③	Methidathion	Non-systemic insecticide, acaricide with contact and stomach action
	②	Spinetoram	Insecticide with contact action
Phomopsis husk rot	①	Copper as cuprous oxide	Protective fungicide
Phytophthora	①	Copper as cuprous oxide	Protective fungicide
	①	Metalaxyl	Protective fungicide with slow release activity
	②	Phosphorous acid	Systemic protective fungicide

<sup>1</sup> Source: InfoPest <http://infopest.com.au> and APVMA Pubcris <https://portal.apvma.gov.au/pubcris>

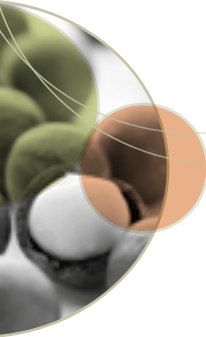
Coloured dots before the chemical common name denote that chemical's compatibility with IPM:

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

② 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.

③ indicates that this chemical is likely to have a negative off-target effect including on beneficial arthropods.

<sup>2</sup> Adapted from *The Pesticide Manual*, 15th Edition, British Crop Protection Council 2009.



# Pollination with native stingless bees

Chris Fuller; Kin Kin Native Bees



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

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

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

An inventory of insects that visited macadamia flowers at the different trial sites was compiled. Stingless bees and honeybees 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 79). When hives are kept on farm all year, growers should consider planting alternative forage for the bees to collect nectar and pollen from when the macadamias are not flowering (see Figure 80 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 cobbler's pegs or billy goat weed (also known as blue top) can provide pollen and nectar over winter when little else is available.

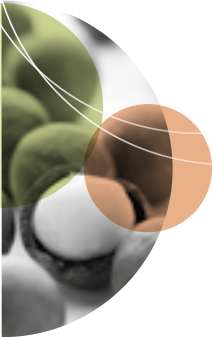


Figure 79. As hive numbers grow on orchards, stands are created for multiple hives. This stand will eventually house 20 hives.



Figure 80. 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](mailto:info@nativebees.com.au).



# Honeybee best practice management

Honeybees play a vital role in agriculture, pollinating a vast number of food crops including macadamia (Figure 81). Honeybees and other pollinating insects, birds and mammals are attracted to crops in bloom. Special consideration is required regarding the danger of pesticides to beehives in or near orchards. Legally, pesticides must not be applied during bloom when bees are foraging. Consequently, cooperation between growers, spray operators and beekeepers is necessary.



Figure 81. A honeybee 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 honeybees can easily fly two kilometres from their hive to forage on flowers. In addition to word of mouth and written pollination contracts, the BeeConnected app (Figure 82) is a valuable tool for farmers who would like to be informed of, and connected with, beekeepers near their farm, spray contractors providing the application of crop protection products and beekeepers who want to be informed of crop protection activities near their beehives (Figure 83). After registering as a user, farmers can input 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 82. The BeeConnected app. Source: CropLife Australia.

Farmers can also 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/>.

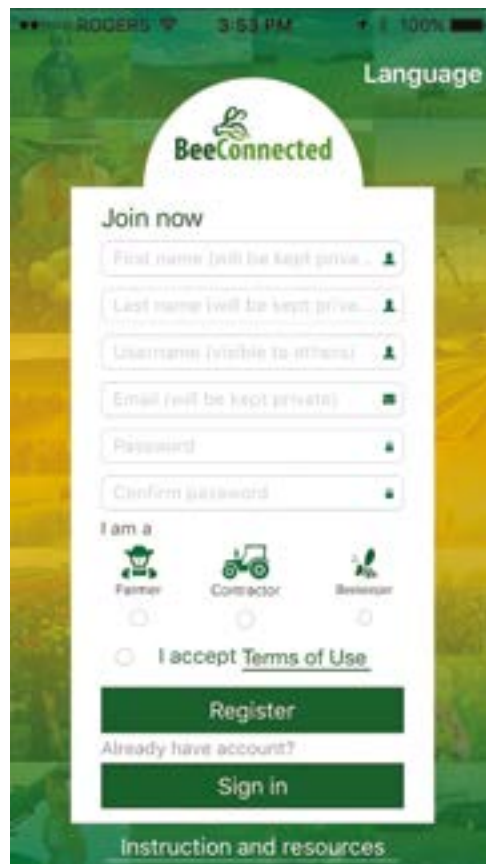


Figure 83. The BeeConnected app enables farmers, contractors and beekeepers to be connected. Source: CropLife Canada.



## Monitoring

### Pre-flowering

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

### During flowering

Ideally, if no pests were observed during pre-flower monitoring, then no further action should be required. However, if pests are identified through flowering, then a short acting chemical could be applied; but certain rules apply for bee protection including:

- always choose short acting chemicals
- finish your application at least 6 hours before bee activity begins
- spray late in the afternoon or evening, when bees are not foraging and pollen is not present
- turn off nozzles when near beehives, even if at night
- avoid directly spraying bees in flight (Figure 84) or beehives
- remove hives at nut set when no pollination is occurring (bees will travel long distances (8 km) to find alternate food sources and can come in contact with insecticide treated crops).

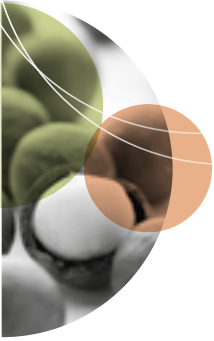
### Other ways to help bees

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.



Figure 84. A native bee in flight honing in on a macadamia flower. Photo: Chris Fuller.



# Biosecurity 'how to'

Rebekah Pierce; Plant Biosecurity Officer, NSW DPI



Primary producers across Australia should be very familiar with the term 'biosecurity' and its importance in protecting our Australian industries and environment. However, familiarity with the term does not necessarily provide you with the know-how for implementation on-farm. If you are keen to contribute to the biosecurity of your industry, but not exactly sure where to start or how to build upon your current practices, let us help you.

## Biosecurity – a legal responsibility

Biosecurity laws in NSW mean that everyone has an active role to play in managing biosecurity risks under their control. The introduction of the [General Biosecurity Duty](#) in NSW makes it more important than ever, to not only be aware of biosecurity risks to your property, but to take action to mitigate these risks.

## Farm biosecurity planning

Quick and simple measures can easily be built into everyday practices that will help protect your farm and your future from biosecurity threats.

A Farm Biosecurity Plan is an easy way to help you identify biosecurity risks on your farm and provide guidance on how to address them. By developing a biosecurity plan you will be able to identify and prioritise biosecurity practices relevant to your property.

One strategy might not suit all and the actual management practices you choose to use will vary depending on the parameters of your property(s).

To get started or to improve your own farm biosecurity plan visit [www.farmbiosecurity.com.au](http://www.farmbiosecurity.com.au).

There are a variety of tools and resources available to start building your plan today.

## On-farm biosecurity risks

Biosecurity risks on-farm can generally fall into one of six essential categories. Actions identified in your farm biosecurity plan will help to improve biosecurity in these fundamental areas.

1. **Farm inputs:** Anything moved onto your property can be a source of pests and diseases. Monitor plant materials that enter the property as well as sources of water and fertilisers.
2. **Farm outputs:** Responsibility for biosecurity does not end when the produce leaves the farm gate. The measures in place on your property support biosecurity in your region.
3. **People, vehicles and equipment:** If it can move, it can carry diseases, pests and weeds. Hence people, vehicles and equipment pose a high biosecurity risk and should be managed accordingly. Biosecurity signage alerts visitors to protect your property (Figure 85).
4. **Production practices:** Good on-farm hygiene reduces the risk of spreading pests and diseases. Implementing simple hygiene practices for water, product packaging, storage facilities, waste materials and plant propagation activities is essential.
5. **Weeds:** These are a continuous biosecurity threat. Ensure you monitor and manage these widespread risks to your business.
6. **Train, plan and record:** Ensure staff are well trained, that you can trace where plants have come from and where they go, and keep records of purchases, sales and movements.



