AUSTRALIAN MACADAMIA SOCIETY

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AUSTRALIAN MACADAMIA SOCIETY

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Front cover. Ross Arnett is producing macadamia amongst a riot of life in his orchard on the Alstonville Plateau in the Northern Rivers region. His orchard is a biological case study that features from page 58.

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Hort Innovation Strategic levy investment | MACADAMIA FUND

Thanks to our industry partners

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Our Mission

The Australian Macadamia Society Limited is established to promote all aspects of the macadamia nut industry; to encourage a free interchange of ideas and information amongst macadamia growers and marketers of macadamia nuts and by-products; and to foster and promote goodwill among members of the Society in furtherance of its objects.

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What's On

DATE	EVENT	LOCATION	CONTACT
September 2021 (TBC)	Consultants meetings		AMS: 1800 262 426 office@macadamias.org
Tues 21 September	AMS Board meeting	Teleconference	AMS: 1800 262 426 jolyon.burnett@macadamias.org
Mon 1 November	AMS Board meeting	Gold Coast	
Tues 2 November – Thurs 4 November	AusMac2021 conference, including AMS AGM	Gold Coast	AMS: 1800 262 426 office@macadamias.org https://www.ivvy.com.au/event/AUSMAC2021/
Wed 24 November	Australian Macadamia Handlers Association (AMHA) meeting	Brisbane	Jacqui Price Marketing Manager 0424 107 731 jacqui.price@macadamias.org



CEO's report



The 2021 crop is almost done with harvest over in Bundaberg and places north and rapidly winding up in New South Wales. The AMS together with the Australian Macadamia Handlers Association has revised the forecast down from an optimistic 54,400 tonnes at 10% moisture to 52,000 tonnes. The modest reduction is partly as a result of the severe weather experienced by NSW growers in recent months, which caused crop losses in many parts of the state. But there also seems to be some trees which are still recovering from the severe drought of 2019. These losses have been largely offset by new plantings coming into production in Bundaberg. The new forecast represents an increase on last year's crop of approximately 3.5%.

Unfortunately, COVID has intervened once again in our best efforts to hold the July round of MacGroups. At the time of writing, we are developing a series of videos to highlight the important information that would have been presented. These videos will cover the latest pollination research, the changing pest and disease landscape, managing water extremes, the voluntary marketing fund and the new AMS. The videos will be followed by a live Q&A session. Watch the *enews* for more details.

This all makes getting to AusMac2021 even more important. The conference is being held from 2 to 4 November at the Royal Pines Resort on the Gold Coast, the same venue as the hugely successful 2018 event. The program is available on the event website: https://www.ivvy.com.au/event/AUSMAC2021/

This is a must attend event, with something for everyone including international technical and marketing presentations, debates, workshops, trade stands and equipment displays and, of course, the cocktails and the gala dinner. We would love to see you and appreciate your support.

The development and establishment of the World Macadamia Organisation (WMO) continues to gather pace. This is the organisation funded by macadamia producers internationally that will drive global demand stimulation. The AMS sees this initiative as vital and as reported previously, we have appointed Jillian Laing as CEO. Jillian has a very strong background in international food marketing and has already developed some key market initiatives and strategies that build on the work of the Australian marketing program to give us deeper and more useful insights into key markets such as China. International support is building. As I write, I have just finished a telephone call with industry representatives in Guatemala and they are committed to supporting the program.

I would like to thank those growers who are contributing to the voluntary marketing fund (VMF). It is not an easy decision and not made any easier by the thought that some growers are prepared to let others shoulder the cost. But the industry was founded by big thinkers with a clear vision and we have all benefited from their efforts. I am confident that the VMF, together with the WMO, will deliver the necessary resources and the marketing program to maintain demand as the global supply grows strongly.

If you are not contributing, it is not too late to support your industry, either through your processor or directly to the AMS. Simple let your processor know or ask the AMS to send you an invoice for $30 for each tonne you harvested. It will be one of the most important investments you make.

Elsewhere in this *News Bulletin,* I talk about the Board's plans to introduce a new membership structure that will deliver increased resources to allow the AMS to deliver new services and support for members. This is an important step in the evolution and development of your industry body and I hope you will all take the time to read the article, contact me if you have questions and ultimately support the changes at the AGM in November.

Jolyon Burnett, CEO

New digital grant to improve microclimate monitoring and decision making



Leoni Kojetin

Queensland macadamia growers will benefit from a new grant to the Australian Macadamia Society to set up a network of weather stations and tree canopy sensors in macadamia orchards in major growing regions across the State.

Awarded by the Queensland Government, the Digital Transformation Grant will allow the AMS to start work on a project to improve microclimate monitoring and digital data to help growers make better decisions at key crop stages.

The $58,620 grant was announced by Member for Bundaberg, Tom Smith, who said it would help growers like those in the Bundaberg region to access new opportunities.

It is matched dollar for dollar by the AMS and other project collaborators, The University of Queensland, University of New England and Davis Instruments Australia, to a total of $118,960.

The project will enable macadamia growers to utilise real time, localised weather data to inform orchard management decisions and critical timing to maximise productivity.

Welcoming the new funding, Leoni Kojetin, AMS Industry Development Manager, said data from the network of weather stations will be integrated into a single platform, creating a dashboard that macadamia growers will be able to access.

"Once the infrastructure and dashboard are in place, the AMS will be holding field days and online information sessions to help growers make orchard management decisions based on the data from weather stations in their local area," she said.

"It will also have the capacity for growers to link weather data into the network from other compatible weather stations they may have on-farm."

Leoni explained that while many macadamia growers are investing in weather stations, others are unsure about their accuracy and authority to inform operations.

"Wading through the huge volume of weather data growers can access online is time consuming. Some of this data is local and helpful, but some is not," she said.

This grant will develop the skills of growers and farm staff to confidently utilise this local weather information and apply it to the key environmental factors affecting macadamia productivity to better time critical orchard operations.

"Tree crops are unique in the microclimate they create within canopies, so the grower weather dashboard we are developing will show weather data from a base station on the property as well as the linked microclimate in the tree canopy, all in real time," Leoni said.

"A grower's day is all about working the orchard with a constant eye on the weather, as it dictates farm operations, orchard access, the timing of key inputs and crop protection, as well as risk management.

"While growers use many on-farm monitoring tools, this one will save growers time by gathering and analysing weather information and interpreting it in relation to key crop stages in a matter of seconds.

"For example, flowering is an important crop stage to protect. If we know the real time orchard conditions and the risk to flowering, we can arm growers to respond rapidly and mitigate environmental conditions and potential crop losses."

Leoni said the dashboard will also offer alert level information about crop risks based on extensive research, like conditions conducive to developing disease or environmental factors leading to tree stress and the potential for nut immaturity.

The AMS is collaborating with research organisations to develop these dashboard alert models.

"We see this project as a practical way to extend macadamia research outcomes, develop the digital skills of growers and their staff, as well as providing real time crop information," she said.

This grant to the AMS was awarded in the first round of the Agribusiness Digital Solutions Grant Program.

Queensland Minister for Agricultural Industry Development and Fisheries Mark Furner said a total of $5.5 million is being invested over three years through the initiative.

"This funding will support agribusinesses to become digitally aware and ready to respond to future disruptions," he said.

"Digital technology creates new ways of doing things that add value to the agricultural sector by working more precisely, efficiently and sustainably."



The AMS has won a Queensland Government grant to set up a network of weather stations to improve microclimate monitoring and help growers make better decisions at key crop stages.

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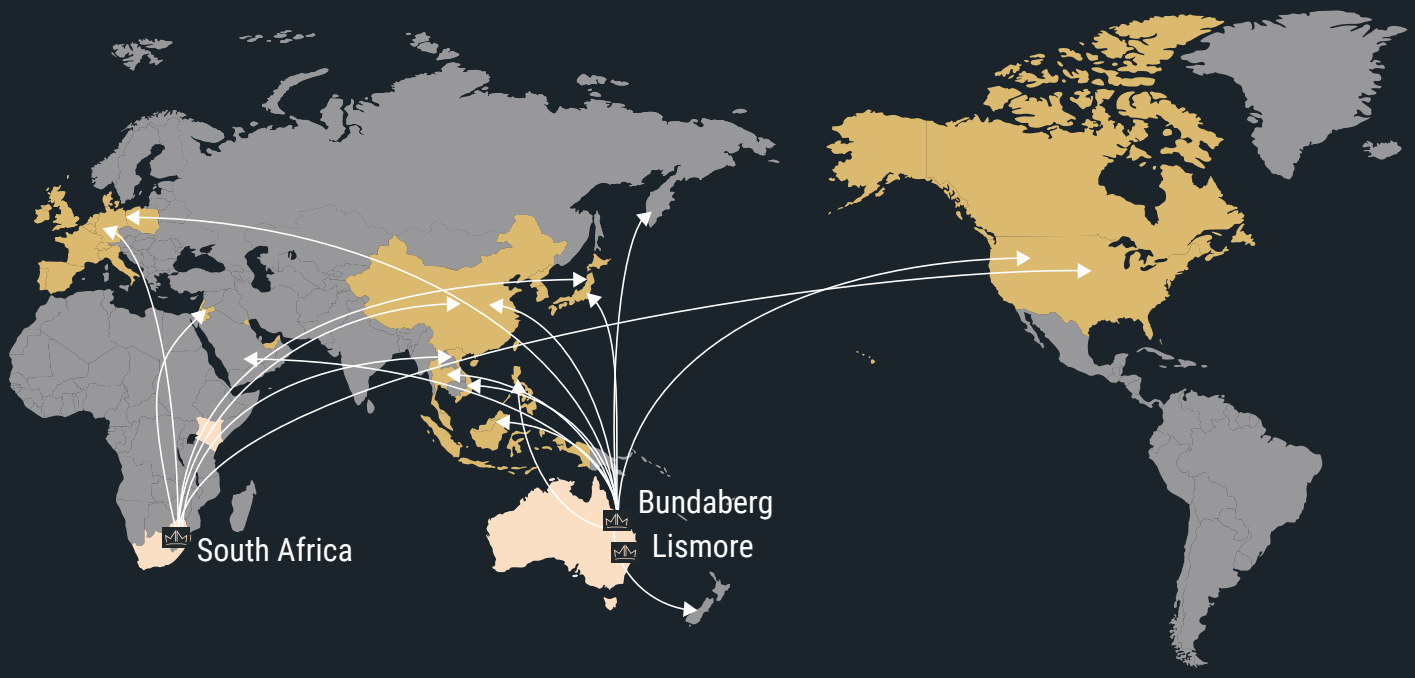

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Australian kernel sales improve as global supply holds firm

Jacqui Price Market Development Manager, AMS **P:** 02 6622 4933 **E:** jacqui.price@macadamias.org

Supply

The 2021 Australian macadamia crop forecast has been revised down by 4.5% from 50,770 to 48,500 tonnes in-shell at 3.5% moisture (from 54,440 to 52,000 tonnes at 10% moisture). In the New South Wales growing region, severe weather experienced in recent months delayed first new crop harvest and caused physical crop losses reducing original published crop expectations. With the majority of the Australian macadamia crop now collected, nut sizing is more normal this season and whilst kernel yields are slightly down, overall quality is very good.

The global forecast for the 2021 season is 239,034 tonnes in-shell @ 3.5% moisture, an increase of 5%. Australia's revised forecast represents an increase on last year's crop of approximately 3.5% due to favourable growing conditions in most regions despite the ongoing legacy of previous years' sustained drought. Macadamias South Africa's (SAMAC) published crop estimate for 2021 has been reduced from 57,834 tonnes in-shell to 54,174 tonnes in-shell @ 3.5% moisture. This is 11% higher than the 2020 season result. China and Malawi are expected to return solid crops but Kenya is experiencing ongoing challenges.

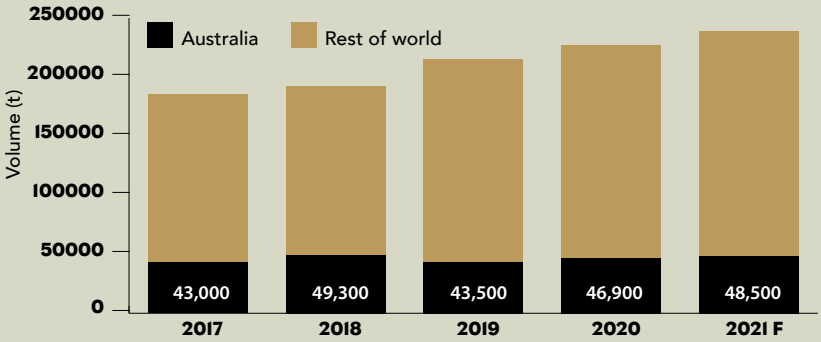

Figure 1. Global macadamia crop volumes 2017-2021 (tonnes).
Source: INC. All volumes are at 3.5% MC.

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Demand

Eighteen months since the onset of the COVID-19 pandemic, the World Bank is reporting the global economy is poised for a strong recovery, however the rebound is expected to be uneven across countries as many continue to grapple with the virus. Global demand for total macadamia kernel imports continues to improve in line with this. Apart from USA, all major regions are up on the prior MAT period (June-May). Interest from the USA in recent months has been strong and imports into this market are expected to improve. China/HK is the key driver of growth, up 33%. NIS imports were at their highest since 2018 at 11,172 tonnes and were 35% higher than the prior MAT period, driven by rapid economic recovery, a strong Chinese New Year and increased competition in the ecommerce sector resulting in wider distribution into Tier 2 and 3 cities.

Australia's market share continues to hold in its priority markets. Taiwan is the exception, where there has been increased competition from other origins.

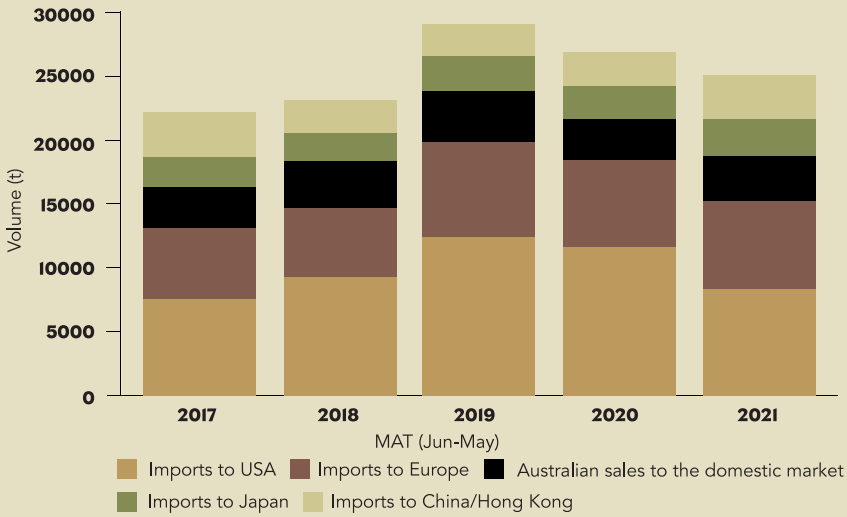

Figure 2. Macadamia kernel imports to top 5 markets (tonnes) MAT June – May.
Sources: USDA, Eurostat, Japan Customs, China Customs, Hong Kong Census & Statistics Department via IHS Markit Inc, AMHA

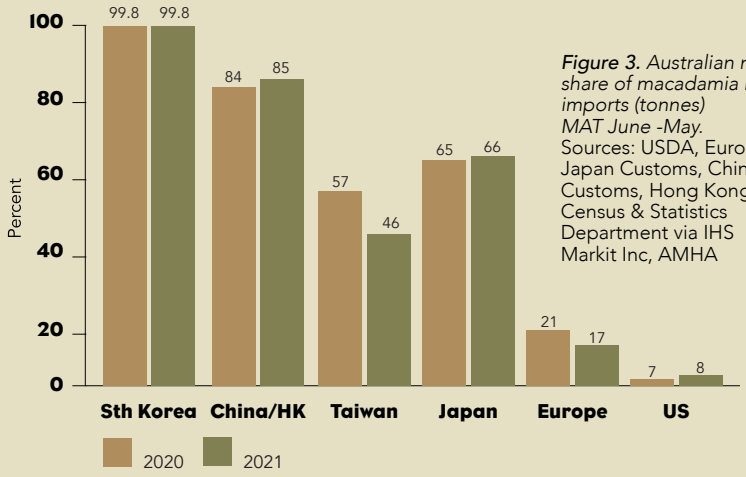

Figure 3. Australian market share of macadamia kernel imports (tonnes) MAT June -May.
Sources: USDA, Eurostat, Japan Customs, China Customs, Hong Kong Census & Statistics Department via IHS Markit Inc, AMHA

Australian sales

Australian macadamia kernel sales are following the global trend and showing strong improvement with all major regions experiencing growth on prior MAT period, although there was some fluctuation across the specific markets. The fastest recovering market for Australian sales was Korea, up 60%. It was also positive to see domestic sales increased 10% on prior year. Disruption to the international markets and a strong Australian dollar saw improved availability and value for domestic buyers. The intermittent closure of foodservice operators and the growing number of employees working from home fuelled the home cooking trend. Consumers have redefined the concept of indulgence and are nourishing themselves with healthy, nutritious food to support their mood and wellbeing during these tumultuous times.

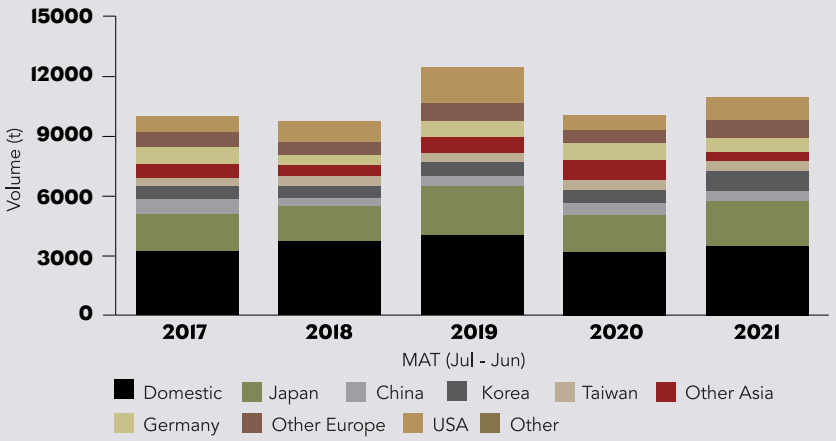

Figure 4. Australian macadamia kernel sales (tonnes) MAT (July-June).
Source: AMHA. In-shell sales quoted at 3.5% MC. AMHA represents 90% production, sales are adjusted to represent non-AMHA members


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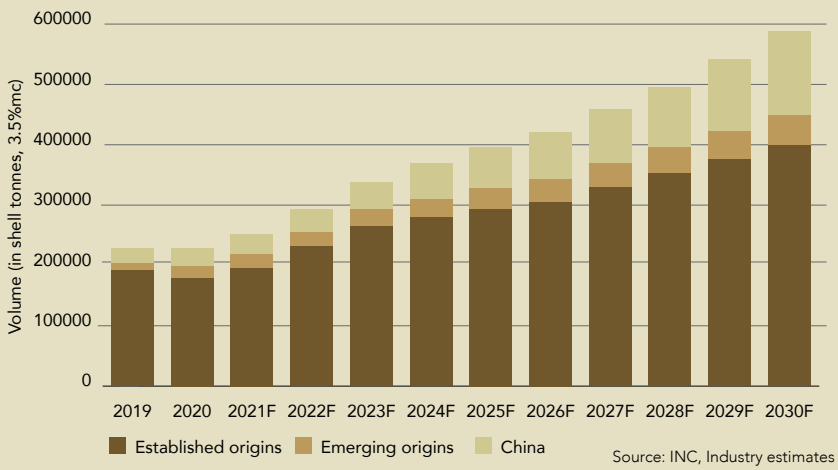
New industry marketing fund to strengthen the future

Jolyon Burnett, Chief Executive Officer, Australian Macadamia Society

With the development of significant macadamia industries in China and Africa, global production has entered a new phase of accelerated growth. Detailed modelling is consistently forecasting that production will double in the next five years and triple in the next 10 years. This equates to an additional 70,000 tonnes in the next five years.