Figure 85. Biosecurity signage situated on-farm alerts visitors to protect your property.

# UNWANTED: TREE NUT PESTS

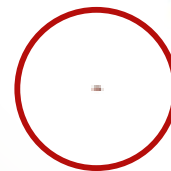
## TROPICAL NUT BORER

**HIGH RISK TO:  
MACADAMIAS**

Tropical nut borer (*Hypothenemus obscurus*) is an exotic plant pest not present in Australia.

This beetle bores 0.5 mm holes into macadamia husks and tunnels through the husk, shell and edges of the kernel.

Up to 190 borers have been found in a single nut. A heavy infestation of borers can damage up to 60% of the crop.



Actual size

Adult tropical nut borer (1.5 mm)  
Courtesy of Pest and Diseases Image Library, Bugwood.org



0.5 mm holes bored into macadamia husk  
Courtesy of Vincent P. Jones



Tunnelling of tropical nut borers inside a macadamia nut  
Courtesy of C. Maddox, NSW Department of Primary Industries

### Damage

- Numerous perfectly round holes (about 0.5mm diameter) in the husk
- Extensive tunnelling throughout the husk, shell and kernel
- Kernel is not consumed but is damaged and open to secondary infection

### Identification

- Adult borers are 1.5 mm in size
- Numerous borers at all life stages present beneath the husk

IF YOU SUSPECT TROPICAL NUT BORER  
CALL THE EXOTIC PLANT PEST HOTLINE

**1800 084 881**

OR EMAIL PHOTOS AND A DESCRIPTION TO  
**biosecurity@dpi.nsw.gov.au**



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# UNWANTED: TREE NUT PESTS

## BACTERIAL LEAF SCORCH

Bacterial leaf scorch (*Xylella fastidiosa*) is an exotic plant disease **not present in Australia**.

Also known as 'almond leaf scorch' or 'golden death'.

Disease survives in sap and is **spread** between plants by sap feeding insects and grafting.

Be on the look out for symptoms on trees as well as the exotic insect vector **glassy winged sharpshooter**, also **not present in Australia**.



**HIGH RISK TO:  
ALMONDS, PECANS  
AND MACADAMIAS**

Bacterial scorch of an almond leaf showing the yellow band between healthy and dead tissue

Courtesy of Sam Livingston, Department of Plant Pathology, California



Glassy winged sharpshooter – insect vector  
(12-14 mm)

Courtesy of Roy Niswanger, Texas



Infected almond tree

Courtesy of Franz Niederholzer, UC Cooperative Extension



Scorching of leaves

Courtesy of Sam Livingston, Department of Plant Pathology, California

## Damage

- Delayed growth and flowering
- Stunted growth
- Reduced productivity
- May appear on one branch before spreading throughout the tree
- Eventual tree death

IF YOU SUSPECT BACTERIAL LEAF SCORCH  
CALL THE EXOTIC PLANT PEST HOTLINE

**1800 084 881**

OR EMAIL PHOTOS AND A DESCRIPTION TO  
**biosecurity@dpi.nsw.gov.au**

## Identification

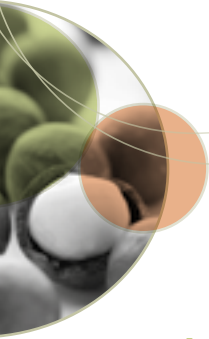
- Leaf margins appear scorched or burnt
- Golden yellow band between burnt edge and green leaf tissue
- Scorching usually progresses from leaf tip to base
- Infected leaves remain attached to tree
- Unlike salt burn, scorch symptoms are not uniform along the leaf margin



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AUSTRALIAN MACADAMIA  
SOCIETY



# Managing spray drift

## What is spray drift?

Spray drift is the airborne movement of chemicals with the potential to cause injury or damage to humans, plants, animals, the environment or property, onto a non-target area. All pesticides are capable of drift. People have a moral and legal responsibility to prevent pesticides from drifting and contaminating or damaging neighbours' crops and sensitive vegetation areas. In areas where a range of agricultural enterprises co-exist, conflicts can arise, particularly from pesticide use. Some labels now carry spray drift management instructions including buffer zones. Anyone using any chemicals must read and follow all label instructions.

## Types of drift

- **Droplet drift** is the easiest to control because, under good spraying conditions, droplets are carried down by air turbulence and gravity to collect on plant surfaces. Droplet drift is the most common cause of off-target damage from pesticide application.
- **Particle drift** occurs when water and other pesticide carriers evaporate quickly from the droplet leaving tiny particles of concentrated pesticide. Particle drift has damaged susceptible crops up to 30 km from the source.
- **Vapour drift** is confined to volatile herbicides such as 2,4-D ester. Vapours can arise directly from the spray or evaporation from the sprayed surfaces. Using 2,4-D ester in summer can lead to vapour drift damage to highly susceptible crops such as tomatoes, sunflowers, soybeans, cotton and grapes. This can occur hours after the herbicide has been applied.

Vapours and minute particles float in the airstream and are poorly collected on catching surfaces. They can be carried for many kilometres in thermal updraughts before being deposited.

## Factors affecting chemical spray drift

Any herbicide, fungicide or insecticide can drift. The drift hazard, or off-target potential of a chemical in a particular situation depends on the following factors:

- **Volatility of the formulation being applied:** Volatility refers to the likelihood that the chemical will evaporate and become a gas. Esters volatilise (evaporate) more readily than amine formulations. Many ester formulations are highly volatile when compared with the non-volatile amine, sodium salt and acid formulations. Some low volatile ester formulations can contain high volatile esters, so caution should be exercised when using these products.
- **Proximity of crops** susceptible to the chemical being applied, and their growth stage.
- **Application method and equipment used:**
  - aerial application releases spray at ~3 m above the target and uses relatively low application volumes
  - ground rigs have lower release heights and generally higher application volumes, with a range of nozzle types
  - misters produce large numbers of very fine droplets that use wind to carry them to their target.
- **Amount of active ingredient applied:** The more applied per hectare the greater amount available to drift or volatilise.
- **Efficiency of droplet capture:** Bare soil does not have anything to catch drifting droplets compared with crops, erect pasture species and standing stubbles.
- **Weather conditions** during and shortly after application.

**Sensitive crops can be up to 10,000 times more susceptible than the crop being sprayed. Even small quantities of drifting herbicide can cause severe damage to highly sensitive plants.**

## Minimising spray drift

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

### Before spraying

- Always check for susceptible crops and sensitive areas such as houses, schools and riparian areas.
- Notify neighbours of your spraying intentions.

- Under the Records Regulation of the [Pesticides Act](#) it is essential that weather and relevant spray details are recorded. An example spray record form is provided in Table 6.

### **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 type and location of crops to be grown, 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.

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

### **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
- 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
- minimise spray release height (lowest possible boom height)
- 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, e.g. keep a boom width from the downwind edge of the field. Where buffer zones are mentioned on the label, follow label instructions
- if sensitive crops are in the area, use the least damaging herbicide.

### **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 coverage of the spray. 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:** Operate within the pressure range recommended by the nozzle manufacturer. Fine droplet production increases with increased operating pressure. Lower volumes, such as 30–40 L/ha, 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.

## 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 the summer months.

**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 86) 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.

**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 (80–120 L/ha). 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](http://www.bom.gov.au/lam/glossary/beaufort.shtml): [www.bom.gov.au/lam/glossary/beaufort.shtml](http://www.bom.gov.au/lam/glossary/beaufort.shtml).