Global macadamia production forecast to double in next decade



Source: INC, Industry estimates

We need to be on the front foot and prepare to meet the challenges to demand – and nut-in-shell price – that will come with this tripling of supply.

The AMS and processors have worked to develop a global marketing strategy funded by growers and processors from around the world. To fund the Australian contribution to this strategy, the AMS and participating processors have established the voluntary marketing fund (VMF).

The voluntary marketing fund is:

- industry owned
- industry run
- independently audited
- used to leverage support from other origins to promote marketing of macadamias
- has an initial three-year life.

The aim is to collect $2 million over the three years to devote to international macadamia marketing. So far, growers and processors representing over half our production have signed on to support the fund. We are asking you to jump on board too and join them by opting into the fund by contacting your processor.

How does the VMF work?

The VMF operates using **voluntary** contributions.

Growers are asked to contribute 3 c/kg of nut-in-shell in addition to the statutory levies which are allocated to the Australian brand marketing and paid to Hort Innovation, not the AMS.

Almost all processors are participating, but if your processor has not or your trees are not yet bearing, you can contribute directly to the Fund through the AMS. Just ask us for an invoice.

All VMF contributions will be used only to support marketing campaigns or health, market and consumer research to support these campaigns. This includes supporting the World Macadamia Organisation (WMO), the international body being established to oversee and coordinate the global marketing campaign.

VMF has been designed to:



CAPTURE OPPORTUNITIES
to grow and diversify our markets



PROTECT GROWER INCOMES
and farmgate price



LEVERAGE MARKETING INVESTMENT
from other origins

The VMF contributions will be held in a separately audited account. Before any funds are spent, advice on the WMO's marketing plan will be sought from the Market Development Manager and the Australian marketing committee, which has run the existing marketing program successfully for the last 10 years.

The Australian funds will be combined with contributions from other origins in a collectively agreed marketing program developed and overseen by the WMO.

The WMO will:

- be incorporated as a not for profit in Singapore
- have up to two board members per fee-contributing country, nominated through the national body (or equivalent)
- have voting rights based on the member country's financial contribution.

How do I help support the VMF?

It's simple. If you have not opted-in to the VMF in your supply contract, just contact your processor, or if they are not participating in the program or your trees aren't bearing yet, contact the AMS. If your processor has not offered you the chance to opt-in, ask them why not or call the AMS on 1800 262 426 to opt-in directly. Jump on board now and help us help you.



Here for the love of macadamias

At the WMO, we're passionate about growing global demand for one of the world's most untapped and undiscovered wholefoods.

As the worldwide industry champion, our key focus is to drive a greater affinity, understanding and appreciation of macadamias. Ultimately, we're here to stimulate growth and provide the long-term foundations for a strong, sustainable market.

The WMO is positioned right where it needs to be - at the intersection of the global industry and the consumer. We have seven of the eight largest producing countries on board for our incorporation in Singapore in August. By coming together as an industry, we can leverage the resources of everyone.

Our focus is on building demand in three key areas; seeding the emerging Indian market, growing frequency of consumption in China, and strengthening demand in the rapidly increasing plant-based diet sector. The WMO will also facilitate health and science-backed research to build our credentials, collect insightful industry data, and create alignment in global product standards.

By supporting the World Macadamia Organisation you're supporting the future of your industry.

The WMO.
Here for the love of macadamias.

wmo world macadamia organisation

The World Macadamia Organisation website is being crafted right now and will be ready very soon.
Please check it out for updates on our progress. **www.worldmacadamia.com**

Leoni's orchard rounds

Leoni Kojetin Industry Development Manager, AMS **M:** 0433 007 925 **E:** leoni.kojetin@macadamias.org

From grower reports, it seems that varying seasonal conditions are having a big impact on nut yield and quality. Wet weather in New South Wales has affected yields, and there is a general decrease in premium kernel with TKR (total kernel recovery) similar to or below long-term averages. In contrast, quality reports from Queensland are good, with a general increase in premium kernel. Central Queensland, which remains in drought, has a TKR above long-term averages, while South-East Queensland's TKR is only slightly below to date. These varying conditions have resulted in the industry crop forecast being downgraded by 4.5% in July 2021 to 52,000 tonnes in-shell @ 10% moisture.

The industry is maintaining its optimism about the future, and expansion has continued rapidly, with an estimated 10,000 hectares planted over the last five years. Many of those trees are cultivars that have a higher kernel recovery, and this is being reflected in the figures that show a general increase in KR.

We estimate there are now about 800 macadamia growers in the industry. Despite the fact that they come from a multitude of backgrounds, age ranges and levels of growing experience, our growers continue to be collaborative and generous in sharing information, qualities that make us the envy of other horticultural industries.

Members of a recent horticultural grower panel were asked to nominate their most reliable source of information, and they unanimously said other growers. So, while there are fewer formal grower gatherings at present, I encourage you to take the time to step outside your orchard or organisation, listen to the challenges and triumphs of other growers and learn from their experiences.

Preparing for next season

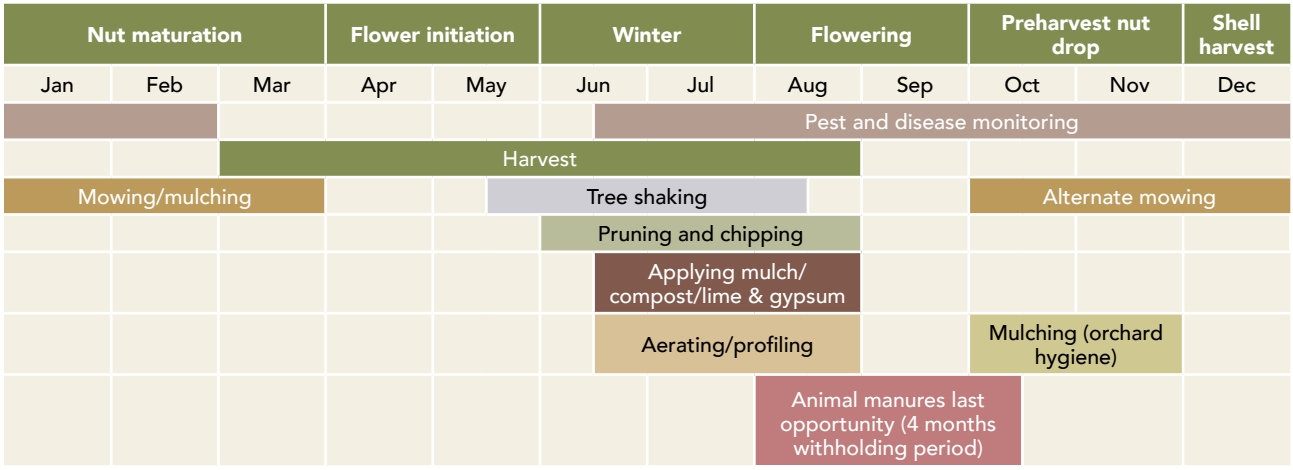
Whether you are still harvesting or your crop is fully consigned already, I am sure preparation for a new season is a priority for you now. With this in mind, we have put together an edition that is full of grower stories and the latest research to help prepare your orchard and yourself for the season ahead.

As part of our aim to provide the latest information to growers, the AMS recently launched a new resource called MacAlerts, which are phenologically based crop management guides. The most recent editions include a "year view" of the macadamia management cycle. The start and finish for this cycle depends on your region, so it is likely to be earlier the more north you are and be later, the further south you are.

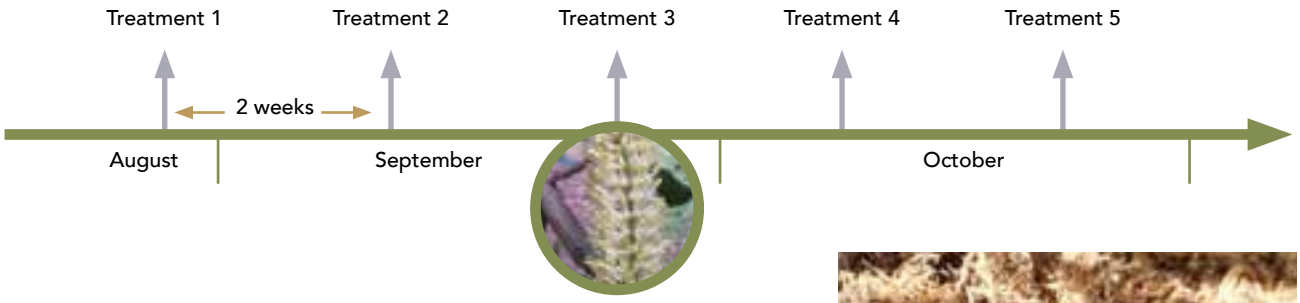
One issue this timeline highlights, especially for NSW growers, is that of later natural nut drop and harvesting coinciding with the need to prepare early for the next season. Research is unequivocal on the critical nature of well-timed, earlier orchard preparation, but the temptation for growers to wait too long can mean mistiming crucial operations and hampering the following season's production. Other growing origins have an advantage in this respect as hand picking nuts means they are able to finish the season in a timely manner.

Mistimed canopy management

Research over the last few years has also shown clearly that completing canopy management tasks like pruning



Management cycle



Experiment tip pruning treatments

within weeks of nut set diverts crucial resources away from this function, often resulting in a yield penalty.

An example of this research was an experiment to assess the impact of shoot vs nut competition by then honours student Hanna Toegel, completed as part of the Small Tree High Productivity Initiative led by Dr John Wilkie. In this experiment, trees were tip pruned at five different treatment intervals spaced two weeks apart, either side of and at full bloom on trial A203 trees.

After the treatments, the researchers measured the nuts per raceme that were set through to final nuts per tree harvested and found that pruning timing had a significant effect on yield.

The pruning treatments that led to the most nuts per tree at final harvest were those that were at least two weeks either side of full bloom - treatments 1, 2, 4 and 5. Treatment 5 produced the most nuts per tree and treatment 3 the lowest.

Researchers hypothesised, as was suspected from earlier research, that competition for resources inhibits yield if both shoots and nuts are growing at the same time. The consistent message is that trees should not be pruned close to peak flowering, when the tree should have just one sink – nuts.

Mistimed orchard floor management

There can also be a penalty for mistiming orchard floor preparation, another operation where it can be hard to achieve a balance between having a harvestable surface and ensuring the biological requirements for healthy trees are met. Often the decision is made to favour a harvestable surface.

While this decision is understandable, restoring the orchard floor to a rich, undisturbed ideal root growing environment post-harvest is the foundation of any season's production. The sooner we can achieve these ideal conditions by spreading organic matter, including chipped prunings and other material, improving the root zone with strategies such as aerating and profiling and by stopping the disturbance of the "magic metre" radius around tree trunks, the sooner roots can grow.

Later harvesting, which is of decreasing benefit later in the season, can further delay orchard floor tasks and stop growers from moving to the next step of orchard preparation. In southern growing regions, which have an extended nut drop, this is most exaggerated. Later harvests tie up resources and continue to disturb the root zone, which often means that the ideal root



Macadamia roots 'consume' woodchip, using microbes to break it down. (Photo: Rohan Orford)



Double ground woodchip is incorporated on the orchard floor much quicker than standard woodchip. (Photo: Rohan Orford)

growing window of late winter through spring is missed.

Organic material takes time to break down and roots take time to grow up into that material and bed it down, forming the harvestable surface we need. Roots that are put down too late have just a few weeks of ideal growing conditions before the heat of summer, and organic material won't have been incorporated into the orchard floor before the next harvest. In addition, you need to consider withholding periods for animal manures of at least four months when developing a schedule for applying organic materials.

Missing the critical period in spring when roots grow and organic matter should be incorporated because of later and later harvests is often the law of diminishing returns. In many cases, having healthy, more resilient trees can add far more in productivity than a few tonnes late in the season.

Tree shaking provides enormous benefits with this goal, and many growers are incorporating the practice as standard now. If you haven't seen it, take a look at the latest video on the AMS YouTube channel, *Tree Shaking: grower insights* or download the new tree shaker fact sheet.

Don't forget to register for conference!

We are on the downhill run to our AusMac2021 Conference, which will be a highlight of the macadamia calendar. It is an opportunity to relax, network and gain valuable insight into macadamia growing which is not to be missed.

I look forward to seeing you there.

Leoni

Positioning the Australian macadamia industry for a prosperous future

Jolyon Burnett, Chief Executive Officer, Australian Macadamia Society

The opportunity

The Australian macadamia industry is a rising star of the horticultural sector in this country. The industry is worth $300 million at farm gate, close to $500 million at factory gate, $700 million at retail and is both NSW's and Queensland's most valuable horticultural export with earnings over $300 million annually.

The industry is growing its planted area at around 10% a year with 30,000 ha currently planted and an additional 3,000 ha a year currently being added. With establishment costs close to $50,000 per hectare, this is an annual investment of $150 million.

The Australian macadamia industry could be the primary industry that drives the economy of north-eastern Australia, driving regional investment, jobs, value adding and exports on the back of sustained global demand.

The AMS needs to ensure that as the only peak body for the industry it has the structure, resources and strength to lead and support this development. The AMS Board is keenly aware of this challenge and has developed a proposal to ensure the organisation stays fit for purpose and able to help the industry fulfil its potential.

This is important whether you are just entering the industry, are looking at generational participation or are planning to exit the industry in the near future. A strong, united and profitable industry will protect future earnings and asset values.

This will require an industry body that is well connected and engaged and has the people and resources to work with government to maintain a favourable operating environment for sustainable industry growth and development.

The proposed changes

Our current flat membership structure and service delivery does not reflect the true potential of our growing industry and its needs.

It's time to consider a new approach to membership that is based on scale and size. The larger a member's investment in the industry, the more benefit they receive from the right service and policy settings and the greater the contribution they should make. The Board are proposing a per hectare based membership for growers and a scale based membership for processors and other commercial participants.

Grower membership fees will be based on planted hectares. With a floor at the bottom and a ceiling at the top, members will pay between $400 and $5,000 on a sliding scale.

The table below gives some examples:

Hectares	$/ha	Annual fee $
1-20	Floor of $400	$400
35	$20	$700
70	$20	$1,400
120	$20	$2,400
200	$20	$4,000
250 +	Ceiling of $5,000	$5,000

Voting rights will be aligned with fees paid, with members getting a vote for each $ of annual fee. In doing this, the Board is very conscious of the need to balance the continuing rights and influence of smaller growers with the need to better recognise the contribution larger growers make and the importance of maintaining a strong level of membership and participation across all orchard scales.

For processors and handlers, fees will be based on tonnes handled and for commercial suppliers, fees will be based on employees working in macadamias.

These changes have been proposed based on extensive consultation and feedback from members. Focus groups were held in Nambucca, Lismore, Gympie and Bundaberg. Follow up presentations open to all members were given across all growing regions.

What additional resources will be used for

The Board is planning to adopt some of the services and activities that members have indicated would help their businesses, including:

Better regional engagement

With a new membership structure that encourages greater contribution from larger players, the AMS aims to grow our capacity to establish a network of regional advisory committees (RACs) to identify and bring forward regional issues and solutions and facilitate greater membership engagement with the Board and key industry stakeholders.

The RACs will be critical to the AMS better capturing and responding to the regional challenges of members. They will be owned by the members in that region.

AMS Business Facilitation Officers

One of the key roles of the AMS is the facilitation of activities and opportunities across the membership, between the members and other stakeholders such as local and state government programs, commercial opportunities and so on. Major growing regions could be supported by AMS Business Facilitation Officers who will be a resource available for members with the

support and resources of the national organisation. We intend to start with one in Queensland and one in NSW.

Improved and amplified advocacy and government liaison

The industry is being increasingly impacted by government policy and regulations at all three levels - federal, state and local.

Statutory levies and R&D incentives, biosecurity, food safety and labelling, labour, tax and access to chemicals are all federal government responsibilities that are increasingly affecting your business. At state level, recent developments on Paradise Dam, state owned electricity utilities, disaster responses and assistance and environmental issues are all having a material effect on your right to farm. At a local council level, there are zoning restrictions, vegetation under power lines and a wide range of community based issues that cost time and money.

The new resources will underpin the support the AMS will provide around compliance with new regulatory requirements. Reef Certification is already here for members within the catchment of the Great Barrier Reef. Freshcare or equivalent is already necessary for domestic supermarket supply, Fair Farms or SEDEX will soon be required to access European markets and under their Farm to Fork initiative greater certification will be required on sustainable practices.

The aim is to be better placed and resourced to help you navigate through these issues to get the best outcome for your business. Success can mean savings of many thousands of dollars and months of time.

Targeted and relevant training and development

The new resources will allow the AMS to do more on training opportunities such as facilitating the delivery of Freshcare training, expanding the number and type of TAFE courses targeted to the macadamia industry and providing opportunities for targeted training for senior managers and innovative growers through master classes and other concepts.

Board Directors are continuing to talk to members and refine their ideas. The aim is to put a series of changes to the AMS constitution to members at the November 3 AGM. This article describes the general approach the Board is taking but the details may change before the proposal is sent to members with other information prior to the AGM.

Members who would like to discuss this aspect of these proposed changes should call Jolyon Burnett on 0416 224 935 and any Director (see page 2 for contact details).

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Understanding the risk of crop loss to macadamia nut borer (*Cryptophlebia ombrodelta*)

Craig Maddox, Technical Officer Entomology and **Ruth Huwer**, Research Entomologist, NSW DPI, Wollongbar **M:** 0418 318 818 **E:** craig.maddox@dpi.nsw.gov.au

Macadamia nut borer (MNB) was the major source of crop loss in the 1980-2000 period for Australian macadamia growers. The pest has the capacity to drop large numbers of immature nut when it feeds in the husk, as well as physically damage the kernel if it penetrates the shell.

With the development of the pheromone lures, MNB culturing and access to *Trichogrammatoidea cryptophlebiae,* research teams have been able to reduce this problem to a sporadic issue for coastal orchards.

Certain climatic conditions limit the effectiveness of the parasitoid (extended periods > 35^0 C and continuous heavy rain), but good monitoring and a well-timed beta-cyfluthrin spray normally result in negligible losses. Establishing the egg parasitoid in summer prevents the moth from overwintering within the orchard.

Flight trapping has been a long standing protocol to monitor flights leaving the main breeding areas (mangrove areas - Komai and Nasu 2003), and arriving in the orchards. We change the lures every fortnight and the plates every six weeks.

The further orchards are from the coast, the less of a problem MNB usually is. The most elevated part of an orchard tends to catch more moths, and traps placed higher in trees (6 m > 2 m) receive twice the catch.

There are egg laying and survivorship preferences. Varieties like 344, 246, A4 and 849 are all favoured, less so 741, and others like 333 are almost impervious to the larvae once the husk toughens.

The pheromone trap monitoring is scored as male moths per week and the season begins in September as moths fly into the orchard. We rank seasonal flights by accumulating that moth rate from September to March and then compare this to the egg laying rates and the tunnelling in the nuts to work out how effective the treatments are (Table 1 and 2).

The critical data is when the egg laying appears on the nut, usually in the December – January period, and whether larvae resulting from these eggs are entering the nut. This is why you pay the crop scouts to detect that fresh egg laying. These eggs are normally only on the nut for 2 - 4 days and if the conditions are warm and humid at night, larval penetration is much higher.

Once inside the nut, larvae become difficult to treat and can then emerge within the orchards at an increasing rate. Beta-cyfluthrin is very effective on that flight in the early summer period. The flights we can detect through monitoring with pheromone traps are normally about a week in front of that summer laying so they are a good guide.

The next generation usually emerges around late January and it is on this one the wasp population should be beginning to build up. Egg parasitism will be close to 100% by autumn. If the levels are still high, growers could alternate with a methoxyfenozide (Prodigy®) application which will be wasp compatible. Acephate is effective if both *Leptocoris* sp. and MNB are active, but it will take longer to re- establish the wasps, than if beta cyfluthrin was used.