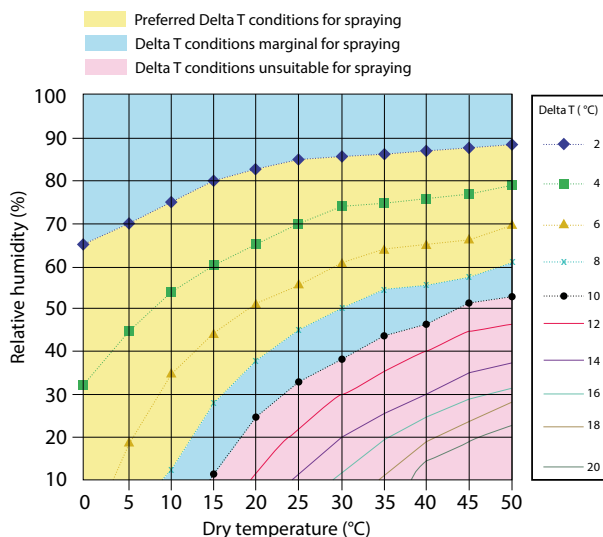


Figure 86. Delta T conditions for spraying. Source: Bureau of Meteorology.

## 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 87). This is the opposite (inverse) of the normal temperature decrease with height.

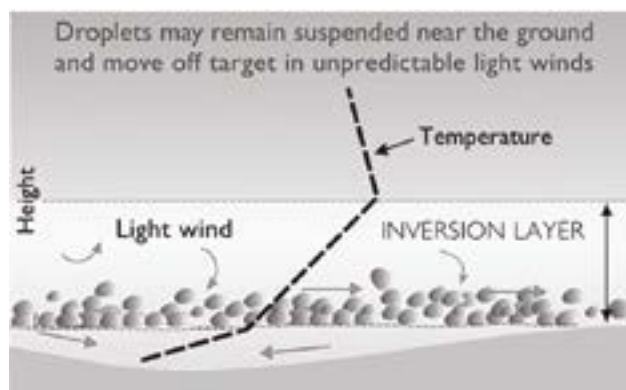


Figure 87. Surface inversion layer. Source: Bureau of Meteorology.

### Hazards of surface inversions

Surface inversions strongly suppress airborne pesticide (and similar) dispersion. Surface inversions can cause airborne pesticides to:

- remain at high concentrations for long periods over and close to the target
- travel close to the surface for many kilometres in light breezes
- move downslope and concentrate into low lying regions
- be transported, often in unpredictable directions.

### **Radiation inversions – the most hazardous**

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

Inversions caused by radiation cooling are the most hazardous to pesticide applications because they can severely restrict dispersion and promote transport (drift) of the airborne pesticides at high concentrations.

Radiation inversions occur most nights. Only when winds are strong enough to completely mix the lowest layers of the atmosphere, or cloud cover severely restricts surface heating and cooling, is there a chance that surface radiation inversions will not form overnight.

Radiation inversions also form over sloping terrain when the air in contact with the ground is cooled by terrestrial radiation. The cooled layer remains shallow, often only 2–10 m deep, because gravity continually pulls it down causing drainage winds. Drainage wind advection (horizontal convection) of cool air away from the slope and over or into lower lying regions can initiate a drainage inversion or intensify an existing radiation inversion. Once formed, drainage inversions have similar attributes to radiation inversions. Drainage winds can transport airborne pesticides long distances downhill, over flat terrain toward the lowest lying regions and into valleys.

Radiation and drainage inversions typically begin in the evening at about sunset as the ground surface cools and the air in contact with the surface loses sufficient heat by conduction to become colder than the air immediately above. With continued overnight cooling, inversions usually intensify and deepen up to the time of the overnight minimum temperature. Radiation and drainage inversions have caused substantial damage in northern river valleys to cotton crops and to vineyards in the Murray Valley.

### **How to anticipate and recognise radiation inversions**

The potential for inversions to occur and to adversely hold high concentrations of airborne pesticides near the surface should always be

anticipated between sunset and up to an hour or two after sunrise; unless one or more of the following conditions occur:

- there is continuous overcast, low, heavy cloud
- there is continuous rain
- wind speed remains above 11 km/h for the whole period between sunset and sunrise. However, be aware that established inversions can sometimes still occur when winds are in excess of 11 km/h.

For more information on inversions, refer to:

- the Cotton Map [factsheet on temperature inversions](http://www.cottonmap.com.au/Content/documents/Temperature%20Inversions.pdf) ([www.cottonmap.com.au/Content/documents/Temperature%20Inversions.pdf](http://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) (<https://grdc.com.au/Resources/Factsheets/2014/08/Surface-temperature-inversions-and-spraying>)
- the Bureau of Meteorology (BOM) factsheet: [Weather for pesticide spraying](http://www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf) ([www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf](http://www.bom.gov.au/info/leaflets/Pesticide-Spraying.pdf)).

**Never spray during a surface inversion.**

### **Where to find helpful meteorological information**

Ideally, real time data should be collected in the paddock when spraying. This can be done with handheld units, on-farm weather stations or mobile phone apps that measure temperature, Delta T and wind speed.

### **Hourly data**

Forecasts are available from a number of websites. Hourly data from the [Bureau of Meteorology](http://www.bom.gov.au) (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 kilometres away from the actual spray site, the information might not be as accurate as required. Therefore growers would benefit from investing in a weather station (Figure 88) on farm (around \$3,000) as this data will be more accurate and thus assist with spraying decisions.

As well as a weather station, another measure to prevent spray drift would be to install wind socks throughout the orchard. You can take a video (on your mobile) of the current conditions and refer the video to the Beaufort wind scale. This will give

you an accurate account of conditions throughout the orchard on the day of spraying. To see the [Beaufort scale](http://www.bom.gov.au/lam/glossary/beaufort.shtml), 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](http://www.weatherzone.com.au/models/meteogramdrill.jsp) ([www.weatherzone.com.au/models/meteogramdrill.jsp](http://www.weatherzone.com.au/models/meteogramdrill.jsp)), or [Spraywise decisions](http://www.spraywisedecisions.com.au) ([www.spraywisedecisions.com.au](http://www.spraywisedecisions.com.au)). Meteograms™ provide seven-day forecasts of:

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

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

### Further information

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

- [Practical tips for spraying](https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/08/practical-tips-for-spraying) (<https://grdc.com.au/resources-and-publications/all-publications/factsheets/2014/08/practical-tips-for-spraying>)
- [Weather essentials for pesticide application](https://grdc.com.au/__data/assets/pdf_file/0024/248181/GRDC-Weather-Essentials-for-Pesticide-Application-2017.pdf) ([https://grdc.com.au/\\_\\_data/assets/pdf\\_file/0024/248181/GRDC-Weather-Essentials-for-Pesticide-Application-2017.pdf](https://grdc.com.au/__data/assets/pdf_file/0024/248181/GRDC-Weather-Essentials-for-Pesticide-Application-2017.pdf))
- [Spray drift management principles, strategies and supporting information, 2002, CSIRO Publishing](http://www.publish.csiro.au/book/3452) ([www.publish.csiro.au/book/3452](http://www.publish.csiro.au/book/3452))
- [Reducing herbicide spray drift](https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift) (<https://www.dpi.nsw.gov.au/biosecurity/weeds/weed-control/herbicides/spray-drift>).



Figure 88. A weather station in a macadamia orchard. Photo: Graham Wessling.





# Managing your legal responsibilities when applying pesticides

## The Pesticides Act

The [Pesticides Act 1999](#), administered by the Environment Protection Authority (EPA), is the primary legislative instrument controlling pesticide use in NSW. The underlying principle of the *Pesticides Act* is that pesticides must only be used for the purpose described on the product label and all the instructions on the label must be followed. Consequently, all label directions must be read by, or explained to, the user before using the pesticide.

All pesticide users should take reasonable care to protect the health of themselves and others when using a pesticide. This includes preventing damage occurring from using a pesticide, such as off-target drift onto sensitive areas, or harm to endangered and protected species.