There is certainly discussion among the ex-South African growers about the use of pheromone pastes for trapping male moths on trees. Our work with Last Call® paste in 2003-2004 found its effectiveness was limited. The key assumption is that the female moths arrive in the







Figures 1 - 3. *Tools for macadamia nut borer management include (left) flight traps with a male pheromone lure checked weekly, (centre) checking fallen nut for pest oviposition and fresh tunnelling by the moth larva once they are greater than 20mm diameter, and (right) releasing the egg parasitoid around the spray schedule downwind.*

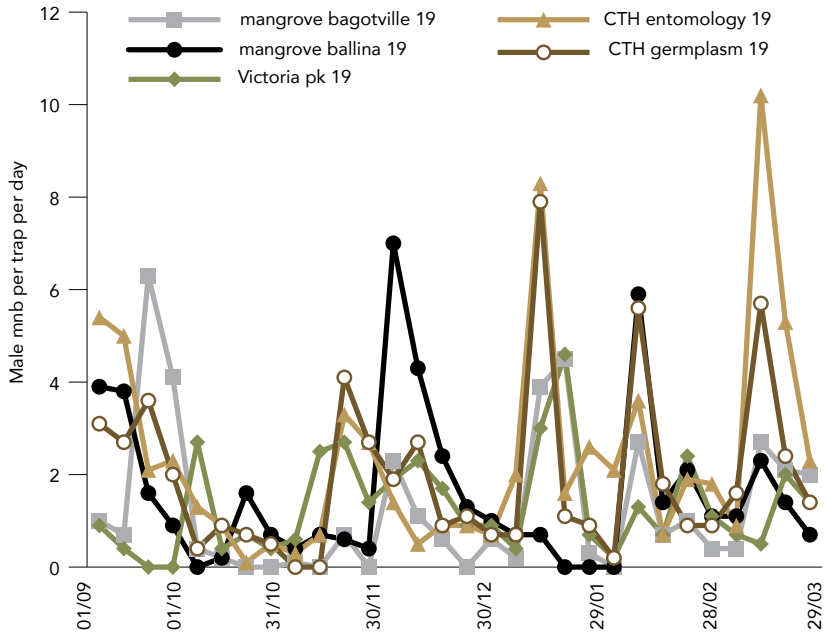

Figure 4 shows the daily male MNB moth catch rate for the 2019-2020 season between September 1 and March 30. The traps are placed in the estuary mangroves to the east and south of the plateau, the southern edge of the Alstonville plateau at Victoria Park, and the macadamia orchards at the Centre for Tropical Horticulture Alstonville, showing the way the population changes.

orchard unmated. The pheromone paste then attracts and kills the male moths and prevents their further mating, resulting in infertile eggs. However, if the moths mate before they get to the orchard (such as in the mangroves), then the egg laying when they arrive in the orchard is not affected.

Table 1 shows the male *Cryptophlebia ombrodelta* (MNB) flight trapping sum ranks for each season from 2013 and 2020 between September 1 and March 30 on the Alstonville plateau and the neighbouring estuary. Traps are placed at 4 m in the tree canopies and 2 m above the high tide mark in the rivers. MNB tunnels /100 nuts examined in March the following year for the standard beta-cyfluthrin sprayed trial plots at the Centre for Tropical Horticulture Alstonville except for 2013 (single tree plots*) show the impact that MNB had on the crop from flight at those levels into the area.

Our experience has been that the wasp colonises quickly when released around MNB prone areas in orchards once the nuts reach 20 mm diameter and egg laying is detected. If in doubt, we often added the gravid female MNB when we released, to make sure there was plenty of fresh eggs about to stimulate the population. The MNB risk period runs from late November to crop maturity. Re-establishing them after high temperature periods may become a priority in some areas.

Table 2: Green husk examinations under 10 X magnification of 30 macadamia nuts samples from the 2020/21 season, collected at CTH Alstonville Front Block (246 and 816) after spray applications (12 L per tree in 8 m canopies) were made 18/12/20 and 25/1/21. Data is numbers of nuts with MNB tunnels, more than 25% thrip damage to husk surface, or more than 10 felted coccid present on the husk.

Recent changes in pest pressure from *Leptocoris* sp. on the Australian macadamia crop, which unfortunately shows a level of tolerance to beta-cyfluthrin, may be the reason for perceived failures in the MNB control. Growers in the central Queensland and Gympie areas have been treating that new problem with Trivor® which does not impact on the moth larva as much as beta-cyfluthrin (Table 2).

In NSW, we only had issues with *Leptocoris* sp. in 2019-20 with the extreme drought conditions and MNB was not as active compared with this current season. The correct spray timing which needs to coincide with the egg lay of the first summer generation uses beta-cyfluthrin for fruit spotting bug and macadamia nut borer, and

Site host	Germplasm macadamia	Entomology macadamia	Victoria Pk longan	Ballina mangrove	Bagotville mangrove	MNB tunnels/ 100 nuts
2013	14.5	19.9	25.4			48.0*
2014	15.6	9.3	15.9			
2015	18.9	3.9	15.1			4.0
2016	29.1	26.0	27.0			7.1
2017	35.7	35.8	27.3	52.3	53.0	3.0
2018	22.8	18.7	21.6	14.3	14.3	3.8
2019	45.2	54.7	33.9	35.5	26.3	11.0
2020	40.4	50.8	54.5	50.7	32.6	16.2

Table 1

Sampling 1/03/21	plots	Nuts examined	MNB tunnels	Tunnels/ 100 nut	Thrip damaged	Felted coccid
Transform® 0.4ml/L	4	120	58	48.3	43	1
*Sivanto® 1.0ml/L	4	120	39	32.5	27	3
Trivor® 0.4ml/L	4	120	54	45.0	40	3
Bulldock® 0.5ml/L	4	120	14	11.7	53	10

* Sivanto does not have a general registration for use in macadamias at this stage.

Table 2

then wasp releases to remove the carry over within the orchard. This has worked well at CTH Alstonville for 20 years.

We have also seeded the mangrove districts with wasps, timed on the spring generations in September/ October/ November to try and reduce the levels that are flying into the plateau. Over the past two years, we have had more moths than usual and tunnelling has increased with the wet weather, starting in January 2020 and continuing right through until June 2021 (Table 1).

The highest flight periods we have measured were in December 2016 at three times normal levels, which did damage the crop and we were not releasing wasps down in Ballina. Since then, the weather has been extreme so plagues are common. Our ability to respond becomes more challenging for some biocontrol options lagging behind the pest populations. We want minimum applications to deliver the crop quality required but sometimes the climate works against that.



Craig Maddox and Ruth Huwer from NSW DPI check MNB traps in the Ballina mangroves, a common breeding ground for the pest.

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IPM in macadamias – not one strategy but different options

Dr Ruth Huwer, Research Entomologist, **Craig Maddox**, Technical Officer Entomology, **Jeremy Bright**, Development Officer, Macadamia, and **Matt Adkins**, Leader Northern Horticulture, NSW DPI Wollongbar **E:** ruth.huwer@dpi.nsw.gov.au

The project "IPM Program for the Australian Macadamia Industry - NSW DPI component" is now in its final stages. What have we learned after four years of field trials?

It was important to have case study sites in the main growing regions for macadamias and all sites have adopted some level of IPM through a combination of different management tools. The pest issues of each case study site are different. Therefore, there is not one single recipe for an IPM strategy that suits all farms. However, there are certain components that are key IPM strategies for macadamia farms. These include:

1. **Monitoring:** Monitoring is a cornerstone of any IPM strategy. It is important to have an understanding about the population dynamics of different pests and beneficials. A monitoring protocol was developed in collaboration with pest consultants overseeing the case study sites in the different regions. The adoption of monitoring of beneficials and pests using yellow sticky traps, macadamia nutborer (MNB) pheromone traps, monitoring of MNB eggs, spotting bug monitoring hedges, banana-spotting bug (BSB) pheromone traps, pheromone traps for different scolytid beetles (bark beetles, branch borers and pinhole borers) was part of the IPM strategy for all case study sites.
2. **Cultural control:** Cultural control measures as part of the Integrated Orchard Management are most important for increasing orchard health and resilience. This includes tree height and canopy management. Canopy management was applied as it is important to keep the orchard open and ensure good coverage of chemical applications. Further cultural control measures included on our case study sites were hygiene for the management of macadamia seed weevil (i.e. removal of infested nuts on the ground) and growing interrow crops to increase biodiversity and presence of general predators and parasitoids.
3. **Biological control:** Releases of biological control agents *(Anastatus sp. and/or Trichogrammatoidea cryptophlebiae)* were made on all case study sites. As mentioned above, the encouragement and preservation of natural enemies also plays a part in this.

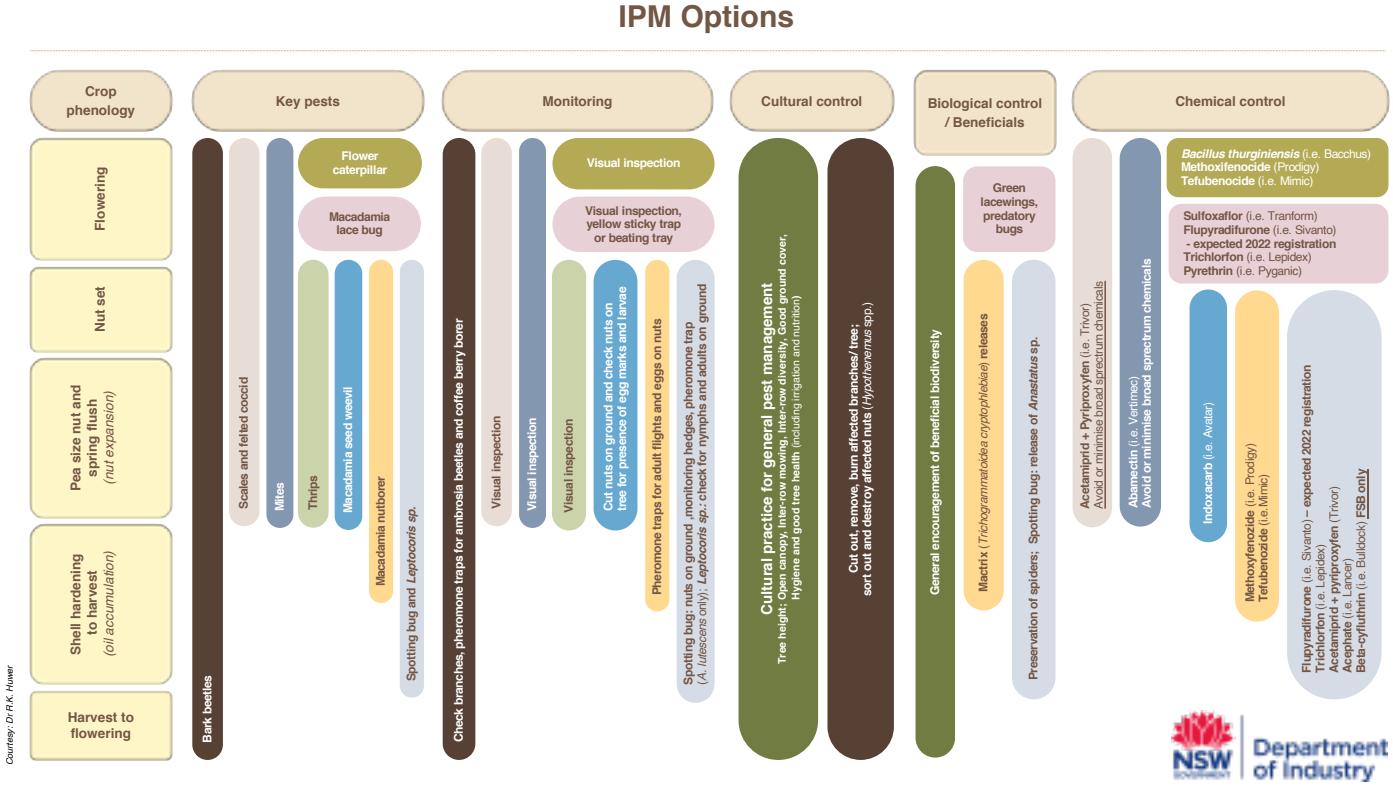

Figure 1. Illustration of IPM options, showing different choices of management tools for key macadamia pests

4. **Chemical control:** Strategic use of more specific chemicals on the basis of monitoring (rather than calendar spraying), compatible with biological control and minimising use of broad spectrum insecticides, was implemented on all case study sites. This also included the use of new chemicals like sulfoxaflor (Transform®). A rotation of groups of chemicals to avoid secondary pests is also important.
   - Our IPM strategy does not exclude broad spectrum insecticides completely, but we recommend they are only used when absolutely necessary for some of the key pests.
   - Chemical options are always subject to change, as different pests become important, registration/ permits for old chemicals are not renewed and new chemicals are registered.
   - The main aim of an IPM strategy with regards to chemical control is to avoid or minimise broad spectrum insecticides that may have negative effects on beneficials.
   - The key pest in all macadamia growing regions is fruit spotting bug (FSB), so FSB management is the main driver of the IPM program. With such a difficult and important pest, it is generally not possible to completely avoid broad spectrum insecticides. The important issue is to use pesticides strategically, at the optimal timing and with good coverage. Different chemicals are required over a season for resistance management and the chemicals that are least disruptive should be used wherever possible. Again, using FSB management as an example, softer options should be applied early in the season and broad spectrum options should be delayed until the end of the season.

An illustration for an IPM strategy is shown in Figure1. The diagram lists key pests for the macadamia industry, monitoring techniques, general cultural control practices, biological and chemical control options. For resistance management there is more than one option, particularly for pests that need more than one treatment per season (i.e. FSB).

The different tools applied for different key pests across the different case study sites are shown here in an example, using a summary for season 2019/2020 (Figure 2).

When deciding on pest management options, it is important to relate these to:
1) the general impact on beneficials, and
2) the impact on yield.

For each harvest season we compared the relative success of the pest management strategy at the case study site based on yield. Figure 3 considers the macadamia yield from the 2018/2019 season as it relates to the pest management strategy implemented and its impact on beneficial insects (IPM score).

Due to the study design, no statistical analysis could be made on the relationship between yield and IPM score. However, when summarising the results for the six sites with available yield data (2018/19 season), three of the four highest yielding sites used pest management practices that would be considered high impact (negative) for beneficial insects. Study sites that had low impact scores (case study sites 5 and 7) had highly contrasting yield results. Study site 5 produced ~1.5 t/ha while study site 7 recorded the second highest yield with 3.8 t/ha. The results from case study site 7 are promising in that valuable returns (t/ha) can be achieved through low impact pest management strategies.

However, case study site 5 suggests that it is not without risk.

None of the remaining four case study sites (all with IPM scores > 30) produced yields of less than 2.5 t/ha. When looking at these results we need to keep in mind that we are only looking at one season. We need to apply this analysis to all seasons of the study to get a better picture and draw final conclusions.

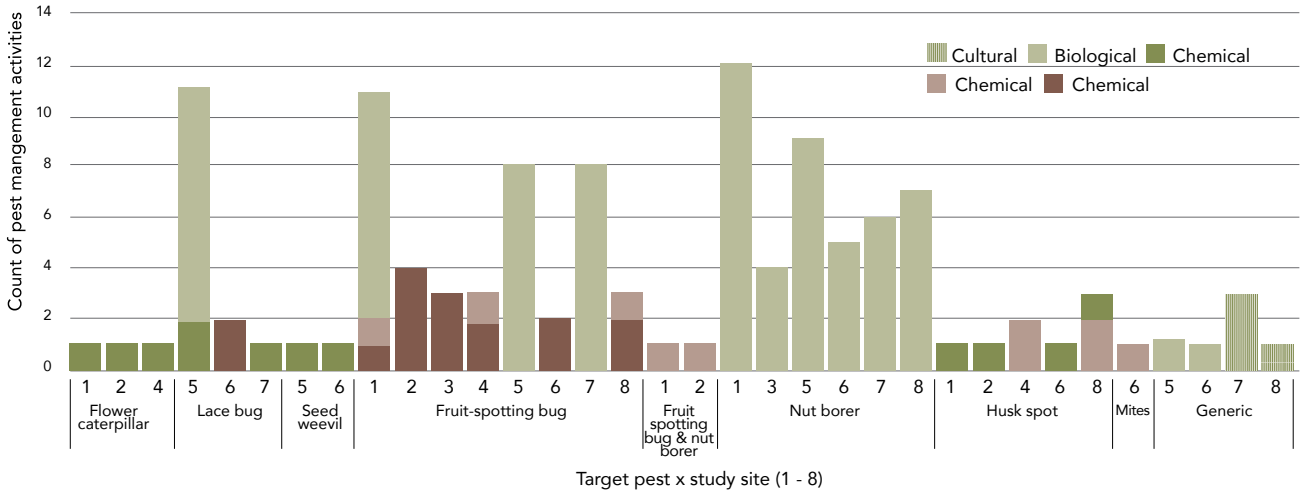

Figure 2. Summary of pest management activities (cultural, biological or chemical) utilised to control specific pests by case study site during the 2019/2020 season. The different colours (green, brown and beige) refer to the impact of each activity on beneficial insect populations i.e. green has minimal impact, beige potentially some negative impacts, brown significant negative impacts on beneficial populations.

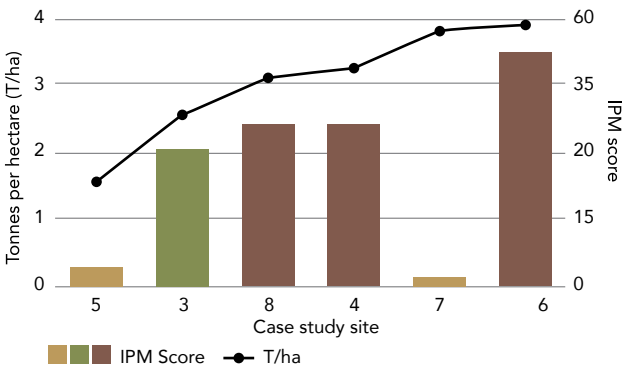

Figure 3. Summary of the yield (t/ha) produced at six of the eight case study sites (sites 3 to 8) from the 2018/2019 harvest season and the impact of pest management activities on beneficial insects (IPM score) in achieving this yield. The IPM score displayed is the sum of all activities at each site using the following scale: low impact activity (Gold) = 0.1, moderate impact activity (Green) = 5, high impact activity (Brown) = 10.

As part of our preliminary analysis of data, we explored results for the 2019/2020 season from the trial at the Centre of Tropical Horticulture (CTH) Alstonville. We investigated the correlation between FSB damage with yield and the presence of selected beneficial insects (wasps, spiders, assassin bugs, micro-wasps, ants and ladybird beetles). This analysis needs to be made for all seasons of the project to draw definite conclusions.

However, preliminary major findings were:

- the correlation between FSB damage and yield was very weak (R^2=0.02). This result suggests there are many more factors other than FSB that influence crop yield.
- there was a very strong correlation between FSB damage and wasps (R^2= 0.9950), assassin bugs (R^2=0.8182) and spiders (R^2=0.8086).
- the correlation between FSB damage to kernels and micro-wasps was moderately strong, (R^2=0.5996), although very weak with ladybird beetles (R^2=0.1204) and ants (R^2=0.0485)
- the data therefore indicates that wasps in general, assassin bugs and spiders are most likely to be useful beneficials with regards to FSB. Further work is to be done this year to verify these findings and to classify the wasps and micro-wasps according to species.

Conclusion

- There is no one size fits all IPM solution. There are a number of options that need to be considered and the options taken need to suit the individual farm and the season and align with the resources available.
- Key points for any IPM strategy are monitoring and knowing the orchards.
- There are different levels of IPM strategies used that are on a sliding scale. A ranking of IPM options would be helpful for comparing different strategies and illustrating to growers where a management strategy sits on the IPM scale.
- As a bottom line, the impact on beneficials and environment, as well as yield needs to be considered.
- It is more complex and takes more effort to apply a pest management strategy that has lower impact on beneficials.
- Key pests are driving any IPM strategy.

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The changing face of macadamia inter row management

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Conventional vegetation management in the macadamia orchard inter row typically focuses on macadamia tree nutrition and management, access and harvest, weediness and possible rat hides. The upshot is heavy mechanical and chemical management of ground cover, which limits vegetative species diversity and the presence of vegetation overall. This can in turn erode a number of key ecosystem services associated with soil health, pollination and pest regulation. In time, the consequences of these on-farm vegetation management decisions can be detrimental to the longer-term profitability, productivity and sustainability of the orchard. Is there another way?