A Regulation was gazetted in 2017 renewing the requirement for all commercial pesticide users to keep records of their pesticide application. Records must be made within 24 hours of application, be made in legible English, and kept for three years. While no set form has to be used, records must include the following:

- full product name
- description of the crop or situation
- application rate and quantity applied
- description of the equipment used
- address of the property, identification of the area treated and order of paddocks treated
- date and time of the application (including start and finish)
- name, address, and contact details of the applicator and the employer (or owner if an employee or contractor is the applicator)
- estimated wind speed and direction (including any significant changes during spraying)
- other weather conditions specified on the label as being relevant (e.g. temperature, rainfall, relative humidity).

An example spray record from SMARTtrain is provided in Table 6.

The [SMARTtrain spray record book](#) is available from NSW DPI (\$10.00). Call 1800 138 351 or visit [www.smarttrain.com.au/resources](http://www.smarttrain.com.au/resources) to order your copy. More information on your spray record responsibilities is available on the [Environment Protection Authority](#) website ([www.epa.nsw.gov.au/pesticides/pestrecords.htm](http://www.epa.nsw.gov.au/pesticides/pestrecords.htm)) as well as [spray record form](#) ([www.epa.nsw.gov.au/resources/pesticides/130814PestFmEg.pdf](http://www.epa.nsw.gov.au/resources/pesticides/130814PestFmEg.pdf)) you can download and use. Sequentially numbered forms are required for those producers in QA schemes where spray records are mandatory.

The 2017 Regulation requires all commercial pesticide users need to be trained in applying pesticides. Trained aerial applicators, pest control operators and fumigators are recognised as satisfying the requirements of the Regulation. Other commercial users must have a prescribed qualification. Only domestic use, such as home gardens, is excluded, provided the pesticide is a specific domestic/home garden product.

Covered by the Regulation is pest control by or on:

- public authorities, e.g. State Rail
- golf courses, sporting fields and bowling greens
- agricultural, horticultural, aquacultural and forestry operations
- businesses, educational institutions and hospitals.

The minimum prescribed training qualification is the AQF2 unit of competency, 'Apply chemicals under supervision', although owner-applicators are encouraged to train and be assessed in the two higher AQF3 competencies, 'Prepare and apply chemicals' and 'Transport, handle and store chemicals'.

Growers are recommended to undertake the SMARTtrain course Chemical Application, or the standard ChemCert course, both of which cover the higher AQF3 competencies. For growers with literacy and/or numeracy problems, the lower level AQF2 competency will provide a minimum qualification that satisfies the Regulation.

Table 6. 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 °C	Relative humidity%	Delta T	Wind direction from	Wind speed	Variability eg. 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.

## Hazardous chemicals legislation

Many registered pesticides are classified as hazardous chemicals. The [Work Health and Safety Act 2011](#) and the Hazardous Chemical section of the [Work Health and Safety Regulation 2017](#) detail the legal requirements of suppliers, workers and persons conducting businesses or undertakings for managing hazardous chemicals. The Act and Regulation are intended to protect workers from both the short- and long-term health effects of exposure to hazardous chemicals and to improve current health and safety practices by:

- providing health and safety information to workers (including a list of all hazardous chemicals and an SDS (Safety Data Sheet) for each hazardous chemical)
- consulting with workers
- training workers
- minimising the risks from exposure to hazardous chemicals
- health surveillance (if warranted by the risk assessment in respect of organophosphates).

Storage limits have changed. Premises storing large quantities require both the storage shed and the entrances to the premises to have placards. If very large quantities are stored (which would be rare on-farm), a manifest, site plan and written emergency plan are required. WorkCover NSW's [Code of practice for the safe use and storage of chemicals](#) explains the specific quantities of the various chemicals.

WorkCover NSW's [Code of practice for the safe use and storage of chemicals](#) (including pesticides and herbicides) in agriculture is an approved industry code of practice and provides practical guidance for farm chemical users to comply with the legislation.

## Pesticides and worker safety

Most registered pesticides pose some health risk to those who use them or are exposed to them. Pesticides can have both immediate (acute) and long term (chronic) effects.

### Acute toxicity

The acute or immediate toxicity of a farm chemical is reflected in the Poisons Schedule or poison warnings that appear on the pesticide label. The acute toxicity is assessed in terms of the potential of the active ingredient to poison an individual by the route of exposure that is most lethal, e.g. oral ingestion.

## Poisons Schedule

Pesticides are classified into categories based on their acute health hazard to the user. Each schedule has a corresponding signal heading that appears in large, contrasting lettering on the pesticide product label.

The Poisons Schedule (Table 7) will largely determine the Safety Directions and First Aid Instructions that appear on the label. The Safety Directions specify the personal protective equipment (PPE) to be worn and the safety precautions to be taken, e.g. 'do not inhale spray mist'. The First Aid Instructions specify what to do if a poisoning occurs. Safety Directions and First Aid Instructions can vary for different formulations of the same pesticides.

Note: Before opening and using any farm chemical, consult the label and the Safety Data Sheet (SDS) for specific safety directions. The Hazardous Substances Section of the [Work Health and Safety Act 2011](#) requires resellers to provide end users with an SDS.

**If you suspect a poisoning, contact the Poisons Information Centre on 131 126 (24 hours).**

## Anticholinesterase compounds

Insecticides are generally more acutely toxic than herbicides or fungicides. This is because most insecticides act on the central nervous system (CNS). Organophosphates (OPs) are the most acutely toxic insecticides because they depress cholinesterase enzyme action in the CNS. The carbamate group of insecticides also depresses cholinesterase, but the health effects are less severe because the enzyme regenerates rapidly by itself following carbamate exposure. Nevertheless, carbamates (such as aldicarb) have extremely high acute toxicity and are capable of causing severe illness and death.

Products that depress cholinesterase are especially hazardous, not only because of their effect on the CNS, but because they are readily absorbed through the skin. These products must be identified by the words 'an anticholinesterase compound' underneath the name of the active ingredient on the product label.

The Safety Directions on the label will include advice on safe work practices and the PPE specific to anticholinesterase products. Where work practices and application technology create a high risk of exposure to anticholinesterase compounds, it might be necessary to monitor the health of those workers who are exposed.



Additional details on biological monitoring and health surveillance are included in the [Code of practice for the safe use and storage of chemicals](#) (including pesticides and herbicides) published by the NSW WorkCover Authority.

### **Solvents and distillates**

In addition to the active ingredient, pesticide formulations contain surfactants and carriers that can also be toxic. Many liquid pesticide formulations are based upon petroleum distillates (e.g. xylene) or organic solvents. These are corrosive to the skin and eyes, and their vapours can affect the brain if inhaled. The exposure risk with these is highest when handling the concentrate, which is why pesticide labels often carry warnings to avoid inhaling the vapours and avoiding splashes to the skin and eyes.

### **Routes of exposure**

The most hazardous route of exposure for insecticides is dermal absorption (through the skin) and the most hazardous phase of the application is mixing and loading the concentrated product.

Excepting fumigants, the inhalation risk for most pesticides and application technology is low. Nevertheless, a respirator might be required when mixing, loading or applying pesticides:

- in an enclosed space (such as a shed)
- if the pesticide is highly volatile and likely to be breathed in as a vapour (such as 2,4-D ester)
- if application carries the risk of inhaling the spray mist (such as having to turn back into the drift in crops with short rows).

Ingestion or swallowing are a risk for applicators who do not wash their hands before eating and drinking, or who smoke during application. Unsecured storage is high risk to children who could accidentally ingest a pesticide.

Many pesticide formulations can have direct or topical effects on the skin and eyes. These effects are often unrelated to whether or not the chemical is acutely toxic. Some pesticides might have low acute toxicity but severe topical effects. For example, glyphosate has very low acute toxicity but is irritating to the skin and eyes. Warnings regarding skin and eye irritation and other topical effects are usually found on the product label under 'Safety Directions'.

Table 7. Poisons Schedule.