Cover cropping is one option and it is being trialled and incorporated into industries ranging from dairy to vineyards. It is a "non-economic" crop that is carefully selected for functional ecological traits, which can regenerate and sustain farming systems.

For example, a number of plant species are selected for their root structures and can be grown to break up compaction and clay pans, improving water penetration and nutrient cycles.

Likewise, plant attributes can help in conservation biological control by providing habitat and specific nutrients needed for reproduction and survival of beneficial insects. For instance, different species and types of plants have different insects associated with them, so insect composition will change with the stage of vegetative growth and attributes such as hairy leaves or height as well as flower structure and relative amounts of pollen and/or nectar.

Larger pollinators such as European honeybees will tend to seek larger flower structures, whereas smaller native honeybees such as *Tetragonula* and *Austroplebeia,* which are less than 4 mm long can take advantage of smaller flowers. There is also correlation between abundance of flowers and types of bees attracted. Insects that are highly mobile and require a lot of energy such as a hoverfly, require regular amounts of nectar. Some parasitoid wasps require both nectar and pollen, and some egg parasitoids use only nectar for increased survival and fecundity.



A cover crop in the inter row of a new macadamia block in the Bundaberg area, in August 2021. (Photo: S. Zunkel)

Insects that eat cover crop plants provide important nutrient recycling to the soil and help in growth of new and/or surrounding plants. The insects eating the plants are similarly consumed by carnivores (predators and parasitoids), which increases the food web structure in the farming system. The health, variety, structure and longevity of cover crops are all factors influencing the degree and diversity of predators and parasitoids.

As these and numerous other examples indicate, there is very good evidence available establishing the various benefits arising from the incorporation of cover crops into farming systems. Where conventional farming practices tend to simplify the ecology of farms, it makes them vulnerable to unpredictable risks such as temperature and weather extremes and changes in insect populations.

Cover crops by contrast, can restore complexity, providing multiple pathways for ecosystem services, whether that be soil organic matter or pollination. This in turn invests in farm resilience.

Bundaberg growers start trialling cover crops

Given that there are clear benefits to adopting practices like cover cropping and there are a growing number of cover cropping success stories in many industries including macadamias in northern NSW, can it be done in the Bundaberg region, particularly in new blocks under development?

To find out, a number of Bundaberg growers have recently begun to trial options for cover crops in



Varieties of daikon and tillage radish are common additions to seed mixes because of a number of soil benefits associated with their powerful tuber root. This specimen has been growing in a pasture mix in the Bundaberg area in autumn 2021. Note that the tuber is bent, where the root has encountered a clay pan but continued to grow through time. (Photo C. Scott).

the inter row. There are some genuinely impressive results evident for some growers in terms of seed establishment, improved vegetative diversity, soil benefits and an improved presence for beneficial insects. Other growers have seen fairly limited results in terms of establishment following on from seeding.

While the successes give reason for cautious optimism, the challenges have been perhaps more instructive. Take for example one trial block where inter row cover cropping occurred within the context of a major site development for new tree plantings.

The objective was to plant out a spring seed mix in October 2020 with cover crop species likely suited to the site to improve basic plant species diversity in the inter row. The seed mix included sunflower, sorghum, couch and tillage radish.

The decision to seed followed immediately after the completion of site development and tree planting in the trial block area and also the first rain (24 mm) on-site after a prolonged dry period. The extent of heavy soil disturbance in the preparation of rows, v-drains and so on was extensive, as would be expected for large-scale farm development. In the trial block area, there were areas of either clay pan or heavy sands with no ground cover present. The area was subject to wind and there was no irrigation in the inter row.

The adverse site conditions during the life of the trial resulted in a low establishment rate overall. Despite this, all species in the seed mix were observed growing across the trial area, indicating that the objective for increased plant species diversity in the inter row can be revisited in future seeding, once overall site conditions (soil compaction, soil moisture) improve after the site development phase.

The low establishment rate of plants influenced the diversity and numbers of insects, as well as the seasonal conditions. Certain predators like lacewings that are strong dispersers were found (feeding off aphids), but there was a lack of ants, bees and wasps as well as flies.

Flies are important in decomposition. Some can be pollinators (hoverflies), predators (robberflies) or parasitoids (phorids) and they are usually diverse in ecosystems. The general lack of parasitoids may be due to there being less insects for them to feed on and like the cover crop, they had not established well.

What have we learned so far?

It is early days yet for cover cropping in the macadamia inter row in the Bundaberg region, but lessons learned to date make it very clear that there are two major initial considerations to be addressed by interested growers.

Firstly, in terms of soil moisture, is it preferable to proceed opportunistically following on from suitable seasonal rainfall? Or is it best to incorporate irrigation into the inter row?

Secondly, what is the current condition of the soil in the inter row? One of the primary objectives for cover cropping is to improve soil health, but it is quite likely that the soil in new blocks generally and the inter row specifically is in a poor, degraded or in some way compromised condition, including clay pans.

It can be asking a lot of a cover crop in the initial seedings to establish and thrive under these conditions. Are there options for incorporating organic matter into the inter row with mulch, mill mud or mowing as part of a seeding schedule?

On the basis of these early outcomes, BioResources has begun working with interested growers to review seed mixes best suited to their farm and the region. A seeder is available at a nominal fee for growers ready to trial cover crops in their inter row. The team will also be contributing to "farm walks" for growers interested in seeing cover crops in action.

Looking further ahead, BioResources will be building a picture of ways in which cover cropping in the region contributes to soil health, pollination and pest regulation as part of an IPM program. We will also be considering the ways in which areas for insectaries and native vegetation can contribute to ecosystem services.

For more information on this project, see:
http://www.bioresources.com.au/inter_row_project/
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The BioResources team will be speaking at AusMac 2021.



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New insights into the cause of AVG syndrome in macadamia

MCM Zakeel and Associate Professor **Femi Akinsanmi,**
Queensland Alliance for Agriculture and Food Innovation, Centre for Horticultural Science,
The University of Queensland, Brisbane **P:** 07 3443 2453 **E:** o.akinsanmi@uq.edu.au

Abnormal vertical growth (AVG) is a serious threat to the Australian macadamia industry. Although AVG incidence was attributed to certain soil properties, previous studies have been inconclusive about the cause and showed AVG is spreading in areas with different soil properties. This PhD study by Mohamed Zakeel has dismissed previous hypotheses and proposed a soil-borne bacterium as a prime candidate causing AVG. Variations in host resistance is not based on the origin of cultivar selection, but rather it is due to the genomic composition of the cultivars, particularly for those containing a high proportion of *Macadamia tetraphylla* genome. It is imperative for future research to determine the relative risks of the bacterium in macadamia orchards, prove its effect on trees and develop strategies to manage and prevent the spread.

AVG is characterised by alterations in tree architecture (Figure 1). Symptoms are expressed as upright growth with limited lateral branching, reduced flowering and nut set. AVG trees tend to have smaller leaves and a few axillary buds. AVG symptoms tend to be very pronounced after extreme dry weather events. Previous studies have shown AVG is spreading, and it occurs in most macadamia growing regions in Australia. AVG trees currently occupy over 4% of macadamia production areas[1, 2, 3].

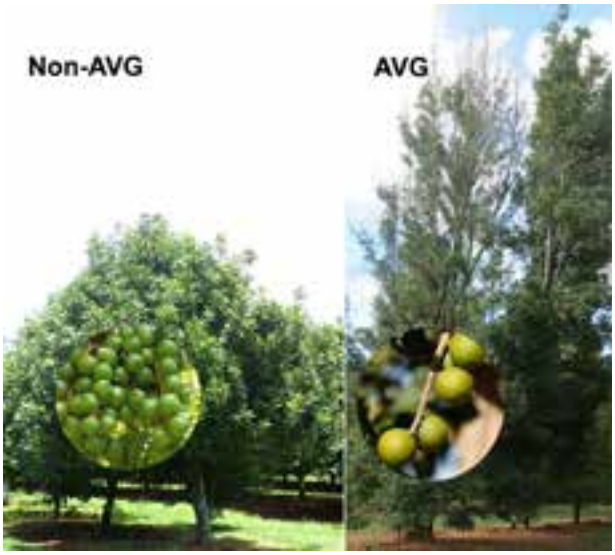

Figure 1. Healthy (non-AVG) and AVG macadamia trees. Relative yield produced by the trees is indicated by number of nuts shown in the circle.

The impact of AVG is very serious, resulting in over 70% yield loss in most years, increased management costs from clearing frequent broken branches, and extra farm operations to induce flowering. There are substantial economic impacts to affected growers and the removal of mature trees due to AVG reduces farm and industry productivity in the short to medium term. It is estimated that the industry loses over 2,000 tonnes of nuts-in-shell per year due to AVG [2].

Due to lack of progress in determining the cause of AVG, a **PhD study** by **Mohamed Zakeel** (supervised by Associate Professors Femi Akinsanmi and Andrew Geering) at The University of Queensland was established to investigate the cause of AVG syndrome in macadamia. Specifically, the study:

a. examined the pattern of spread of AVG as an indication of the nature of its spread caused by biotic or abiotic agents
b. tested previous hypotheses that either *Bacillus megaterium*, a geminivirus or a phytoplasma is the cause of AVG
c. explored correlations between the presence of fungi or bacteria and AVG symptoms, and
d. identified genetic markers that are associated with AVG resistance in macadamia.

Risk and pattern of spread

AVG trees are clustered and the pattern of spread is more commonly along the rows than between rows. As more trees become infected, the aggregated pattern of AVG expands over time, regardless of orchard size (Figure 2). It is estimated that AVG spreads at a slow rate of 2% increase per annum, under normal conditions (Figure 2). Due to the pattern and rate of spread, we ascertained that AVG is not transmitted by highly mobile insect pests such as aphids and leafhoppers that are often vectors of viruses and phytoplasmas. Also, we found that AVG is not transmitted by fungal or bacterial pathogens that produce profuse number of spores. We stated that AVG is most likely transmitted by root grafting, root-to-root direct contact, or vectored by very slow moving organisms[5].

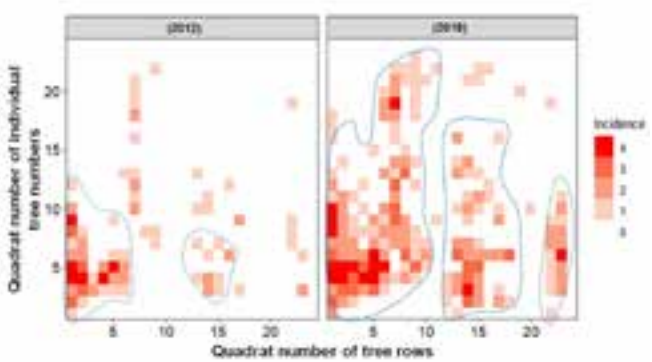

Figure 2. AVG incidence is spreading along the rows and the affected areas are expanding over time in a commercial macadamia orchard in 2012 and 2018. Each square consists of four trees and blue lines demarcate the clusters of AVG trees. The colour range indicates number of trees out of the four tree per quadrat with AVG symptoms.

Previous unconfirmed hypotheses of casual agents of AVG

Previous studies have already ruled out soil nematodes as a cause of AVG[3]. Soil physical and chemical properties were found not to directly cause AVG, but they may accentuate the expression of AVG symptoms. AVG trees are found in all diverse soil types with varied physical and chemical properties[1]. However, it has been suggested that soil water stress condition is a trigger for AVG symptom expression[1].

This PhD research evaluated the likelihood that any of the three previously suggested putative pathogens (*Bacillus megaterium*, geminiviral elements or phytoplasma) as putative causal agent of AVG in macadamia[4]. Using existing and new molecular assays developed in this study, we detected *Bacillus megaterium* and geminiviral elements in samples with and without AVG symptoms. We did not detect phytoplasma in macadamia samples with and without AVG. The absence of phytoplasmas and the detection of *Bacillus megaterium* and geminiviral elements in the trees with and without AVG symptoms suggests that they are also not the cause of AVG. The geminivirus in macadamia is new and integrated in the plant genome. We have developed the genome of the macadamia geminivirus and confirmed it has ancestral association with macadamia. The geminivirus cannot incite any diseases in macadamia.

Detecting and isolating fungi and bacteria associated with AVG

Two different approaches (culturing techniques and DNA metabarcoding) were used to profile the microbiomes in trees with and without AVG symptoms. The results using both approaches revealed no fungal species was unique to trees with or without AVG symptoms, leading to the conclusion that AVG was unlikely to be caused by a fungal pathogen.

The presence of the bacterium - *Serratia* - was reported for the first time in *Macadamia* and its exclusive presence in roots of AVG trees, which indicates that this bacterium is a prime candidate for causing AVG. The bacterium is known to reside in the rhizosphere, which is the zone of soil surrounding a plant root, and able to manipulate plant hormone balance. On the basis that *Serratia* was only found in AVG trees or macadamia roots in soils from AVG sites and its potential characteristics in controlling plant growth in soils or in plant roots, we concluded that it is a prime candidate for causing AVG.

Genetic markers associated with AVG resistance

Using a genomic approach, this study discovered 10 genetic markers that correlated with AVG resistance. We confirmed that AVG resistance trait is not based on the origin of selection of the cultivars but on the percentage composition of the genome of *Macadamia* species in the cultivars.

The results showed that a few loci associated with AVG resistance appear to be derived from the genomic introgression of *Macadamia tetraphylla* through interspecific hybridization. Cultivars A16, NG8, A199 and A538 with no AVG symptoms or yield reduction that exhibited resistant reaction to AVG, possess 30 – 50% of *M. tetraphylla* genome.

In contrast, the cultivars HAES 781, HAES 344, HAES 804, HAES 741, HAES 816, A38, Daddow and Own Venture that showed susceptibility to AVG, contain 100% *Macadamia integrifolia* genome. The genetic markers associated with AVG resistance trait can be used for screening of germplasm in breeding for AVG-resistant cultivars.

Future work required

The PhD study has provided a prime candidate as the causal pathogen of AVG in macadamia. This should help to focus future research to:

- confirm the prevalence of the bacterium in macadamia orchards with and without AVG
- establish the effect of the bacterium for its ability to alter plant growth and effect on flowering in macadamia
- establish the transmission process via grafting experiments
- map the resistant trait loci for screening and breeding purposes
- establish a management strategy.

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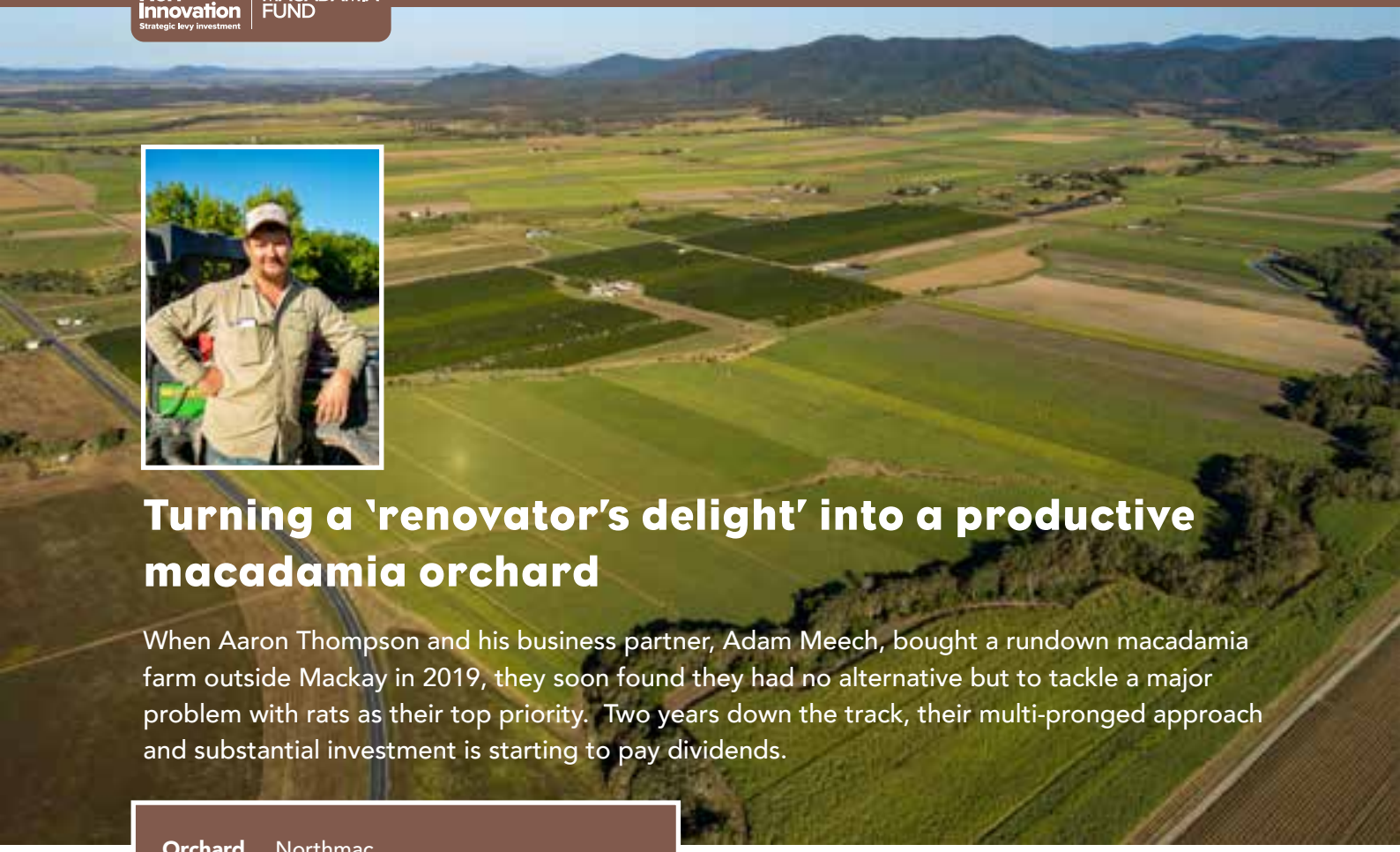

Turning a 'renovator's delight' into a productive macadamia orchard

When Aaron Thompson and his business partner, Adam Meech, bought a rundown macadamia farm outside Mackay in 2019, they soon found they had no alternative but to tackle a major problem with rats as their top priority. Two years down the track, their multi-pronged approach and substantial investment is starting to pay dividends.

Orchard	Northmac
Owners	Aaron Thompson and Adam and Tracy Meech
Location	Oakenden, south-west of Mackay, Queensland
Total size	112 ha
Cultivars	A203, 246, 741, 816 and 842 planted at 6 m x 2.5 m spacing.
Soils	Sandy loams

Aaron Thompson and Adam Meech plan to expand the orchard by planting another 13,000 trees over the remainder of the farm.

Aaron Thompson and Adam Meech knew they were buying 'a renovator's delight' when they acquired Northmac at Oakenden, outside Mackay, in October 2019.

While the two both grew up in Bundaberg, escalating farm prices forced them to look further north around Mackay when they decided to buy their first macadamia farm.

"Farm prices were astronomical when we started looking around Bundaberg, and despite the fact that the orchard had been neglected for some years, we saw its potential, given the right inputs," Adam said.

"Even though we are new to the macadamia industry, Aaron is a real estate agent and an electrician by trade and I have built sheds on a number of macadamia farms and processing facilities as a commercial builder, so our practical experience is a big advantage.

"I have completed many construction projects for Hinkler Park Plantation and Costi Farms and have learned a lot from industry leaders like Phil Zadro and Peter Costi. Peter has been very generous with his advice and assistance through this journey with us."

Within days of acquiring the orchard, Aaron and Adam realised that more than 80% of the orchard was not receiving any water because the irrigation system hadn't been properly maintained for years.

"The remote irrigation system underground wasn't working and the driplines were extensively damaged. It was clear we had a rat plague on our hands, so we had to focus our efforts on getting rid of those pests," Adam said.

"The orchard had been neglected for some time, so the grass was overgrown in most areas and orchard hygiene was really poor.

"By my estimates, we had 5,000 rat nests on the farm, about one in every six trees, and 50% of our yields were eaten by the rats. The previous owners harvested only 15 tonnes of nuts that year.

"We had no choice but to put in as much money and effort as possible controlling the pest, starting at one end of the orchard and working through to the other."

As well as doing his own research on rodent management, Adam sought advice from several advisers including their grower liaison officer and an agronomist at their local farm supplier.

He and Aaron tackled the problem head on, using a multi-pronged approach including:

- equipping two staff with poles to knock the rat nests out of the trees



Shells on the ground show signs of recent rat damage. The distinguishing features of rat damaged shells are a large hole and an empty shell. There can be distinct bevelled edges and teeth marks.



Corey Pearce, farm manager at Northmac, checks one of the rat bait stations in the orchard, built simply using poly pipe and cable ties.

- modifying two petrol blowers, like the Cheetah rodent control machine, to gas the rodent burrows with carbon monoxide
- flooding the holes with water and covering them with fresh soil
- cleaning up the orchard
- trialling several different rodenticides, including Racumin, Tomcat and Selontra, a new product from BASF, and making their own bait stations.

Adam said the first step meant two employees spent weeks knocking the nests out of the trees, with another crew following behind them gassing the burrows and filling them with fresh soil to get rid of them and make it obvious if there was any more rat activity.

Initially, they trialled the three different rodenticides before deciding on Selontra Soft Bait from BASF, because those baiting stations attracted more rats to feed on the baits and its softer environmental profile on secondary animals.

Dr David Elmouttie from BASF has done extensive studies on rodents and his knowledge and advice in this situation was invaluable.

"David was a great help when he came to the farm and spent some time explaining rodent behaviour and how important it was to clear their habitat, reduce the food sources and control the population," Adam said.

As the baiting program rolled out with the help of several backpackers, they increased the rodent traps from 500 to more than 1,000 around the orchard.

"At the same time, we were cleaning up the orchard because you can't just bait the rats without managing the environment where they are breeding.

"As soon as we were able to mulch and clean up all the old grass and headlands, the natural predators started arriving, including whistling kites and white bellied sea eagles which really helped to clean up the rats."

Another strategy was to use a water tanker mounted on a tractor to flood the holes and then throw an old fishing cast net over the holes to stop the rats running away before getting rid of them and refilling those holes with soil.

"There's 100 kilometres of rows on our farm, so there was a lot to do," Adam said.

"We needed a complete management system in place, and as I've always been told with farming, timing is absolutely critical."

A costly exercise

Adam estimated the cost of the rat management program at more than $250,000, including labour, repairs to the irrigation system, rodenticides, bait stations and crop losses.

"Over the past 20 months, we have had up to five people working full-time on rats, but it has averaged out at two to three full-time workers for the whole time," he said.

"In rough figures, I believe we have put up to 5,000 hours into the rat program, but Aaron and I knew we had to go flat out getting rid of them or else the farm would be a complete basket case.

"Six months into the program, it seemed like we were never going to beat the rats, but we had to keep going to break the breeding cycle. Once we did that and the predators moved in, it snowballed in the right direction, so instead of finding holes every six or eight metres, it became 100 or 200 metres and then whole sections where we couldn't find any evidence of rat movement.

"It's a case study I would have preferred not to do, but we can look back now that we are on the other side."

Importantly, yields are heading in the right direction, up from the 15 tonnes harvested by the previous owners in 2019 to 60 tonnes in 2020 and on track for another significant yield increase this season.

New phase begins

With rats under control and the irrigation system replaced, Aaron and Adam say they are putting the repair and renovation phase at Northmac behind them to start farming.

Their priorities are improving the health of the orchard through practices such as spreading organic matter with the purchase of a new bulk spreader. They also intend to expand their existing orchard by planting another 13,000 trees over the remainder of the farm.



Surprise! Snakes sometimes find the rat bait stations a convenient place to sleep in winter.



Northmac is expecting significant increases in yield this season, now that the rats are under control.



Northmac's farm manager, Corey Pearce, takes a break with Ronan Madam in the orchard in between refilling rat bait stations with Selontra and harvesting.

"We are keen to get the orchard up to where it should be and plant the remaining section," Adam said.

First developed in 2008 and 2009, the orchard was planted to more traditional varieties such as A203, 246, 741, 816 and 842 on a 6 m x 2.5 m spacing.

"The trees are very close by today's standards and we were advised to remove every second row, but Aaron and I decided to continue pruning correctly and see how it unfolds," Adam said.

"For the first time this season, we have been able to separate all five varieties at harvest and get reports back on how each one is performing, so we will be analysing this data before deciding whether to plant any new varieties.

"We will probably stay with what we know, recognising that there is not a lot of research on varieties for this region. Peter Costi's advice is to pick two or three of our best performing varieties and stick with them.

"We are getting great kernel recovery from 816 and 842, but their fruit production is no match for A203 or 741, which are staple varieties."

Adam said wet weather was likely to be an ongoing challenge.

Comparing growing conditions in Mackay with Bundaberg, he said flowering and harvesting generally occurred three to four weeks earlier.

"Long-term records show Mackay's annual rainfall averages 1,550 mm, more than Bundaberg, so our harvest strategy will be to harvest the wettest areas of the orchard first, so those areas are done when the rain arrives," Adam said.

"Our place is on a sandy loam which is easier to manage in wet conditions. The grass grows quickly up here, so there is plenty of grass coverage on the orchard floor and good drainage.

"People talk about cyclones, but the worst damage I've seen around macadamias is from hailstorms. Our tightly spaced trees might even have an advantage in cyclonic conditions."

Adam paid tribute to Corey Pearce, their farm manager, and two employees at Northmac.

"We are fortunate to have such a good team, and with Aaron more involved in the production side, he makes sure the timing of every operation is spot on.

"It's the best way of making the most of all our inputs."



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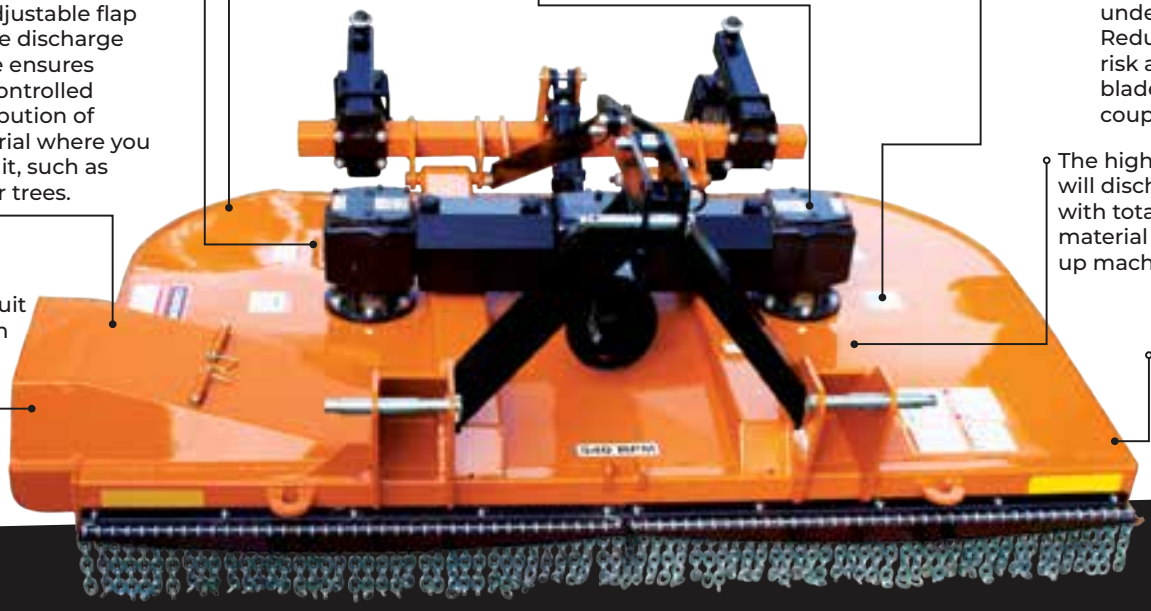

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For any orchard to effectively manage rodents, a season long integrated management approach is fundamental to success.

Strategies to manage rodents must be developed and aimed at reducing alternative food resources and nesting sites, ensuring nuts are harvested as quickly and regularly as possible, maintaining hygiene throughout the orchard system and considering conducive varieties to rodent damage when establishing new plantings. However, once rodents do establish an effective, targeted baiting and eradication program needs to be implemented to quickly reduce numbers and reduce crop losses.

Implementing a baiting program

Within orchards baiting programs should be developed strategically and target known areas of rodent activity. Growers should become familiar with areas of the orchard where damage is more prevalent and identify early signs of activity, whether that be tree nests, burrows or damaged nuts.

Using an expression we have become all too familiar with when rodents are located within an orchard the key is to ***"go hard and go early"***, before they establish. It is also imperative that rather than spreading limited baiting resources around the entire orchard system, growers focus on key blocks which have suffered rodent activity previously and ***"go hard"***.

Early, pre population establishment rodent baiting will likely mean that activity is captured early in the season and that rodents are most active in the tree canopy, as nuts have yet to fall. Therefore, rather than applying baits on the ground layer of the system, strategic placement of baits within the canopy is recommended. As the season progresses, baiting on the ground may become more effective as the proportion of nut on ground vs nut in tree changes, bringing more rodents to the ground. However, it is likely that if baiting is left to this stage of the crop cycle, effective control will be difficult to achieve and damage for the season will be high.

Using bait stations is critical. They are a legal requirement of registered bait products and are essential to increase bait acceptance and maintain



bait freshness. Baits should be secured within bait stations ensuring they are kept off the base of the bait station using the securing rods provided. In stations where securing rods are not provided, a wire tie should be used to keep baits elevated – this maximises the longevity of baits by minimising spoilage resulting from water and rodent urine.

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

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Selontra Soft Bait Rodenticide is a unique non-anticoagulant rodenticide which was first registered for use in Australian macadamia orchards in 2019. This innovative rodenticide solution is neither persistent nor bio-accumulative and contains stop-feed technology which results in reduced bait wastage and faster control of affected rodents. The formulation has also been developed to be palatable in the most competitive of environments.

To optimise results, it is recommended that Selontra be applied in conditions where no rain is anticipated for a minimum of 3-4 days – this enhances palatability and reduces spoiling of the bait from prolonged water exposure. Where this is not possible due to an extended period of wet weather, stations should be positioned so that rain and moisture entry into the bait station and particularly, the bait chamber are minimised.

To maximise their palatability, stability and longevity in Australian conditions, Selontra soft baits have been redesigned (since their initial launch) and are now formed in a tighter wrapped square shaped block with a pre-punched hole for securing. This redesign has produced a more user-friendly rodenticide and improved levels of bait acceptance. Growers from northern NSW, south-east Queensland and as far north as Mackay have had great success, with the product becoming an essential tool in any rodent control program.

For more information, contact Mark Wilson, Technical Services Manager, BASF Professional and Specialty Solutions, by email at mark.wilson@basf.com or phone 0408 826 845.

Describing flowering and nut set stages for common ground

Jeremy Bright Development Officer, Macadamia NSW DPI **M:** 0427 213 059 **E:** jeremy.bright@dpi.nsw.gov.au

Before joining the macadamia industry, my experience from other tree crops such as mango, apple, cherry, stone fruit and citrus gave an overview of similar crop development stages even though their final products are very different. The usual descriptors for growth stages in these crops include terms such as bud emergence/ swell, king/ early bloom, full bloom and petal fall/ fruit set.

In contrast, macadamia had defined stages 1 (pre-flower) to 4 (match head) for flower development. Researchers would refer to match head stage or stage 4 as a critical stage for husk spot control. So even early on, stage 4 was often referred to as match head.

Other descriptor stages I have mentioned are relevant because they are stages when pests and disease will be present. An example of this is pea size for fruit spotting bug and macadamia seed weevil, a period where nut shedding occurs.

Standardising these terms is important for consistency within the industry. *The Plant Protection Guide* for macadamia has previously described all the relevant phenological stages relating to growth and includes more easily understood descriptors for bud break through flower and nut development stages.

However, the early stage of bud break will now be included for the first time in this year's edition, due for release in Spring 2021.

One of the challenges for macadamia growers is that several different growth stages may occur within trees at the same time. We are seeing this right now while harvest continues (June 2021). Individual trees have fully mature nut as well as plenty of bud break and a little bit of pre-flower.

However, look for the development stage that most of the trees are displaying to classify the main crop stage. Ask yourself, "what is the dominant stage for the block right now?"



Different growth stages may occur in individual trees at the same time, but look for the dominant stage for the block.

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The growth stages are as follows:



Bud break: includes the emergence of the flower bud tissue from the axil of leaves. Bud break includes early small bud emergence right up until the green raceme is fully extended. Similar stage in other crops: green tip in apples, budswell in stone fruit, blueberries, bud burst in grapevines, bud break in citrus, floral bud initiation in mango.



Pre-flower: includes fully extended elongated green raceme. Buds/ perianth tube along the raceme up to the stage of full elongation. Previously referred to as stage 1 flowering. (Called pre bloom in citrus, pink in apple, flower cluster initiation in grapevines, early panicle elongation in mango).



Early flower: Some bud/ perianth tubes from preflower have started to open, generally starting from top of raceme to bottom of raceme order. Flower will still have some buds/perianth tubes that have not yet fully opened. (Called open king bloom in apple, late pink bud in blueberry, early anthesis in mango)



Peak flowering: most of the tree has fully extended and opened flowers. Formerly described as stage 2-3 flower development. (Called full bloom in apple, peach, blueberry and citrus, full-size panicle maximum anthesis in mango, flowering in vineyards)



Nut set: Pollinated nut is up to and including match head size. The ovary at the base of style is starting to swell up to the size of the "red head" of a match. This was formerly described as stage 4 flowering.



Pea size nut and spring flush: Nut is now expanding from match head size up to pea size 8 - 10 mm in diameter.



Shell hardening and oil accumulation: Nut sizing has ceased and nut is now accumulating oil for maturity and harvest.

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Countering cultural amnesia

Denise Bond, Executive Officer, Macadamia Conservation Trust
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East coast Australia abounds with interesting stories about macadamias, yet many Australians are still surprised to learn that macadamias are our very own nut. Countering this cultural amnesia is an important goal for the Macadamia Conservation Trust, recognising that awareness is the first step towards protection.



Paul O'Hare stands beneath the original H2 tree with DPI tag. (Photo: MCT)

First and foremost is an amnesia towards the relationship of Indigenous Australians with macadamias. European colonists were happy to be shown and gifted edible nuts, but they did not ask and certainly did not record the wealth of knowledge that First Nations had about the different species and their natural and cultural values (apart from being edible).

The Trust is hoping to atone for this appropriation in a very small way by supporting an Indigenous-led project to contact traditional owners of macadamia habitat and talk with them about their cultural and natural knowledge of macadamias.

This project will address whether they would like traditional ecological knowledge about macadamias recorded and stored, and if so, where to store it, how to control access, and what, if anything, can be shared with the wider public. This process has been undertaken numerous times for the retrieval and storage of traditional ecological knowledge associated with an Indigenous community, place or language group, but seldom with a focus on a particular species.

Next is the history of early settlers who also shared and promoted the nuts. Macadamias were sent up and down the coast, with venerable old trees still existing as far south as Camden House near Sydney, and on properties out west.

In 1870 and 1877, the Queensland Government enacted regulations banning the felling of macadamia and bunya trees, to retain food for Aboriginal people and stop macadamias from becoming extinct in the Bauple district.

In the Gold Coast hinterland, an immigrant from Buckinghamshire in England arrived with his brother to take up a selection on the upper reaches of the Nerang River. Jim Hinde named his farm Colliston and according to family lore, used to walk over to Pimpama to visit his fiancée in the early 1880s.

On the way, he passed by wild macadamias and collected seedlings to plant at Colliston. These trees have now formed a dense hedge, but Jim later developed an orchard of both *M. integrifolia, M. tetraphylla* and hybrids, all of which grow wild in the Gold Coast hinterland.

Probably planted in the 1920s, it was effectively one of the earliest breeding trials and soon attracted the interest of Jack Wills, Queensland's Senior Advisor in Horticulture and a great proponent of macadamias.

Jack Wills assessed the trees at Colliston, tagging some and sending off scion wood to grow in various trials, including at the Maroochy Horticultural Experiment Station. In 1960, three varieties from Colliston were assigned cultivar names and registered as sources for



M. tetraphylla *grows out over a viewing platform at Natural Bridge, Numinbah.* (Photo: MCT)



Russell Bennet with Macadamia ternifolia. (Photo: MCT)



Gavin Lerch (Photo: MCT)



Mel Caccianiga (Photo: Ron Caccianiga)

scion wood by the then Division of Plant Industry: H1 Colliston, H2 Hinde and H3 Stevenson.

Sadly, Jim died long before H2 was taken up to become an industry standard, first as a bearing tree and now as the dominant rootstock used by the Australian industry. The tree has been on the Queensland Heritage list since 2008 and listed as a National Trust Significant Tree since 2014 (https://trusttrees.org.au/tree/QLD/Gilston/926_Gilston_Road_3).

Visit the original H2 mother tree

The Trust is organising a field trip to visit Colliston and see the original H2 tree as part of AusMac2021, followed by a walk to the beautiful Natural Bridge at Numinbah, where wild *Macadamia tetraphylla* grow next to the board walk.

The Macadamia Conservation Trust welcomes three new members to its Management Committee. They are Mel Caccianiga, a grower, plant enthusiast and host of the NSW Wild Macadamia Arboretum; Russell Bennet, a Gubbi Gubbi man who is an expert in Gympie district flora and fauna and dedicated to their protection; and Gavin Lerch, a third generation farmer, now macadamia grower and Grower Liaison officer for Nutworks.

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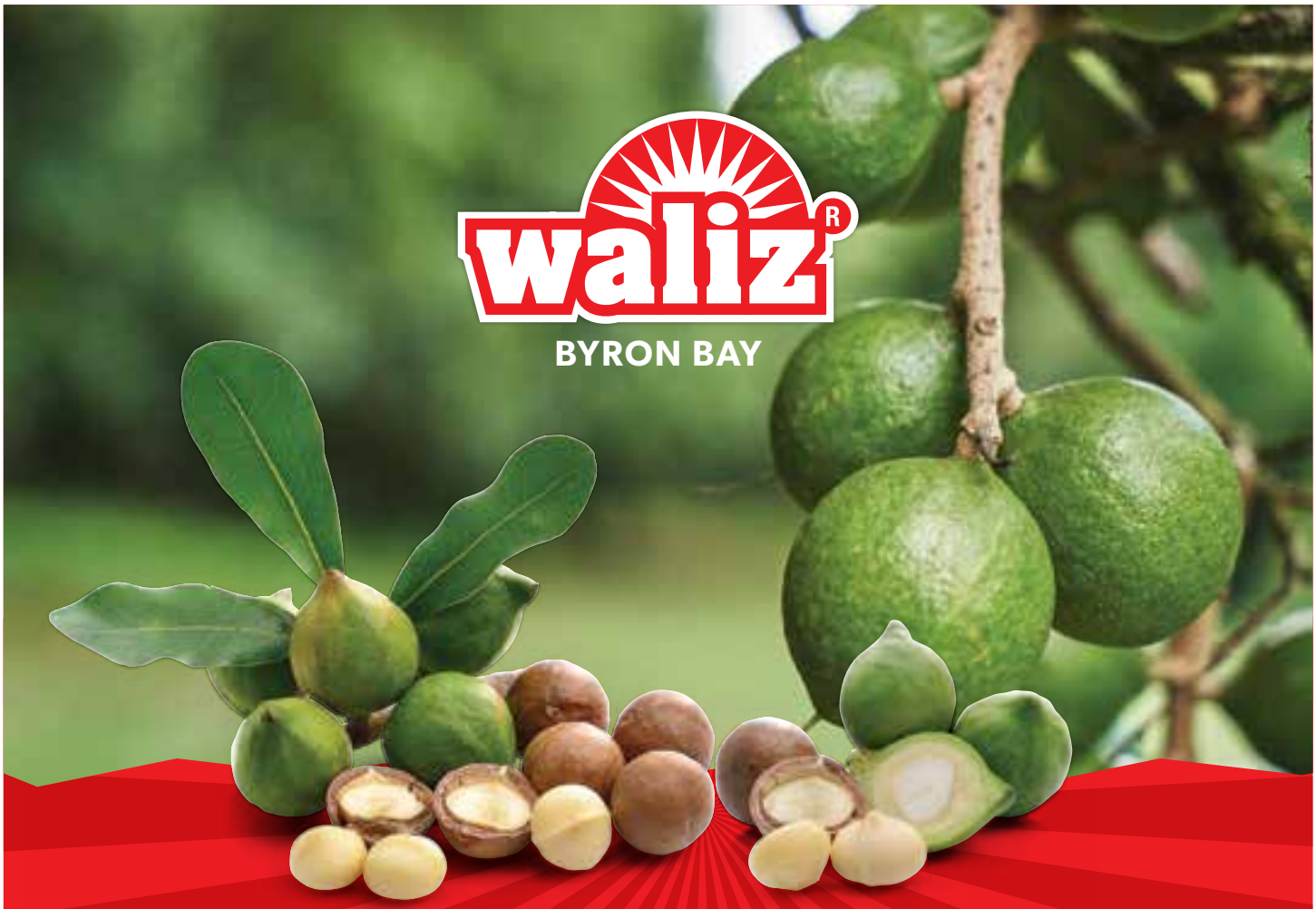

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Macadamia industry supports Reef Certification program

Michelle Haase, Hort360 Facilitator, Growcom **M:** 0428 586 890 **E:** mhaase@growcom.com.au

Macadamia growers in Great Barrier Reef catchments have been working with Growcom on their Hort360 Reef Certification initiative, making significant progress in contributing to Reef water quality improvements. Twenty one macadamia growers have undertaken the Reef Certification module across 24 properties covering approximately 1,000 hectares, with four growers achieving Reef Certification to date.