<b>Schedule 1</b>	This Schedule is intentionally blank.
<b>Schedule 2</b>	Pharmacy Medicine – substances, the safe use of which may require advice from a pharmacist and which should be available from a pharmacy or, where a pharmacy service is not available, from a licensed person.
<b>Schedule 3</b>	Pharmacist Only Medicine – substances, the safe use of which requires professional advice but which should be available to the public from a pharmacist without a prescription.
<b>Schedule 4</b>	Prescription Only Medicine or Prescription Animal Remedy – substances, the use or supply of which should be by or on the order of persons permitted by State or Territory legislation to prescribe and should be available from a pharmacist on prescription.
<b>Schedule 5</b>	Caution – substances with a low potential for causing harm, the extent of which can be reduced through the use of appropriate packaging with simple warnings and safety directions on the label.
<b>Schedule 6</b>	Poison – substances with a moderate potential for causing harm, the extent of which can be reduced through the use of distinctive packaging with strong warnings and safety directions on the label.
<b>Schedule 7</b>	Dangerous Poison – substances with a high potential for causing harm at low exposure and which require special precautions during manufacture, handling or use. These poisons should be available only to specialised or authorised users who have the skills necessary to handle them safely. Special regulations restricting their availability, possession, storage or use may apply.
<b>Schedule 8</b>	Controlled Drug – substances which should be available for use but require restriction of manufacture, supply, distribution, possession and use to reduce abuse, misuse and physical or psychological dependence.
<b>Schedule 9</b>	Prohibited Substance – substances which may be abused or misused, the manufacture, possession, sale or use of which should be prohibited by law except when required for medical or scientific research, or for analytical, teaching or training purposes with approval of Commonwealth and/or State or Territory Health Authorities.
<b>Schedule 10</b>	Substances of such danger to health as to warrant prohibition of sale, supply and use – substances which are prohibited for the purpose or purposes listed for each poison.

Source: Therapeutic goods administration [www.tga.gov.au/scheduling-basics](http://www.tga.gov.au/scheduling-basics).

### **Re-entry intervals**

The re-entry interval is the time that must elapse between applying the pesticide and re-entry into the sprayed crop, unless the person is wearing the PPE specified for re-entry on the label. The reason for setting a re-entry interval is that pesticides sometimes remain on crops in the form of foliar aerosol particles. These residues can be dislodged by contact with the crop and absorbed through the skin by those working in the crop.

Re-entry intervals only appear on the label of a small number of pesticide products. If a re-entry period is not specified on the label, the rule of thumb is to wait 24 hours after application or until the crop is dry, whichever is longer. Crops should never be re-entered when wet from dew or light rain, irrespective of the time elapsed, unless appropriate PPE is worn.

### **Chronic toxicity**

The effects of long-term exposure to small doses of chemical is known as chronic toxicity. Some of these effects include:

#### **Neurotoxic effects**

Organophosphate pesticides are suspected of having long-term effects on the CNS. To date, these effects are slight and have only been detected in a tiny proportion of those exposed. It is important to note that all effects, both acute and chronic, are dose related. This means that adherence to label directions to control acute exposure will similarly control chronic exposure.

#### **Reproductive effects**

Some pesticides are suspected of being foetotoxic (fatal to foetuses) and teratogenic (causing birth defects) based on laboratory studies involving animals. However, there is little evidence that pesticides can affect human reproduction or the health of the unborn foetus at the levels of pesticide exposure that most of the population experiences through their food supply.

The Australian College of Occupational Medicine recommends that women who are pregnant or likely to become pregnant protect themselves against chemical exposures that can have adverse reproductive effects. Pregnant women should not be involved in spraying agricultural chemicals or working in recently sprayed crops. Advice on pregnancy and occupational exposure to pesticides is available from medical practitioners accredited by WorkCover NSW in occupational health.

### **Cancer and pesticides**

Despite widespread public suspicion of pesticides as cancer-causing agents, evidence is lacking to implicate all but a few. As most cancers are caused by a number of factors, it is extremely difficult to determine whether or not a particular cancer resulted specifically from pesticide exposure or other factors. Apart from the organochlorines and arsenic, which are now banned, only chlorothalonil, dichlorvos and amitrole have been classified as possible (less weight of evidence than probable) carcinogens by the World Health Organisation.

### **Endocrine disruption**

The endocrine system is made up of many glands in the body and the hormones they secrete. These hormones guide the development, growth, reproduction and behaviour of all animals including humans. Some of the glands include females' ovaries and males' testes. Endocrine disruptors are chemicals that interfere with the normal functioning of the endocrine system. Large, acute exposure to some chemicals, such as the organochlorines, has caused adverse effects to the endocrine systems of animals.

**The best way to manage health risks from chronic pesticide use is to reduce exposure by following all the directions on pesticide labels.**

### **Pesticides and the environment**

Most insecticides are toxic to aquatic organisms, bees and birds. Fungicides and herbicides are relatively safe to bees in terms of their active ingredients, but their carriers and surfactants can be toxic. The risks that a particular product poses to the environment are reflected in statements on the label under headings such as 'Protecting wildlife, fish, crustacea and the environment'.

### **Protecting the aquatic environment**

The risk to aquatic organisms can be managed by:

- preventing drift into surface waters during application
- locating the mixing, loading and decontaminating facilities away from surface waters and providing these facilities with bunding and sumps to prevent movement of either concentrate or rinsate into surface waters
- installing valves that prevent back-flow when filling spray tanks from surface waters and in suction lines for chemigation systems which draw directly from surface waters

- avoiding aerial spraying areas under irrigation
- building sufficient on-farm storage capacity (including provision for storm run-off) to contain pesticide contaminated tail water from irrigation
- spraying in an upstream direction when it is necessary to spray near surface waters; this will reduce the maximum concentration at any one point in the watercourse
- using only registered products to control aquatic weeds, e.g. Roundup® Biactive rather than Roundup®
- avoid disposing of used containers in surface waters, on flood plains or river catchments.

### Protecting bees

Many pesticides are toxic to bees and can damage the productivity of hives if bees or the hives are contaminated. Some pesticides are particularly toxic to bees and these pesticides will have the following statement on the label:

**Dangerous to bees. Do not spray any plants in flower while bees are foraging.**

The pesticide risk to bees can be reduced by:

- only applying pesticides toxic to bees when bees are not foraging i.e. early in the morning or later in the evening
- notifying the apiarist when beehives are in the vicinity of crops to be sprayed to allow them time to remove the hives before spraying
- where possible, using emulsifiable concentrate (EC) and granular formulations in preference to wettable powders, which are particularly hazardous to bees. Micro-encapsulated formulations are particularly hazardous to bees because of their persistence in the environment and because bees transport the micro-capsules back to the hive along with pollen
- using ground rigs rather than aerial application to minimise drift, especially when crops and adjacent plants are flowering
- avoiding drift and surface water contamination where bees drink (see Protecting the aquatic environment).

### Protecting birds

Organophosphate and carbamate insecticides can be particularly toxic to birds, especially in granular formulations. Bird kills from diazinon and carbofuran have been well documented in Australia and overseas. Insecticidal seed dressings can pose similar risks. Just a few seeds or granules can be lethal to birds. Spillages can be very hazardous to birds as they can easily ingest a toxic dose from a small area.

Risks to birds from granular products can be managed by:

- ensuring complete incorporation beneath the soil, particularly at row ends where spillage can occur
- immediately cleaning up any spillage, however small.

Bait materials to control rodents or soil insect pests can also be hazardous to birds, either through direct bait consumption or from feeding on bait-affected animals or pests. The risks to birds from baits can be managed by:

- ensuring even bait distribution, with no locally high concentrations
- not baiting over bare ground or in more open situations, such as near crop perimeters, where the baits are more likely to be seen
- not baiting near bird habitats such as remnant native vegetation
- using bait stations, which prevent access by birds, particularly near bird habitats
- only baiting where pest pressure is high
- baiting late in the evening when birds have finished feeding
- promptly collecting and burying rodent carcasses where these occur in open situations
- immediately cleaning up any spillage, however small.