Emily Zunker from Windhum Farms (left) and Annie Attard, Attard Family Farms, celebrate becoming the first growers to become Hort360 Reef Certified in the Burnett Mary region of Queensland.

Bundaberg local farming families, the Attards and the Zunkers, recently came on board, becoming the first growers in the Burnett Mary region to be Reef Certified. Combined, they have 108 hectares of macadamia orchards Reef Certified.

When asked about their motivation for becoming Reef Certified, Annie Attard of Attard Family Farms explained that this was an opportunity to put pen to paper to capture where their management practices were at.

"We're a stone's throw from the Great Barrier Reef lagoon and have no hesitation in participating in a program like this to demonstrate confidence in our management practices. We have beautiful grassy inter-rows, tail-water dams to capture any runoff, fertigation for precision nutrient application, and soil moisture probes for irrigation scheduling," Annie said.

Emily Zunker from Windhum Farms took on the responsibility of getting their macadamia and sweetpotato farms Reef Certified. Emily found that the certification process undertaken with a Hort360 Facilitator was pretty straightforward and a great opportunity to tighten up their record keeping processes.

When asked about the changes adopted as a result of the Reef Certification process, Emily explained that they've only had to make some minor tweaks to their existing management practices.

"I've migrated the paper based system into online documents, and incorporated the additional records required to be Reef Certified which is calibration of fertiliser equipment and weather data," she said.

Reef Certification is an initiative of Growcom's Hort360 Great Barrier Reef (GBR) program. It is a voluntary certification pathway that enables growers to demonstrate a strong commitment to land stewardship through managing their farms to industry best practice standards.

The process involves benchmarking farm management practices, working through the certification requirements with a facilitator, and then an independent third-party audit.

The audit is only required to be undertaken every three years, and currently the cost of an audit is funded through Growcom's Hort360 GBR program.

Reef Certification focuses on water quality outcomes with a strong alignment to existing food safety quality assurance and environmental systems, such as Freshcare Environmental. In fact, any growers who are Freshcare Environmental accredited can become Reef Certified without an audit.

Within the certification there are four key management practice areas – nutrient, sediment, pesticide and water. Practices of focus include soil and leaf testing practices, nutrient budgeting, decision making tools for irrigation, calibration records and management of topsoil.

Technical Advisor for the Australian Macadamia Society (AMS), Chris Searle, encourages macadamia growers to look into Hort360 Reef Certification.

"Macadamia growers have a strong commitment to limiting their impact on the environment. The AMS has been working closely with Growcom on Reef Certification as it can assist growers understand their business and the standard of land management practices required to ensure no detriment to the Reef from our industry," Chris said.

Orchard General Manager for Macadamias Australia John Vaughan recently went through the process of becoming Reef Certified. Like the Attards and Zunkers, their operations are also based in the Burnett catchment.



SciQual auditor, Neil Rungert (left) congratulates Ethan and Emily Zunker on their Hort360 Certification.

Macadamias Australia decided to certify all seven macadamia farms with a combined area of 720 hectares, as well as their lemon orchard.

John shares Chris Searle's sentiments about environmental stewardship.

"We found the Hort360 process relatively easy to comply with and it fits well with our company values which influence the way we farm with the goal of leaving the environment in a better condition than when we started," John said.

Hort360 Facilitator, Michelle Haase, is delighted with the number of growers coming on board for Reef Certification.

"Once we go through the questions of the Reef module in Hort360, the majority of growers see that they are already operating at or above best practice. If not, then we work out an action plan to assist that grower in lifting those practices so they can become Reef Certified," she said.

Michelle outlined the practices already commonly adopted specifically by the macadamia industry:

- extensively grassy inter-rows
- use of side throw slashers to mulch tree line
- crop growth stage leaf and soil testing
- fertigation systems
- incorporation of ag-tech such as soil moisture probes, weather stations and sap-flow meters
- grassed headlands, contour banks, riparian vegetation or grassed verges near waterways
- accurate spray records and automated record keeping
- sediment traps and tail-water dams to capture any runoff.

"We are confident that with continued efforts by growers to aim for best management practices, our industry will be in a position to meet Reef Certification standards to demonstrate stewardship towards the Reef," Michelle said.

The Hort360 GBR is funded through the Queensland Government's Reef Water Quality Program and delivered by Growcom. The program is free and participation is not limited to Growcom members.

Macadamia growers interested in receiving more information on Reef Certification are encouraged to contact Growcom; the module can be undertaken independently online, remotely online or over the phone, or in consultation with a Hort360 Facilitator.

For more information, contact Hort360 Facilitators:

Michelle Haase – Southern GBR
Email: mhaase@growcom.com.au, Mobile: 0428 586 890
Lindsay Allen – Northern GBR
Email: lallen@growcom.com.au, Mobile: 0477 588 677.

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Cross-pollination versus self-pollination: effects on nut size and kernel recovery

Professor Stephen Trueman, Anushika De Silva, Dr Wiebke Kämper, Joel Nichols, Dr Shahla Hosseini Bai, Professor Helen Wallace, Griffith University, **Dr David Hawkes, Trent Peters,** Australian Genome Research Facility, **Associate Professor Steven Ogbourne,** University of the Sunshine Coast
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Macadamia flowers are covered with self-pollen when they first open but bees may then remove most of the self-pollen and deposit cross-pollen from another cultivar. Stephen Trueman and his team have been using DNA methods to identify whether mature macadamia nuts arise mostly from self-pollination or cross-pollination. Here, they determined whether cross-pollinated nuts are larger and have higher kernel recovery than self-pollinated nuts.

Macadamia growers and researchers have long suspected that cross-pollinated nuts are larger than self-pollinated nuts. However, it has not always been clear how many nuts are produced by cross-pollination and whether cross-pollinated nuts are actually larger than self-pollinated nuts.

We have been using custom-designed DNA methods to identify cross-pollinated and self-pollinated nuts in commercial orchards.

Here, we determined the levels of cross- and self-pollination among nuts of cultivar 816 in two orchards. We then compared the nut-in-shell mass, kernel mass and kernel recovery of cross-pollinated nuts against self-pollinated nuts.

The project (PH16001) was funded by the Hort Frontiers Pollination Fund, part of the Hort Frontiers strategic partnership initiative developed by Hort Innovation.

Methods

We established two field trials in the Bundaberg region in 2018. The first trial was at Sandy Creek, where we hand cross-pollinated the racemes of 10 whole trees in the middle of a 42-row block of 816 trees and 10 whole trees in the first 816 row next to a 48-row block of Daddow trees. Nut-in-shell (NIS) yield and kernel yield were much higher on trees that had been hand cross-pollinated than on control trees (AMS *News Bulletin*, Spring 2019 pp. 68-70 and Winter 2020 pp. 22-25).



Anushika De Silva from Griffith University prepares kernel taken from the two trial sites for DNA analysis to identify the pollen parent of each nut.

The second trial was at Alloway, where we applied three levels of boron fertiliser (0, 1 or 2 g/L) as a soil drench on three occasions prior to flowering. Each treatment was applied to 10 trees in the middle row of a five-row block of 816 trees. This 816 block had five rows of 842 trees on one side and five rows of A4 trees on the other side. Beyond those rows were further rows of cultivars A203 and 741. Boron treatments had no significant effect on NIS yield or kernel yield.

We weighed the nut-in-shell (NIS), dried it, cracked it and weighed the kernel, from a random subsample of individual nuts from each tree in both trials. We then analysed DNA from each kernel using our custom-designed MassARRAY methods that identify the pollen parent of each nut.

Levels of cross- and self-pollination

The vast majority of nuts arose from cross-pollination, both at Sandy Creek and Alloway.

Levels of cross-paternity at Sandy Creek on control trees and hand cross-pollinated trees, respectively, were 84% and 85% in the middle of the 816 block (Figure 1a) and 94% and 96% in the 816 row next to the Daddow block (Figure 1b). Levels of cross-paternity at Alloway were 97%, 98% and 97% following treatment with boron at 0, 1 or 2 g/L, respectively (Figure 1c).

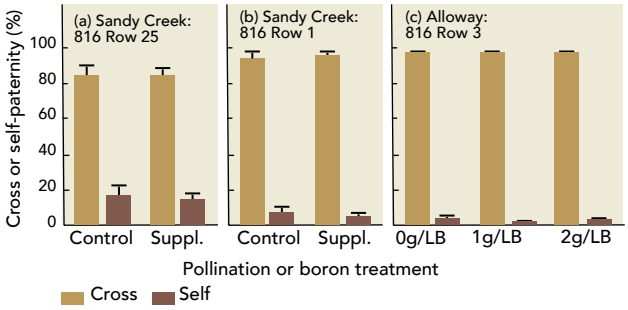

Figure 1. Levels of cross-paternity and self-paternity in cultivar 816 nuts at Sandy Creek and Alloway. Trees at Sandy Creek were (a) 25 rows or (b) 1 row from a Daddow block. They received no supplementary pollination (Control) or were supplementary pollinated (Suppl.) using Daddow pollen. Trees at (c) Alloway were 3 rows in either direction from blocks of A203 and 741. They received no supplementary pollination but received soil drenches of boron (B) at 0, 1 or 2 g/L before flowering. Means are provided with standard errors (n=10 trees).

Nut size and kernel recovery

At Sandy Creek, cultivar 816 nuts that were cross-pollinated by Daddow had much higher NIS mass, kernel mass and kernel recovery than self-pollinated nuts (Table 1). Some nuts in the middle of the 816 block were found to have been pollinated by cultivar 741.

	Maternal parent x pollen parent		
	816 x 816 (self)	**816 x 741 (cross)**	**816 x Daddow (cross)**
Row 25			
Nut-in-shell mass	6.22 ± 0.17 a	6.84 ± 0.18 b	7.98 ± 0.17 c
Kernel mass	2.63 ± 0.10 a	2.88 ± 0.11 a	3.58 ± 0.09 b
Kernel recovery	42.1 ± 0.9 a	41.8 ± 0.8 a	44.9 ± 0.7 b
Row 1			
Nut-in-shell mass	5.89 ± 0.32 a	—	7.81 ± 0.09 b
Kernel mass	2.66 ± 0.20 a	—	3.68 ± 0.04 b
Kernel recovery	44.8 ± 1.6 a	—	47.2 ± 0.3 b

Means (± SE) with different letters within a row are significantly different (random block ANOVA, P<0.05, n = 10–30 nuts for self-pollination, n=37–173 nuts for other pollen parents)

Table 1. Nut-in-shell mass (g), kernel mass (g), and kernel recovery (%) of cultivar 816 nuts with different pollen parents at Sandy Creek

These had higher NIS mass, but they did not have significantly higher kernel mass or kernel recovery than self-pollinated nuts (Table 1).

At Alloway, cultivar 816 nuts that were cross-pollinated by 842, A203 or A4 had significantly higher NIS mass, kernel mass and, except for 842, kernel recovery than self-pollinated nuts (Table 2). Cultivar 816 nuts that were cross-pollinated by 741 did not have significantly higher NIS mass, kernel mass or kernel recovery than self-pollinated nuts (Table 2).

Conclusions

The vast majority of cultivar 816 nuts at both Sandy Creek and Alloway arose from cross-pollination. Cross-pollinated nuts mostly had higher NIS mass, kernel mass and kernel recovery than self-pollinated nuts, although this effect depended on the cross-pollen source.

The heavy dependence on cross-pollination for nut set, and the often strongly beneficial effects of cross-pollination on NIS mass and kernel recovery, highlight the importance of effective cross-pollination for macadamia nut production.

Orchard productivity could be improved by:

1. interplanting different cultivars more closely
2. replacing dead or damaged trees with a different cultivar, and
3. introducing and positioning bee hives to maximise the transfer of pollen between different cultivars.

Acknowledgements

Project PH16001 is funded by the Hort Frontiers Pollination Fund, part of the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from Griffith University, University of the Sunshine Coast, Plant & Food Research Ltd and contributions from the Australian Government. We thank Duane Joyce (Sandy Creek), Johan Oosthuizen and Ngarie Myers (Alloway Macadamia), Chris Searle (MacAvo Consulting), Heather North, Luke Verstraten, Ryan Newis, Sascha Kämper, Rachele Wilson, Tarran Richards, Chris Cannizzaro, Brittany Elliott, Jean Douglas, Tracey McMahon, Nimanie Hapuarachchi, Marta Gallart, Tsvakai Gama, Pevindu Abeysinghe, Saurabh Shrivastava and Jack Royle for assistance.

	Maternal parent x pollen parent				
	816 x 816 (self)	**816 x 741 (cross)**	**816 x 842 (cross)**	**816 x A203 (cross)**	**816 x A4 (cross)**
Row 3					
Nut-in-shell mass	5.58 ± 0.23 a	5.93 ± 0.08 a	6.50 ± 0.09 b	7.02 ± 0.10 c	7.15 ± 0.13 c
Kernel mass	2.21 ± 0.15 a	2.41 ± 0.05 a	2.77 ± 0.05 b	3.18 ± 0.06 c	3.14 ± 0.07 c
Kernel recovery	39.3 ± 1.6 a	40.4 ± 0.7 a	42.6 ± 0.4 ab	45.2 ± 0.5 c	44.0 ± 0.6 bc

Means (± SE) with different letters within a row are significantly different (GLM, P<0.05, n=14 nuts for self-pollination, n=73–124 nuts for other pollen parents)

Table 2. Nut-in-shell mass (g), kernel mass (g), and kernel recovery (%) of cultivar 816 nuts with different pollen parents at Alloway

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Managing pollination: Will bees go the distance?

Brian Cutting, Sam Read, Dr Mateusz Jochym, Dr Lisa Evans, Dr Linley Jesson, Dr Brad Howlett, Plant & Food Research Australia E: brian.cutting@plantandfood.co.nz

Adequate cross-pollination is critical for achieving good macadamia yields. For this to happen, viable pollen must be moved between trees of different cultivars and deposited on the stigma at the very tip of the flower. Plant pollen can be moved in many different ways, but macadamia depends on flower-visiting animals, especially insects. To ensure adequate pollen movement, it is recommended that bees be introduced at the beginning of flowering. Increasingly, growers are deploying Australian native stingless bees in addition to honey bees, but how do these bees compare for pollination? Plant & Food Research has been working for several years to gain a clearer picture of just how useful stingless bees are for macadamia pollination.

Honey bees can be efficient pollinators of macadamia. Previous research has shown that they put pollen onto the stigma in about one of every five visits. Stingless bees can be even more efficient per bee, as they put pollen on stigmas during about half their visits and this may be because of the way the stingless bee lands on the flower which results in close contact with the macadamia stigma (Figure 1).

This pollination *efficiency* is indicative of the amount of pollen that is moved per each bee visit, but overall pollination *efficacy* depends on several additional factors including the number of bees present, the frequency with which they visit flowers, how often they cross between varieties, and how evenly distributed they are in a block. The recommended stocking rate for honey bees is between five and eight hives per hectare, but there have been few recommendations for the stocking rate of stingless bees in crops.

Figure 1. *Stingless bees (Tetragonula) are very efficient macadamia pollinators, as they deposit pollen on stigmas in 50% of visits, but in orchards they are unlikely to forage far from their colonies.* (Photo: Brian Cutting)

The experiment

To test the distribution of honey bees and stingless bees in macadamia plantations, we conducted a manipulative experiment in a single 4-hectare block in Bundaberg with cultivars 842 and 814 planted in alternating rows 325 m long. Twenty strong colonies of the stingless bee Tetragonula carbonaria were introduced to one end of the rows, and 52 honey bee hives were placed at the other end.

We conducted counts of bees on flowers on each of 48 trees at 12 distances across the block, including either end. These surveys were conducted by slowly walking around the tree (about 3 minutes per tree) and counting all pollinators on flowers between 1 m and 2.5 m in height. These counts were conducted three times a day (between 0900–1000 h, 1200–1300 h and 1500–1600 h) every day for eight days. We also kept track of the number of open flowers per tree. These data allowed the development of a mathematical model to test which factors were most strongly affecting the distribution of bees in the block.

To make sure that the results from the manipulative study were relevant to general Australian conditions, we

completed less-intensive surveys of bee distribution and flower density at an additional 17 blocks, including sites in Bundaberg, Gympie, Glass House Mountains and Northern Rivers.

Results

Stingless bees and honey bees had very different patterns of distribution in macadamia blocks. Generally, honey bees were encountered foraging much further away from their colonies, whereas stingless bees stayed very close to their colonies. Interestingly, honey bee distribution was more strongly driven by flower density than it was by distance-from-hive. Trees with high numbers of flowers received a greater-than-expected number of honey bee visits, while parts of the block where flower density was low received very few visits.

More than half (57.4%) of the stingless bees surveyed were within the two rows nearest to the colonies, and more than 96% of stingless bees were encountered within 100 m of the colonies (Figure 2). While Tetragonula is known to travel as far as 700 m to forage, a possible explanation for this close foraging range that we observed could be that when resources are plentiful, they are likely to stick close to home.

As a result of foraging close to the colony, stingless bees were less likely to be encountered in the middle of the block (Figure 2), whereas the distribution of honey bees was more variable. The flower density in the 17 additional blocks was more consistent than in the manipulated trial but we found the same patterns in bee abundance. While the locations of colonies at these sites were not precisely known, most of the stingless bees observed were foraging around the edge of the block (presumably closer to their colonies in surrounding vegetation), whereas honey bee numbers were driven by the number of flowers.

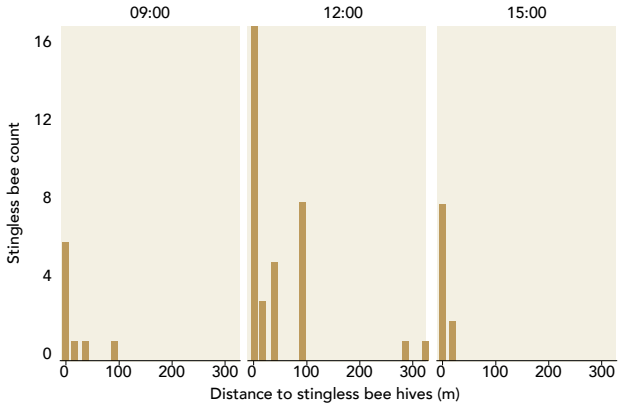

Figure 2. Distribution of stingless bees in a macadamia orchard at three times of day: 09:00, 12:00, and 15:00. Colonies in managed hives were located at the 0 m mark, and few bees foraged further than 100 m from the colonies.

Recommendations

The localised distribution of stingless bees is an obvious challenge for their use for macadamia pollination. To achieve adequate coverage, colonies must be placed at regular intervals through a block (one colony approximately every 100 m), requiring large numbers of colonies per hectare for full pollination.