Insecticide sprays can also be hazardous to birds, either because of direct contact with the sprayed chemical, or by feeding on sprayed insect pests or crops. Even where birds are not killed, they can be sufficiently affected to make them more vulnerable to predation. Contaminated seed and insects collected from sprayed fields by parent birds can also be lethal to young chicks still in the nest. Risks to feeding and nesting birds can be managed by:

- minimising drift into remnant vegetation, wildlife corridors, nesting sites or other bird habitats
- actively discouraging birds from feeding in crops that are to be sprayed
- spraying late in the day when birds have finished feeding
- using only low-toxicity chemicals when large concentrations of birds are nesting nearby.

**The best way to manage any long-term adverse environmental risks is to follow the protection statements on labels, minimise spray drift, and to dispose of chemical containers and waste in accordance with label directions and codes of practice.**



## Managing residues resulting from pesticide application

### Withholding periods

The withholding period (WHP) is the minimum time that must elapse between the last application of a pesticide and harvest. The purpose of the WHP is to avoid agricultural chemical residues and their metabolites exceeding maximum residue limits (MRLs) in raw agricultural commodities and foods for consumption by humans and animals.

Pesticides used on crops can have WHPs for both harvest and grazing. Harvest WHPs can vary with formulation (e.g. EC or ultra-low volume (ULV)), rate (which can vary with the pest controlled), and whether or not the crop can be harvested green or dry. Grazing WHPs can vary depending upon whether or not the crop is grazed or cut for stock food before or after harvest.

WHPs are specific to products and use patterns, i.e. to chemical, crop and pest. Not all labels pick up all registered use patterns. Consequently, not all labels contain the same information on WHPs. Different labels can have different WHPs for the same use pattern.

On some labels the WHP will be within the tables giving directions for use; on other labels the WHP appears separately below the directions for use. Where appropriate, growers are advised to contact the chemical manufacturer for advice on managing chemical residues in the crop or stock.

**Where no WHP is given on the label, do not assume it is zero. If there is no WHP, the label will contain a statement to the effect that no WHP is necessary if label directions are followed.**

### Export requirements

Some export markets either have a lower MRL than Australia or no MRL. Exporters need to identify these requirements by checking directly with the export market. Longer WHPs might be required for some markets to allow the residue to decay to the required level. It is up to the individual producer to be aware of export chemical residue requirements and to amend chemical management practices accordingly.

## Permits

A permit is issued for a limited use and a limited time if the Australian Pesticides and Veterinary Medicines Authority (APVMA) is convinced that such a use is justified. Justification is usually on the grounds that an already registered suitable alternative is not available, and that safety and residue concerns are adequately addressed.

It is possible that permits will be granted during the growing season. Growers wishing to use a chemical in the manner approved under a permit should obtain a copy of the relevant permit from the APVMA and must read and comply with all the details, conditions and limitations relevant to that permit.

Primary producers, organisations and corporations can apply for permits for off-label use. Inquiries should be made through:

Australian Pesticides and Veterinary Medicines Authority (APVMA)  
PO Box 6182  
Kingston ACT 2604  
P: 02 6210 4701  
E: [enquiries@apvma.gov.au](mailto:enquiries@apvma.gov.au)  
W: [www.apvma.gov.au](http://www.apvma.gov.au)

### Analytical laboratories

In some situations a chemical analysis of fruit might be required. Listed below are laboratories which undertake this type of work.

Agrisearch Analytical  
Level 1, 48 Victoria Road  
Rozelle NSW 2039  
P: 02 9810 3666  
F: 02 9810 3866

National Measurement Institute  
105 Delhi Road  
North Ryde NSW 2113  
P: 02 9449 0111  
F: 02 9440 0297



# 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. To contact drumMUSTER, visit the [drumMUSTER website](http://www.drummuster.org.au) (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, the most toxic form of the chemical, even though it is diluted during the rinsing process.

Rinsing is the most effective method while the containers are still moist inside. The longer the residues have to dry and cake on the inside of containers, the more difficult they are to remove. This is the reason for rinsing during mixing and loading because the rinsate can be emptied into the spray or mixing tank of the application equipment. Using the rinsate this way avoids the necessity for having to dispose of the container residues separately.

To **triple rinse** a container up to 20 L to meet drumMUSTER standards:

1. remove the cap, invert the container and allow it to drip drain into the mixing tank for 30 seconds
2. add rinse water – 20% of container volume (e.g. 1 L per 5 L)
3. replace the cap and shake vigorously for one minute
4. remove the cap, invert and drip drain into mixing tank for 30 seconds
5. repeat twice
6. wash the cap separately and replace on the container.

**Note:** Triple rinsing is only suitable for small containers, up to 20 L.

Alternatively, use a pressure nozzle to triple rinse small containers. There are two main types of nozzle. One has a rotating spray head which can be used either to rinse an inverted container in the induction hopper or directly over the tank. The other type has a hardened, pointed shaft to pierce drums and the hollow shaft itself has four holes at 90° to spray the water around the container.

To **pressure rinse** a container up to 20 L:

1. remove the cap, invert the container and allow it to drip drain into the mixing tank for 30 seconds
2. ensure clean rinse water is at 35 – 60 psi
3. insert the pressure rinsing probe either into the container opening or through the pierced base of the container (depending on type of nozzle)
4. invert the container over the mixing tank and rinse for 30 seconds or longer if the water coming from the container is not clear, moving the probe about to ensure all inner surfaces are rinsed
5. wash the cap in clear rinse water
6. turn off the water, remove the probe and drip drain the container into the mixing tank for 30 seconds
7. replace the lid on the container.

Large containers, e.g. 200 L, are best rinsed with a chemical transfer probe that has a flushing cycle as well as the primary suction cycle. Such probes are standard on many boom sprays, and options on most others. The drums might have to be slightly inclined to ensure all rinsate is removed. Typical rinse time for a 200 L drum would be 3–5 minutes.

Non-rigid containers, i.e. bags and cartons, have to be buried. Plastic bags should be rinsed first, and paper bags punctured or shredded. Cartons also have to be punctured or shredded before burial.

Burning is specifically prohibited.

For more information, visit [www.drummuster.org.au](http://www.drummuster.org.au) or call 1800 008 707.

## ChemClear

ChemClear provides Australian agvet chemical users with a collection and disposal pathway for their unwanted chemicals. ChemClear complements drumMUSTER by providing agvet chemical users with a recycling and disposal option. Both programs are funded by AgStewardship Australia Limited through a 6 cents per litre levy placed on participating manufacturers' products and passed on to consumers at the point of sale.

ChemClear® collects two categories of agvet chemicals:

**Group 1** chemicals are those currently registered products manufactured by participating companies signed into the Industry Waste Reduction Agreement. These products are collected free of charge.

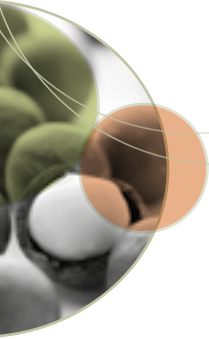
**Group 2** chemicals are those products manufactured by non-participating companies, or, deregistered, unknown, mixed or out of date products (by two years). A per litre/kilogram fee for disposal applies.

For more information or to register for the program, visit [www.chemclear.org.au](http://www.chemclear.org.au) or call 1800 008 182.

## Disposal of rinsate or dilute chemical

Labels contain a prohibition on disposing of concentrate on-site or on-farm, as per state environmental legislation. Unused chemical has first to be diluted and, if not applied in terms of the label use pattern, has to be disposed of in an environmentally responsible manner, such as an evaporation pit. This pit should be a metre deep, lined with plastic sheeting over which has been spread hydrated lime, and any waste covered with at least half a metre of soil. Disposal pits are only suited to small volumes and for diluted chemicals. In the case of a concentrate spill, the chemical would have to be diluted to at least standard label rates before transfer to the disposal pit.





# 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 89).

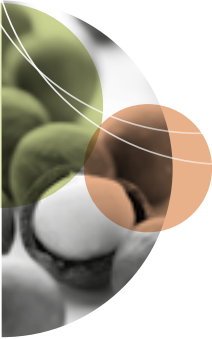
We need to physically check our coverage to ensure it is reaching the tops of the trees. This is where our production front predominates and therefore needs to be covered.

Inspect your orchard regularly and look for pests and diseases. No one knows the orchard better than the person working the orchard. A pest scout or consultant will also complement this knowledge.

Finally we need to ensure we calibrate the spray equipment. Just as we check other machinery, (e.g. your car every 10,000 km and tractor every 1,000 hours) we also need to check our sprayer every year. When we calibrate we can be sure that the right amount of chemical is hitting our target pest.

Figure 89. 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 8) 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 9) 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:

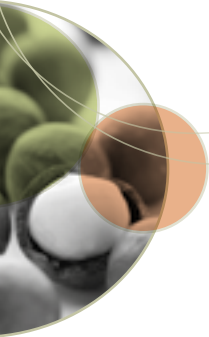
- the target pest
- your equipment
- your use of products and techniques.

Table 8. 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 9. 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



# 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.

## Resistance management

Managing resistance for all pesticides is now an important consideration when choosing a control strategy. One strategy used in resistance management 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 Horticulture Innovation Limited, has been successful in achieving 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, the option is there and 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 options are limited to a range of 1B chemicals. There should be a conscious decision at the later stages of nut development to use the available alternative options to 1B chemicals.

A typical scenario could be to spray lace bug early with a 1B product. Continue monitoring regularly for pests at this critical stage; there could be another requirement for a 1B product to be used around later flowering. Then at premature nut drop, continue monitoring for fruit spotting bug. At this stage there is an opportunity to use a different chemical group, being 3A or 4C.

Suggestions in the remarks column of Table 5 on page 56 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 Olufemi Akinsanmi, plant pathologist at the University of Queensland. These strategies are outlined in Table 10.

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 11 and Table 12. Only fungicides recommended in this guide are shown.

Table 10. Spray strategy for the control of husk spot to avoid resistance.

Spray strategy	1st spray (match head stage)	2nd spray (14–28 days after 1st spray)	3rd spray (14–28 days after 2nd spray)	4th spray (14–28 days after 3rd spray)
1	Carbendazim + copper	Carbendazim + copper	Cabrio only OR copper only	Copper only
2	Cabrio only	Cabrio only	Copper only OR Carbendazim + copper	Copper only OR Carbendazim + copper
3	Cabrio only	Carbendazim + copper	Cabrio only OR Carbendazim + copper OR copper only	Copper only
4	Carbendazim + copper	Cabrio only	Cabrio only OR copper only OR Carbendazim + copper	Copper only OR Carbendazim + copper

Table 11. Insecticide groups<sup>1,2</sup>.

Group	Chemical class	Common name	Example trade name*
1A	Carbamate	Carbaryl	Bugmaster Flowable®
		Methomyl	Lannate L®
1B	Organophosphate	Azinphos-methyl	Gusathion®
		Diazinon	Diazinon®
		Methidathion	Suprathion®
		Acephate	Lancer®
		Trichlorfon	Lepidex®
3A	Pyrethroid	Beta-cyfluthrin	Bulldock®
4C	Sulfoximines	Sulfoxaflor	Transform
5	Spinosyn	Spinetoram	Success Neo®
6	Acermectin	Abamectin	Vertimec®
11	Microbial	Bacillus thuringiensis	DiPel®
16A	Hydrazide	Tubufenozide	Mimic®
18	Diacylhydrazine	Methoxyfenozide	Prodigy®
22A	Oxadiazine	Indoxacarb	Avatar®

Table 12. Fungicide groups<sup>1,2</sup>.

Group	Chemical class	Common name	Example trade name*
1	Benzimidazole	Carbendazim	Spin Flo®
2	Dicarboximide	Iprodione	Rovral®
3	Triazole	Difenoconazole	Score®
4	Phenylamide	Metalaxyl	Ridomil®
7	Pyrazole carboxamide	Penthiopyrad	Fontelis®
11	Strobilurin	Pyroclostrobin	Cabrio
33/Y	Ethyl phosphonate	Phosphoric acid	Phospot®
M1	Inorganic	Copper fungicides	Kocide®

<sup>1</sup> Trade names which include the common name are not listed. Source: [www.apvma.gov.au](http://www.apvma.gov.au) and CropLife Australia.

<sup>2</sup> The information in the table shows insecticide groups based on mode of action only. For a chemical's compatibility with IPM please see the chemical listings for individual crops.

\* Example only. Other products are registered.

## Minimising glyphosate resistance in Australian orchards and vineyards

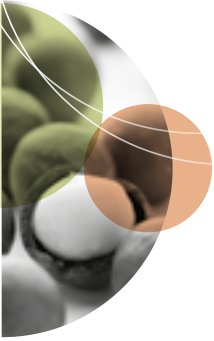
If you suspect glyphosate resistance, further information, industry contacts and testing services are detailed on the website of the [Australian Glyphosate Sustainability Working Group](http://www.glyphosateresistance.org.au) ([www.glyphosateresistance.org.au](http://www.glyphosateresistance.org.au)).

This information (Table 13) 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 13. Tip the scales in your favour to minimise glyphosate resistance risk.

	Risk increasing	Risk decreasing
Orchards and vineyards	Continually relying on glyphosate knockdown as a control agent under tree or under vine	Strategic use of alternative knockdown groups
	Not using alternative herbicide mode of action groups, including residual herbicides	Using alternate mode of action herbicides including residual herbicides
	Relying on herbicides for weed control instead of other means e.g. mowing, mulching, tillage or grazing	Using a double knock technique: full glyphosate rate followed by tillage or a full label rate of paraquat (Group L)
	Allowing weed control escapes to set seed	Adopting non-herbicide practices for weed control e.g. mowing, mulching, tillage or grazing
	Entering the cropping phase with high weed numbers	Preventing weed control escapes from setting seed
	Poor farm hygiene (machinery and stock coming onto farm) which leads to movement of resistant seed	Entering the cropping phase with low weed numbers
	Lack of crop competition on weeds	Ensuring that all machinery and stock coming onto the farm are 'clean'
	All group M herbicides are glyphosate herbicides	Using cover crops to compete with weeds



# Macadamia growers' resources

NSW DPI Primefacts are available free from [NSW Department of Primary Industries website](http://www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts) (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts).

**NSW Macadamia plant protection guide** (this book) can be collected from the NSW DPI Wollongbar office, from processors and is available for free [download](http://www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts) (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](http://www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management) at (www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts/growing-guides/macadamia-integrated-orchard-management).

**Macadamia integrated orchard management case studies 2016** is a companion to the **Macadamia integrated orchard management guide 2016**. Where the guide details the 'what to do' and 'when to do it', the case study booklet details the 'how to do'. It is designed to give growers considering integrated orchard management (IOM) the confidence to start planning. It involves 10 orchard case studies (two from each of the Australian macadamia growing regions). The book can be collected from the NSW DPI Wollongbar office, from processors and can also be [downloaded free](http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/667812/macadamia-iom-case-studies-2016.pdf) 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](http://www.dpi.nsw.gov.au/content/agriculture/horticulture/nuts) (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. NSW DPI will be re-printing a further 1,000 copies under the Marine Park Estate Management funds.

Effective orchard drainage systems keep productive soil in place. Successful orchard drainage systems create a synergy between the orchard layout and the landscape ensuring that:

- minimal soil movement occurs during rain
- concentrated water flows are managed away from macadamia trees
- blocks are protected from run-on water
- good conditions for macadamia feeder roots are maintained
- the orchard floor is trafficable and harvestable.