Growers could potentially place colonies inside their blocks but if doing so, they will need to take into account other orchard management requirements such as machinery access and the use of pesticides. Some growers and beekeepers have successfully overcome these challenges by removing colonies during spraying or blocking bees into their colonies for hours or days until the risk is diminished. Remember that spray adjuvants, especially surfactants, can be harmful to bees even if they are not mixed with pesticides.

Despite the large numbers required for full pollination coverage, bees sticking close to home can actually be a strength for pollination management. Stingless bee colonies should be more reliable pollinators in areas where bee activity is low (such as areas with low flower density that do not attract sufficient honey bees).

Honey bees can forage over many kilometres and rapidly recruit each other to preferred food sources, sometimes reducing their effectiveness as pollinators on the targeted orchard. In contrast, stingless bees may be more likely to stay in the target crop.

We suggest a mixed approach to macadamia pollination management employing a combination of honey bees, stingless bees and other insect pollinators which are not currently directly managed (i.e. flies, beetles and solitary bees). Unmanaged pollinators can provide a significant amount of pollination, and so their activity should be monitored for changes.

As honey bee activity is influenced by flower density, undertaking management to promote evenness of flowering may help to achieve consistent pollination, including:

- selective pruning to promote flowering
- nutrition management and/or application of floral stimulants
- tree girdling (cincturing) to promote flowering.

Stingless bees can be used for general pollination, but they may be especially useful in pollinating areas where honey bee pollination is inadequate. By regularly monitoring insect activity during flowering, growers can identify these problem spots and be prepared to move stingless bee colonies to these locations as flowering starts.

The full results of this pollination trial are published in the journal Basic and Applied Ecology, and can be accessed for free with the following link: https://doi.org/10.1016/j.baae.2021.03.001. More information on macadamia pollination is available via the beeaware website, including the pollination brochure and checklist: https://beeaware.org.au/pollination/pollinator-reliant-crops/macadamias/.

Acknowlegements

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Why are bees important?

James Dorey **E:** jbdorey@me.com

James Dorey describes bees as the darlings of the insect world. Ever since he was child, he has found it a joy to see nature at work. James grew up on a macadamia farm surrounded by a native rainforest that was revegetated by his father, Ken. His fascination with bees only grew in passion and complexity, but it wasn't until his second year of university when the purchase of a second-hand macro lens led James to examine the tiny insects that pervade our world in true detail. It didn't take long for him to focus strongly on native bees. While many people recognise the worth of bees, very few know about the diversity of our native bee species. In ***Bees of Australia: A Photographic Exploration****, James introduces some of the native bees which macadamia growers will find in their orchards.



Blue-banded bees, such as this Amegilla cingulata, *are found commonly across much of Australia. They are a favourite of many amateur bee-watchers because they frequent gardens and feed from many exotic as well as native plant species.*

Australia's bees are an amazingly diverse, visually stunning and important group of animals. Their ecological importance stems greatly from the ability to pollinate the flowering plants of the world. Pollination is a vital ecosystem service, critical for sexual reproduction in plants. Pollination is provided freely in the natural world by insects, birds, bats, lizards, possums, rodents and even lemurs. Although there are many animal pollinators, bees are considered to be the most significant pollinators of the lot, particularly for crop pollination.

Crop pollination by the European honeybee alone has a commercial of A$4 - 6 billion in Australia and A$240 billion worldwide, with 35% of the food that we produce and 75% of our food crops being reliant in some way on animal pollination. Bees also create wonderful and useful products such as honey, beeswax, pollen, propolis and more. Honey and beeswax production by honeybees in Australia is worth A$90 million annually. Although that is a lot of food and money, it is far from the end of the bee story.

Pollination of crops and the making of bee products are the most commonly raised topics when discussing the importance of bees. Unfortunately, these issues are often raised only in terms of the European honeybee. While it is a very economically important species, the European honeybee is actually an invasive species almost everywhere that it resides, frequently stealing nectar from native plants without pollinating them, competing with native animals for food and nest sites, and pollinating exotic weeds. The role of the honeybee in crop pollination and the making of bee products is also only the tip of the iceberg when it comes to how important bees are to us and life on Earth.

With approximately 19,700 named species of bees across the globe, 1,654 of which are native to Australia, it should be clear that it is not just the honeybee that needs to be considered. Having co-evolved alongside flowering plants for over 100 million years, bees have become extremely important to the survival of many natural systems, as well as sustainable agriculture. Animals pollinate almost 90% of all flowering plants — that is over 308,000 plant species! Because bees are the primary pollinators in most ecosystems, it is difficult to overstate the importance of bees to the survival and success of many of these plants and the organisms that depend on them.

One way to explain how important bees are in the natural world would be to imagine what might happen if they were to disappear tomorrow. Direct effects on pollinator loss or decline would result in the loss of pollination services for the plants in that ecosystem.

Some flowering plant species rely on specialist pollinators that will pollinate only one or a few plant species. This is advantageous for the plant because it means that the pollinators must be loyal to them and are hence more likely to travel between two individuals of that same plant species, providing effective pollination.

The obvious downside of such an arrangement is that both the pollinator and the plant require each other to survive. Plants requiring a single species for pollination are particularly vulnerable to extinction if that pollinator



Being successful and common might not always be a good thing. This neon cuckoo bee (Thyreus nitidulus) *does what a cuckoo bird does, but to blue-banded bees. That is, they lay their eggs in the unguarded nest of blue-banded bees and let that host raise their young. But like most flying insects, they require a lot of energy and so are still likely pollinators as they visit flowers for nectar.*



Another common and popular native bee group are the stingless bees. These bees also make their way into macadamia orchards as native pollinators and, more recently, as cultivated livestock. These bees are actually the exception in the bee world in that they are eusocial (truly-social) and have queens, sterile workers and drones.

was lost. In turn, the bee would be vulnerable if the plant was lost. However, these isolated species interactions are rare and specialist relationships can also involve generalist plants and pollinators.

Most flowering plants do not require a specialist pollinator but instead attract a suite of generalist pollinators. While generalists might not always be as efficient at pollinating plants as specialist pollinators, the risk of using such pollinators is much lower. The loss of one pollinator species will not be as much of a problem for these plants because other generalist pollinators will be able to pick up the slack or provide adequate pollination. Such redundancy is typical of many plant-pollinator relationships. However, the problem could become catastrophic when more and more pollinators are removed from an ecosystem and the in-built redundancy starts to fall apart.

The ultimate cost for any flowering plant species after the loss of pollination could be extinction. Extinction for large perennial flowering plant species that have lost their pollinator might be a slow and subtle process that may go unnoticed for many years — particularly for long-lived perennial plants. Other species might disappear in a flash or suffer a gradual population decline because of lessened seed set or seed quality from poor pollination.

Flowering plants make up much of the physical structure in many ecosystems. This structure provides the conditions, shelter, nesting sites and habitat that many animals and plants need to survive. Flowering plants also provide food for many animals. A reduction of roots, stems, flowers, leaves, fruits or seeds produced by plants could set off a cascade of ecological effects. The many frugivores and herbivores that rely on these food supplies would be impacted by a loss of species producing these resources. A decrease in fruit and seed set alone would have a negative impact on the many bird, mammal and insect populations that use these resources. The cascade would then continue onto the many predators, parasites and parasitoids that prey upon these species and each other.

There are many ecological and monetary reasons to preserve bee species and diversity. Perhaps the most often overlooked reason is the non-material benefits that people get from bees, and the wealth of biological history stored in the behaviour and genetics of each species. Without our wonderful diversity of bees, you would not be reading this or enjoying these photos. You would not be able to go out into the garden or bush and see a multitude of bees conducting their important business.

It is very unlikely that we will lose all of our bees overnight. Additionally, bees are not our only pollinators and many flowering plants do not require animals for successful pollination. Yet any pollinator species that is lost or whose population declines could be another chink in the armour that nature's diversity and redundancy provide. Every chink could bring about unforeseen effects that might be another step towards the end of a population, a species, a crop or an ecosystem. Awareness and knowledge of the importance of bee diversity to humanity and the natural world is essential to the conservation of bees worldwide.



There are many other native bee species in Australia. One of the most species-rich groups are an Australian-made (i.e., originate here) group called the masked bees. These wonderful bees often slip under the radar among bee enthusiasts because of their wasp-like appearance.

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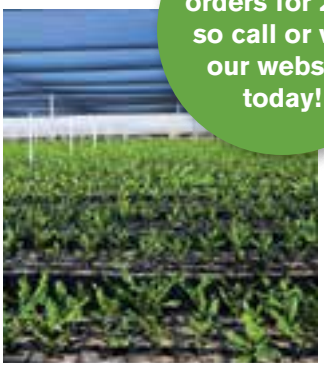

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The benefits of native bees for macadamia growers

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Steve Maginnity has been utilising native bees for pollination purposes in macadamia orchards for more than a decade. His interest in native bees began when he was a teacher, and the more he learned about them, the more his passion grew. This led him to establish The Australian Native Bee Company in 2008, offering hives and pollination services to growers on the Mid North Coast and Northern Rivers of NSW and South-East Queensland.

There is much research to show that native bees, also known as stingless bees and the specific species, *Tetragonula carbonaria*, are valuable pollinators of macadamia flowers.

We know that pollination occurs when the pollen of a plant reaches the stigma of a plant from the same species, and also that macadamia is partially self-incompatible, depending on pollinators transporting cross-pollen from the flowers of one cultivar to the flowers of another cultivar.

Recent research has shown that nut production in these self-sterile cultivars is almost totally dependent on pollinators transporting cross-pollen from the flowers of one cultivar to the flowers of another cultivar (Trueman et al 2020).

Native bees are an effective vector for pollen transfer. While they are small insects, they contact the stigmatic region of macadamia flowers as they collect pollen (Howlett et al. 2016).

Native bees can play a major role in pollen distribution in orchards and help with the necessary cross pollination of cultivars to prevent levels of self-incompatibility. In fact, they are more efficient at macadamia pollination than honeybees.

That's because *Tetragonula carbonaria's* foraging techniques are different to honeybees. One in every two visits (50%) to macadamia flowers results in effective pollination occurring, compared with honeybees which pollinate one flower in every five visits (20%) (Wallace et al. 2018).

Howlett's assessment of five different species in 2016 aligns with this finding. It ranked stingless bees



Hives are best positioned at the base of the tree with a north-easterly aspect to catch the early sunlight.

(Tetragonula carbonaria) as the most efficient pollinators. But the general number of bees in a native hive are significantly less than there are in a honeybee hive.

Tetragonula carbonaria are highly attracted to the pollen of macadamia. In an experiment conducted by Claire Allison from the University of Western Sydney in 2020, the results showed that hives introduced to the orchard at the time of flowering collected only macadamia pollen for the first three weeks of their deployment. See Table 1.

Hives permanently located in orchards maintained a balanced diet throughout the flowering period. This indicates that hives moved into the orchard for flowering collect larger amounts of pollen during the first stages of deployment which could further help with pollination.

This research shows that due to their preference for macadamia pollen, deploying native bees during flowering can help increase the rate of pollination which in turn can help improve yields.

Further research to trial stocking rates, hive placement and orchard design would help growers to maximise their orchard gate returns (Howlett et al 2016).

Getting the best out of native bees

The activity of *Tetragonula carbonaria* is directly affected by the ambient temperature. As the temperature increases, so too does native bee activity.

To maximise the activity of the hives, position them on sites with a north-east aspect that is not obstructed. This will ensure that that hives receive early sunlight to heat them and increase activity as early as possible.

Pruning trees to maximise sunlight to racemes will encourage bee visits.

Some growers use both European honeybees and native stingless bees to maximise visitation rates to racemes.

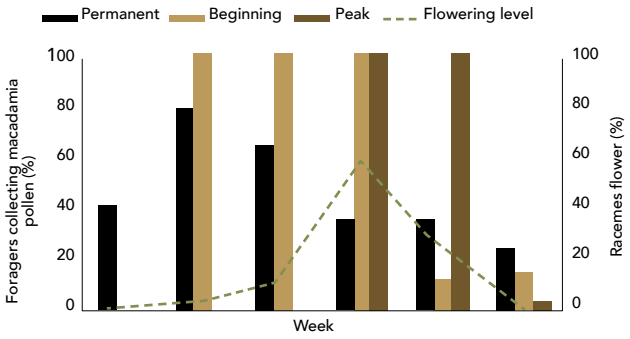

Table 1: Claire Allison studied three treatment groups of Tetragonula carbonaria *during macadamia flowering in the 2020 season. The green line represents an estimate of raceme numbers during flowering. Black represents hives permanently placed in the orchard. Gold represents hives introduced at the beginning of flowering and brown shows hives brought in at peak flowering.*

Checking hive health and activity prior to deployment in the orchard is a best practice method of native bee keeping for improved pollination.

Native bees are also heat sensitive, so during the summer months, place hives in the shade by mid-morning.



Steve Maginnity points to the enlarged queen cell in the top section of a hive when it was split.

On days when extreme heat is forecast, drape wet towels or hessian over the hives to provide evaporative cooling.

How to care for your native bees

Ensure hives are positioned so they are not at risk of being knocked down or broken by machinery. Also, place hives at a safe distance from the orchard when they are not being used for pollination. This will help avoid spray drift during chemical application in the orchard and help maintain the health of the hive.

The timing of sprays for the health of the bees is crucial. Exposing bees to chemicals may kill them or inhibit their development.

The best option is to completely remove hives from the orchard until chemical residues are gone. If this is not possible, cover hives during spraying and do not directly spray hives. Growers and managers should time their spray operation so that bees aren't active in the orchard. This means spraying at night and not spraying once there is open flower in the orchard.

Native bees obtain a significant amount of nectar and pollen during macadamia flowering. However, it is important that they have access to food throughout the year to enable continued brood development of the hive.

Summary

- Native bees are proven effective pollinators of macadamia. *Tetragonula carbonaria* can help improve initial nut set which can lead to higher yields.
- The best results are achieved when hives are positioned correctly and the health of the hive is maintained throughout the year.
- Colonies should be kept safe by managing hives in relation to positioning and chemical application.
- Healthy colonies deployed at the right time and cared for correctly improve the bottom line.



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Simple solutions for supplying water to bees

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"Limitation makes the creative mind inventive." **Walter Gropius**

Finding simple, innovative and cost-effective solutions is all in a day's work for most farmers. This feature profiles some low tech, low cost ideas utilising everyday on-farm equipment.

Bee watering

Water is essential for healthy bees. Not only do they require water for individual survival, but water is also needed within the hive to dilute food for growing larvae and provide evaporative cooling and temperature regulation.

On a hot day, a strong hive needs as much as 5 L of water. Every trip a bee makes to collect water, they could be pollinating in the orchard for you. If hives are close to a safe source of water, this may not be a problem, but if the water source is several kilometres away, bees will waste a lot of energy and time going to collect it.

Talk to your beekeeper first and see if they want you to put out watering points and discuss how they will be managed.

Making a simple bee watering station is relatively easy.

You'll need:

- Any intermediate bulk container (IBC) or a 200 L plastic drum. Any container that has held food grade products will do but do not use any container that has been used to store chemicals.
- Three 20 L drums that are chemical free or at least six 3 L milk bottles
- Sufficient shade cloth to cover the IBC or drum when cut in half
- Tank fittings and taps which can be bought from your rural store.

The how to:

Carefully cut the IBC or drum in half. With the IBC, cut the bars using an angle grinder first and then follow up with a Stanley knife to cut the plastic liner. Make sure you smoothly grind any bar ends and there are no bars protruding. The IBC comes with a tap fitted to the bottom half, so add a second tap to the top half so you can use both.

If you are using a drum, fit taps to both halves. Fitting taps means that you can easily drain the IBC or drum and move it around, rather than attempting to tip the container over. After halving the container and fitting taps, wash it thoroughly.

In the orchard, containers are best placed at least 50 metres away from the hives on level ground, preferably in part shade and somewhere accessible for refilling.



A simple bee watering station made from an IBC or 200 L plastic drum can provide a safe source of water to protect healthy bees and enhance pollination.

Placing waterers close to hives means you and your workers are in close proximity to the concentration of bees, increasing the chances of being stung. It is wise to know if any of your staff are allergic to bee stings.

Once the container is level, fill it with safe water and three-quarter fill the 20 L drums or milk bottles. Place them in the IBC/drum, so they float like icebergs with only a quarter of the bottle above the water. Add enough floating containers to cover about half the surface area of the IBC/drum.

Then drape shade cloth over the floating containers so that it is partially submerged and the bees have access to the water. Shade cloth acts like a 'scramble net', allowing the bees to alight on the cloth and safely walk down to get a drink. This will minimise bee deaths due to drowning.

Bees smell water

It is a myth that water needs to be clean, but it does need to be safe, that is free of chemicals. Biologists believe that bees find most water by scent rather than by sight, so a water source with a smell will be more attractive. Water containing algae, leaves, sticks, aquatic plants and other decomposing material that may seem smelly or slimy to us is perfect for bees and often contains a range of nutrients they find beneficial.

Managing the watering point

Using a large container like an IBC or drum means that you may only have to top up the water occasionally.

If you intend to spray, notify your beekeeper before emptying and removing the watering stations in the orchard prior to spraying and then replace them the day after.

If your neighbour has sprayed and you suspect there may have been drift onto your property, immediately empty the watering point, hose it out and refill it.

Talk with your beekeeper about water management, especially in drier and hotter regions.

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Thriving on an abundance of diversity

Ross Arnett is producing macadamia amongst a riot of life in his orchard on the Alstonville Plateau in the Northern Rivers region.

He took over the family farm in the early 2000s, leaving behind full time work to plant 1,200 macadamia trees and study production horticulture part time at Wollongbar TAFE, picking up the tools and understanding he needed to develop the farm along the way.

He now has 2,000 macadamia trees across four Hawaiian cultivars (344, 246, 816 and 849), growing in a red ferrosol soil on 10 x 5 metre row spacings in the 10 hectare orchard.

"Before farming, I had spent my whole working life in universities, initially at University of NSW in biological sciences as a scientific photographer, and this taught me to think critically about what I am doing," Ross said.

"My mantra has always been – why do you do it this way, and how can I do it better?"

Working with nature

At first, Ross fell in with the conventional dogma of 'a tidy orchard is a healthy orchard', but it wasn't long before he found his direction.

"I soon stopped the regular mowing and herbicide use – a macadamia orchard isn't meant to look like your front yard," he said. "I prefer to have a diversity of vegetation across the whole orchard floor to support insect diversity."

He added that the idea of using a clean-up spray at the start of the season to remove all beneficial insects from the orchard defied logic to him.

Ross's journey along the biological route went swimmingly well until the arrival of macadamia seed weevil.

After persevering for two seasons, he could see that his advancing trees were not producing more crop and decided to use Bulldock (beta-cyfluthrin) and acephate (an organophosphate insecticide) the next season. While this resulted in a larger crop, he was 'gob smacked' by the impact on insects.

"There was nothing living or moving in the orchard after spraying Bulldock," he said. "I did get a better crop, but I thought there had to be a better way."

One of the answers turned out to be a more targeted product, indoxacarb, which is allowing him to keep weevil activity under control without killing important beneficials such as spiders and lacewings.

In the three seasons that he's used indoxacarb in combination with a range of strategies to establish beneficial insects and orchard hygiene, he and his IPM consultant Jarrah Coates have been unable to find any weevils post spraying.

"I collect nuts off the orchard floor prior to and after spraying," explained Ross. "Around 90% of the weevils hatch from these nuts within 10 days of each other. We don't find weevils in the orchard for the rest of the season."

Observation is the key

Ross Arnett's farm is the biological case study site in the NSW DPI's Integrated Pest and Disease Management project for the Northern Rivers.

This means bug checking happens every two to three weeks during flowering and nut development. Ross makes it a priority to accompany Jarrah Coates on his rounds.

"These regular observations have made me better attuned to my orchard's insect diversity," he said.

"I know where the lace bug come in each season and how the spiders, lace wing larvae and other beneficials are able to control their populations. I haven't treated for lace bug in three years."

Ross has also used parasitoids in the last few years, releasing MacTrix wasps for macadamia nut borer and Anastatus wasps for fruit spotting bug, with next to no damage observed from either pest.