**Spray Sense**: a publication providing information on pesticide use, including sprayer calibration, testing for residues, storing pesticides, disposal of empty containers, how to read a label and a number of other topics. The *Spray Sense* series of leaflets can be [downloaded free](http://www.dpi.nsw.gov.au/agriculture/farm/chemicals/general/spray-sense-leaflet-series) (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](http://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): http://era.daf.qld.gov.au/id/eprint/1964/4/mac-growing\_guide\_Part4.pdf

**Macadamia problem solver and bug identifier**: An excellent reference for pest and disease identification. The book is available for [purchase as a booklet](#) or can be [downloaded free with the grower's handbook](#) in several sections (era.daf.qld.gov.au/1964).



**Macadamia variety identifier:** A useful resource that assists in identifying 24 specific macadamia varieties. The publication is [free to download](http://era.deedi.qld.gov.au/1964/14/mac-varieties.pdf) (<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](http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-culture-nsw) ([www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-culture-nsw](http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/growing-guides/macadamia-culture-nsw)).

**Australian Macadamia Society FAQs and factsheets:** An up to date resource identifying current problems and issues within the industry and offering useful solutions and tips to overcome them. Compiled by the Australian Macadamia Society with the assistance of industry experts. Can be downloaded free (to members) (<https://goo.gl/J8jfUd>).

**Establishing and managing smothergrass on macadamia orchard floors, 2008:** A guide on how to establish smothergrass, including costs and management. [Download for free](http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/establishing-managing-smothergrass) ([www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/establishing-managing-smothergrass](http://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition/establishing-managing-smothergrass)).

**Reducing erosion and other soil degradation in macadamia orchards** describes methods for reducing erosion and management practices that can be implemented to achieve this. [Download for free](https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts/soil-nutrition-floor-mgt/soil-macadamia) (<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](http://Bugs for Bugs) ([www.goodbugs.org.au](http://www.goodbugs.org.au)).

## Internet sites for macadamia growers

### Agricultural industry organisations

**Australian Macadamia Society:**  
[www.australian-macadamias.org](http://www.australian-macadamias.org)

**Australian Nut Industry Council:**  
[www.nutindustry.org.au](http://www.nutindustry.org.au)

**Horticulture Innovation:**  
[www.horticulture.com.au](http://www.horticulture.com.au)

**International Nut and Dried Fruit Council Foundation (INC):** [www.nutfruit.org](http://www.nutfruit.org)

**macSmart:** [www.macsmart.com.au](http://www.macsmart.com.au)

**National Farmers' Federation:** [www.nff.org.au](http://www.nff.org.au)

**NSW Farmers' Association:**  
[www.nswfarmers.org.au](http://www.nswfarmers.org.au)

### State government

**Department of Agriculture and Fisheries (QLD):**  
[www.daf.qld.gov.au](http://www.daf.qld.gov.au)

**Local Land Services NSW:**  
[www.lls.nsw.gov.au](http://www.lls.nsw.gov.au)

**NSW Department of Primary Industries:**  
[www.dpi.nsw.gov.au](http://www.dpi.nsw.gov.au)

**WorkCover Authority of NSW:**  
[www.workcover.nsw.gov.au](http://www.workcover.nsw.gov.au)

**WorkCover Queensland:**  
[www.worksafe.qld.gov.au](http://www.worksafe.qld.gov.au)

### Rural assistance

**Centrelink:** [www.centrelink.gov.au](http://www.centrelink.gov.au)

**Health NSW:** [www.health.nsw.gov.au](http://www.health.nsw.gov.au)

**NSW Rural Assistance Authority:**  
[www.raa.nsw.gov.au](http://www.raa.nsw.gov.au)

**QLD Health:** [www.health.qld.gov.au](http://www.health.qld.gov.au)

**QLD Rural Assistance Authority:**  
[www.qraa.qld.gov.au](http://www.qraa.qld.gov.au)

**Rural Skills Australia:** [www.ruralskills.com.au](http://www.ruralskills.com.au)

### Federal government

**ABC Rural Department:** [www.abc.net.au/rural](http://www.abc.net.au/rural)

**Australian Pesticides and Veterinary Medicines Authority:** [www.apvma.gov.au](http://www.apvma.gov.au)

**Australian Trade Commission:**  
[www.austrade.gov.au](http://www.austrade.gov.au)

**Department of Agriculture and Water Resources:**  
[www.agriculture.gov.au](http://www.agriculture.gov.au)

**Land & Water Australia:** [www.lwa.gov.au](http://www.lwa.gov.au)

**Plant Health Australia:**  
[www.planthealthaustralia.com.au](http://www.planthealthaustralia.com.au)

### Climate

**Climate Outlook BOM:**  
[www.bom.gov.au/climate/ahead](http://www.bom.gov.au/climate/ahead)

**Commonwealth Bureau of Meteorology:**  
[www.bom.gov.au](http://www.bom.gov.au)

National Centers for Environmental Prediction:

[wxmaps.org/pix/aus.vv.html](http://wxmaps.org/pix/aus.vv.html)

The Long Paddock:

[www.longpaddock.qld.gov.au](http://www.longpaddock.qld.gov.au)

## **Environment**

Department of the Environment and Energy:

[www.environment.gov.au](http://www.environment.gov.au)

NSW Environment Protection Authority:

[www.epa.nsw.gov.au](http://www.epa.nsw.gov.au)

Office of Environment & Heritage:

[www.environment.nsw.gov.au](http://www.environment.nsw.gov.au)

QLD Department of Environment and Heritage  
Protection: [www.ehp.qld.gov.au](http://www.ehp.qld.gov.au)

## **Alternative systems (organics)**

Australian Certified Organic: [www.aco.net.au](http://www.aco.net.au)

Australian Organic: [www.austorganic.com](http://www.austorganic.com)

Australian Organic Certification and Grower  
Groups: [www.nasaa.com.au](http://www.nasaa.com.au)

Organic Federation of Australia: [www.ofa.org.au](http://www.ofa.org.au)

## **Economic information**

Australian Bureau of Statistics: [www.abs.gov.au](http://www.abs.gov.au)

Department of Agriculture and Water Resources:  
[www.agriculture.gov.au](http://www.agriculture.gov.au)

## **Integrated pest management**

Australasian Biological Control Association Inc.:  
[www.goodbugs.org.au](http://www.goodbugs.org.au)

Bugs for Bugs: [www.bugsforbugs.com.au](http://www.bugsforbugs.com.au)

Bioresources: [www.bioresources.com.au](http://www.bioresources.com.au)

## **Quality assurance**

Freshcare Australia: [www.freshcare.com.au](http://www.freshcare.com.au)

## **Processors**

Macadamia Direct: [www.macnut.com.au](http://www.macnut.com.au)

Macadamia Processing Company:  
[www.mpcmacs.com.au](http://www.mpcmacs.com.au)

Macadamias Australia:  
[www.macadamiasaustralia.net](http://www.macadamiasaustralia.net)

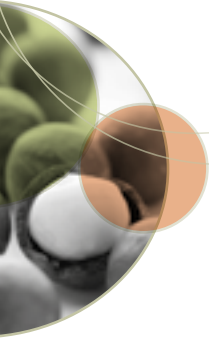
MWT Foods: [www.mwtfoods.com](http://www.mwtfoods.com)

Nambucca Macnuts: [www.macnuts.com.au](http://www.macnuts.com.au)

Pacific Farm Services: [www.macadamia.com.au](http://www.macadamia.com.au)

Stahmann Farms: [www.stahmann.com.au](http://www.stahmann.com.au)

Suncoast Gold Macadamia (Aust) Ltd: [www.suncoastgold.com.au](http://www.suncoastgold.com.au)



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Melinda Simpson



Andrew Creek



Steven Falivene



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Adrian Englefield



Darren Fahey



Matt Weinert

### 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/): <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.



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