"Being able to use parasitoids to control two of the industry's major pests is a dream come true," he said.

He encouraged growers to follow the advice of their supplier and IPM consultant to determine the correct locations and required quantities for release.

"Putting out only a quarter of the quantity needed, and not in the right location is like spraying insecticide at quarter strength with poor coverage – it isn't going to work," he said.



Nuts sitting on dichondra, 10 days after the orchard floor had been mowed.



Sunflower with Assassin bug preying on a honeybee while four native bees feed.



Ross Arnett in his macadamia orchard on the Alstonville Plateau.

Leptocoris is another pest that Ross is battling without chemicals.

"For those not familiar with Leptocoris, it is a piercing and stinging insect, like fruit spotting bug," he explained.

"I chose not to spray, firstly because there is no registered chemical for control, and secondly because I wanted to learn its modus operandi. I discovered that Golden Rain trees, classed as a noxious weed, appear to be a super host for them. I also found them breeding in the soil around the base of a number of macadamia trees in this area."

Ross noticed that using crusher dust around the base of the macadamia trees seemed to inhibit the Leptocoris nymphs from coming out of the soil.

This year, his insect damage is back to being low (less than 0.4%). He still only uses one spray for the season, targeting macadamia seed weevil.

Cover crops the key to biodiversity

Cover crops are the foundation of biodiversity in Ross's macadamia orchard.

He said growing cover crops down the middle of the rows and around the orchard boundary was helping control pests by attracting and providing a home for many beneficial insects.

"Cover crops have a range of benefits," he said. "They generate bulk organic matter, they can bring nutrients and minerals back towards the soil surface, and they can help prevent soil compaction and break up compaction by having lots of roots in the soil at different depths."



A full inter-row of buckwheat, brassicas, clover, vetch, plantain, prairie grass among many other ground cover species.



One of Ross's first inter-row plantings used 'The good bug mix' from Green Harvest. Although it looks spectacular and worked well, he found it expensive and difficult to establish in an orchard situation.

His inter-row plantings consist of softer stemmed species which can be straddled by farm machinery, such as buckwheat, brassicas, clover, vetch, plantain and prairie grass.

"I have been able to develop these inter-row insectaries with the help of BioResources and the direct drill machine they purchased to allow growers to experiment with," Ross said.

There's also an orchard perimeter planting, established over the past year. Here he's growing crops like hemp, sorghum, buckwheat, chicory and sunflower.

"The perimeter planting is where you can be really creative," he said. "You can grow tall species, such as sorghum, which is a host for parasitic wasps so they'll be ready to reinvade your orchard after that indoxacarb spray. You can choose some long-lasting plants such as sunn hemp, chicory and sorghum to grow in parallel with buckwheat, lucerne, a mix of clovers and some brassicas."

Under the trees, there is a mat of dichondra, which grows in low light and forms an extremely tight, low growing mat when mowed.

"It is like sweeping nuts off carpet," he said.

Ross said good canopy management was essential to allow light in for the cover crops and ground covers to grow.

"I'm aiming for 100% ground cover, which means no soil disturbance from sweepers and, more importantly, no erosion of topsoil," he said.

He said tree height was a real issue in many Northern Rivers orchards and he is proactively working to keep his trees at a manageable height and with adequate light throughout.

"I know it's not easy or inexpensive to deal with, but it is extremely hard to get diverse vegetation growing across the whole orchard floor without reducing tree heights and properly managing the canopy density," he said.

"Good canopy management also means you're growing nuts throughout the whole tree, and that's what we are all about, no matter whether we are conventional, organic or regenerative farmers."

ABC Landline featured Ross Arnett's orchard and BioResources' work in biological control on July 25. See ABC iview.

Ross will also be speaking at AusMac2021.

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Making life easier on farm

Samantha Elley, AMS Communications

The Kubota mower sits nestled in the shed at Oliver's Acres, Ben Neilson's macadamia farm in the Northern Rivers. Attached to the mower is the prototype 'plug and play' automated navigation system, serendipitously called KiTT. (See story on page 63).

As a marine engineer Ben normally spends six months of his time out to sea working on various ships.

"I was working at sea six months of the year. It's usually two or three months on, two or three months off so I had plenty of time," Ben said.

"I hunted around for different industries that seemed to be fairly worthwhile and settled on macadamias.

"It's a really mechanical industry so that suited me.

"I could jump on the ship for four weeks, come home, harvest then jump back on the ship and the neighbour does the spraying for me and things like that for me that are time critical."

Ben has now been running Oliver's Acres for the past 15 years, starting with no experience.

In 2006, he took on the going concern that was 11 hectares and had 2,700 trees.

"I mostly grow older varieties like 344, 246, 741, and some A16s and a few 816s," Ben said.

Since taking the farm over, Ben has watched it age, so much of the work is ongoing maintenance.

"I spend a lot of time with Kevin Quinlan from Marquis Macadamias and Steve McLean, our agronomist," Ben said.

"We do a lot of limb removal these days and add a lot more organic matter.



Dave Stuckey and Ben Neilson with the KiTT and the Kubota mower. (Photo: Samantha Elley)



Ben Neilson on his established farm, Oliver's Acres. (Photo: Samantha Elley)

"We introduced smother grass into the orchard as ground cover."

Ben said all the work on the farm has been geared to improve productivity.

"The best we've achieved was about five and a half tonnes per hectare which was pretty good. That was last year," he said.

The work that Ben has been doing on KiTT has been in collaboration with recent Southern Cross University graduate, Dave Stuckey.

"I would have been in my second or third year of university, we were doing a couple of small projects and our lecturer came to us and said here is a project you might be interested in," Dave said.

"I started doing little things on the mower as I had a lot to learn. In fourth year, we had to do a major thesis and capstone project.

"The thesis was based around the mower and the capstone was based around automating tasking equipment all around macadamias.

"From that I just kept working on KiTT and the mower."

A good place to start

Ben said they spent around two years getting to a point where they had something that was going to work, after trying different types of sensors and different computers that could handle everything that was running.

"Dave was the best outcome from approaching SCU and he is the brains of the business now."

Ben and Dave chipped away at the mower, using their method of trial and error to reach a point where they needed more input.

"We could see we could do the technical side of the mower and getting one going, but we were going to be short of time for marketing, website development and project management down the track," Ben said.

That's when Scott Hansen and Corematic entered the scene.

"We approached Corematic with a project that was already quite close to running," Ben said.

"They've done the website and the user interface, and most importantly our simulated environment which has greatly enhanced our testing and tuning program."

Formatt Machinery provided Ben with the new Kubota mower that now sits in his shed with KiTT attached.

"So far it is looking promising."

Beyond macadamias

Plans for KiTT could easily go beyond macadamia farming, according to Ben.

"Our goal is to have half a dozen to a dozen machines running in orchards in the next six to 12 months," he said.

"We know macadamias quite well, so that's easy, but it's no great stretch to move into other tree crops.

"Avocados are ideal and citrus. Almonds may be a bit different, but we can go there.

"There's vineyards as well. What our technology does would work well in vineyards as opposed to relying on really expensive GPS solutions."

The beauty of KiTT is it can be fit into any machine, depending on the interface.

"Around here there will be some interest in zero turn mowers," Ben said.

"Some of the guys from the sugar cane flats have expressed more of an interest in the 4WD out front mowers as they've got different conditions there to deal with.

"A couple of the Bundaberg corporates were more interested in what we could do with a tractor as well."

The feedback from Ben's recent trip to Bundaberg to demonstrate KiTT's capabilities was very positive.

"It's not just about taking people off machines for the purpose of dropping wages, it's well known there are staff shortages this year and expensive machinery is being entrusted to casual, seasonal labour and that causes a lot of problems on its own.

"It's more about getting a consistent job done."

Ben said one of his initial goals was to increase the size of the farm one person could run.

"At the moment, with the right equipment and the right farm layout, one person could comfortably run 6,000-7,000 trees with a little bit of contractor help just for those one-off things like annual pruning," he said.



Ben Neilson and David Stuckey on their demonstration trip in Bundaberg with KiTT and the mower.

"I'd like to see one person be able to manage 10,000-12,000 trees by themselves."

And are there plans for more inventions to make life easier on the farm?

"KiTT's going to expand over time," Dave said.

"We're really focusing on a navigation system for a mower, but once we have the navigation system working very well, it doesn't take much to adapt it to any other equipment.

"Then all of a sudden it's not just a KiTT for a mower, it's a KiTT for anything they drive up and down the tree rows."

Next steps

The next step for KiTT includes incorporating a few changes and improvements from the feedback provided from the demonstration trip to Bundaberg.

"Then the mower will be going off to a local farm to do some serious demonstrations," Ben said.

"Then we will do a production run of some KiTTs.

"Hopefully, as various technologies move into horticulture and start to mature, we'll find new ways to make our data from various platforms interface nicely.

"By combining data yielded by companies such as DataFarming (multi spectral satellite imagery), GridFarm (high resolution soil analysis mapping) and Aerobotics (UAV multi spectral imagery and tree data) with autonomous machinery platforms such as KiTT, we hope to find new efficiencies and more targeted ways to manage tree care rather than block or farm level care.

"Drowning in data is not the answer. Integrated, actionable information is much more useful."



New KiTT technology to automate mowing

A company which specialises in artificial intelligence, computer vision and machine learning is now offering an automated system which could take care of mowing and other jobs around macadamia orchards.

Corematic is introducing the KiTT Automated Navigation System which has been developed in collaboration with macadamia grower Ben Neilson.

A marine engineer by background, Ben had been working on an automated prototype for a number of years through his company AutoOrchard with the assistance of mechanical engineer David Stuckey.

"KiTT is an autonomous solution we believe can be extended to various jobs such as spraying, canopy management and monitoring," said Scott Hansen, Engineering Director at Corematic.

"It is a plug and play solution that allows growers to save capital by re-using their current assets."

KiTT uses multiple technologies to self-navigate around a macadamia orchard and mow the terrain efficiently and effectively.

These technologies include:

- **geofencing** or virtual boundaries which helps KiTT know where it has been and how much area is left to cover. Geofencing also works as a global enclosure for KiTT's local path planning algorithm.
- **a path planning algorithm** which calculates the optimal path from start point to finish within clear established boundaries (geofences). KiTT uses a local path planner that updates often and helps it navigate between obstacles and within the tree rows. It also has the functionality to go beyond tree lines if the user wishes to mow the headlands, and for this, it uses a global path planner and geofencing for guidance.





Top: The KiTT system allows machinery to self-navigate around macadamia orchards for mowing and other jobs.

Left: KiTT can be retrofitted to existing orchard equipment and operated by a mobile app or PC.

- **sensor fusion:** Odometer data, GPS data and IMU (Inertial Measurement Unit) data are fused to accurately locate the KiTT position within the orchard at all times. A macadamia orchard with fully grown trees interferes with the GPS signal, so to autonomously navigate in it, the developers have used a sensor fusion algorithm that ignores the GPS signal (GPS denied) and focuses on data from other sensors to calculate the machine's position accurately. Like this, KiTT can still navigate around the orchard even when there is no GPS signal.
- **LiDAR** point cloud data that allows the system to detect the tree lines which the mower uses to navigate while keeping a sensible distance from them. With LiDAR tech, KiTT can create a high-resolution 3D point cloud of its environment to avoid obstacles during operation.
- **user interface** is available as an app on a PC or a mobile phone, to create tasks and assign them to KiTT in a few clicks. The user has access to operational information such as running time, expected finishing time and percentage of area covered. Some technical data about KiTT is also available such as fuel level, temperature, engine hours, speed and more. The KiTT app also allows the user to control a few settings for operation such as the radius of rotation, speed and distance from obstacles/trees.

Scott said the KiTT team has performed multiple tests at Ben Neilson's orchard, using a Kubota zero turn mower supplied by Nathan Attard of Formatt Machinery, Bundaberg, as the demo model.

In the first stage, they focused on the tree following algorithm and path planning functionalities, ignoring global position and concentrating on following the tree rows.

Once they ensured both algorithms were optimal, they moved onto the GPS denied part by running a physical and virtual testing series.

"We checked that the mower's position was accurate enough for path planning algorithms. Then we connected both parts and started the final physical test with the mower on an orchard, knowing where it is and where it needs to go by following the trees. Finally, we integrated the obstacle detection algorithm to make the mower stop if an obstacle is big enough to affect its movement," Scott said.

For more information or to book an on-farm demonstration, contact the team at KittNavigation.com.au

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Macadamia ecophysiology enlightening management Part 3: Pest and disease management

Leoni Kojetin, **Dr Chris Searle, Dr Theunis Smit** and **Armand Smit**

Macadamias are only a few generations from the wild and understanding how they have adapted over millennia to their environment is essential to unlocking the tree's potential. In a series of articles in the *News Bulletin*, we are examining the unique ecophysiology of macadamia and using this lens to inform management of an essentially wild crop. This article explores macadamia pest and disease management and explains why an integrated strategy is the most effective approach.

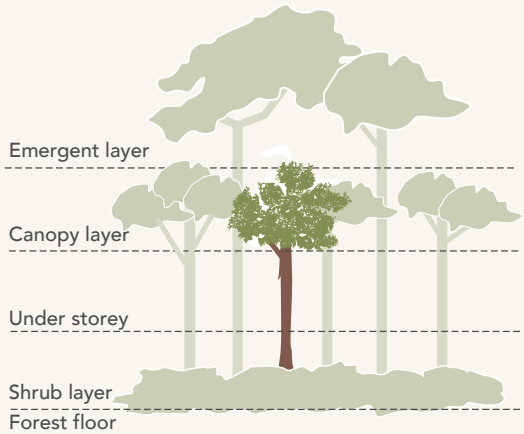
If you haven't read the previous two articles in this series, it's a good idea to go to them first (see the *News Bulletin's* Autumn 2021 issue for part one and the Winter 2021 issue for part two).

Macadamias evolved in the isolated rainforests of south-east Queensland and north-east NSW where they grew as sparsely distributed small groups of trees. At the same time, several pests and diseases that are unique to macadamia also evolved such as macadamia felted coccid *(Eriococcus ironsidei)* and the fungal disease husk spot *(Pseudocercospora macadamiae)*.

In the undisturbed rainforest environment, trees and their pests and diseases are in an uneasy balance where, over time, trees develop defences to resist them, and pests and diseases adapt new methods to overcome these defences. The dispersed nature of macadamia stands in these rainforests would have helped reduce the spread of pests and disease as host trees were much further apart than trees in orchards. Stands of trees were also genetically diverse, making it harder for pests and diseases to develop adaptation mechanisms.

Wild macadamias in the subtropical rainforest

Macadamia evolved in the subtropical rainforests of south-east Queensland and north-east NSW isolated from other rainforests in Australia. A unique group of pests and diseases coevolved with them.



Climate

- Distinctive dry periods (typically winter and spring) with little resistance to flower diseases
- Widely separately groups of trees in the landscape making pest and disease movement harder
- Groups of genetically different trees, less susceptible to pests and diseases

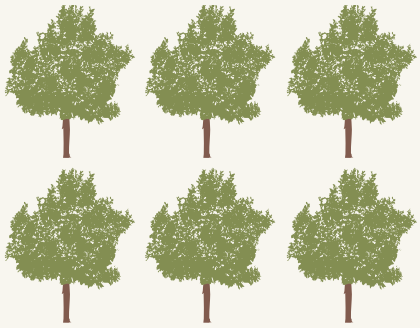
Evolution

- Macadamia evolved with unique pests and diseases
- Over time parasitoids of these pests also evolved
- Evolved on well drained soils rich in organic matter
- Evolved in the absence of exotic root diseases such as *Phytophthora*

VS

Macadamias in captivity, the orchard

Macadamia orchards are unnatural settings with a wide range of differing climates to which macadamia are not evolved. Pests and diseases can thrive unchecked without nature's balance.



Captive conditions

- Mismatched physiology and environment may lead to tree stress and pest/disease attack
- Crowded, often contiguous landscapes allow easy pest and disease movement
- Humans and machinery transport pest and disease
- Monocultures with low genetic diversity, closely related rootstocks and scion cultivars

Introduced invasions

- No evolutionary adaptations to introduced pests or diseases
- Exotic pests and disease have the potential to cause considerable economic damage and ecological damage in wild populations
- Degraded and poorly structured soils, many deficient in organic matter and poorly drained are conducive for exotic *Phytophthora* to which macadamia have not evolved defences

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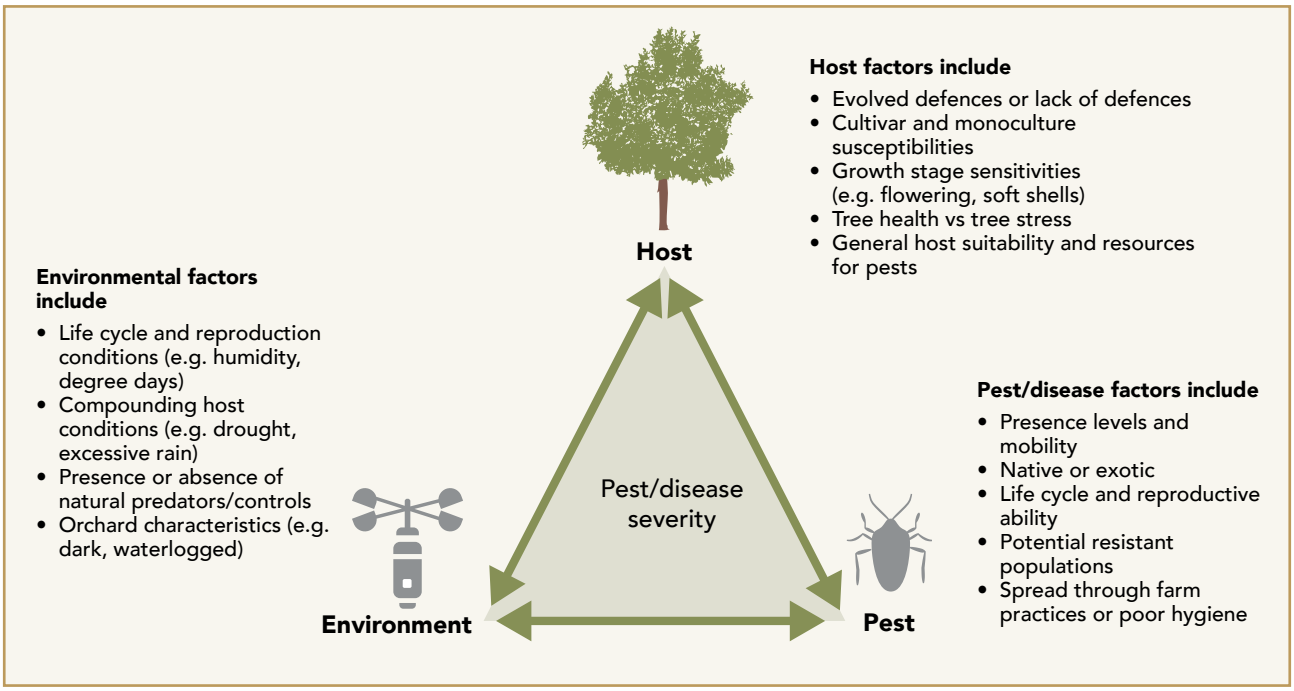
The pest and disease triangle

The pest and disease triangle helps to understand the impact of pests and diseases and to plan control strategies. It depicts the relationship between the tree and pest, disease and environmental factors and identifies the importance of each element for successful management. Removing or manipulating one component can improve the chances of controlling a pest or disease. For example, making the host unsuitable means the pest/disease will be absent.



The host – macadamia trees in captivity

Unlike in a natural setting, commercial orchards contain large numbers of trees often of the same or closely related cultivars. These genetically similar trees planted close together present an opportunity for pests and diseases to proliferate as they encounter little resistance. As well, orchards are often established in environments that are very different from their evolved setting, which can increase the potential for tree stress. Stress impairs a tree's natural defences, leaving it even more susceptible to pest and disease attack.

The environment

An environment that is stressful for trees could provide ideal growing conditions for macadamia pests and diseases, which can thrive when left unchecked. We know that dark, crowded, often high humidity orchards create favourable conditions for pests such as lace bug, fruit spotting bug and a range of diseases. This is further compounded if the host environment doesn't favour the establishment of natural predators.

Pests and diseases

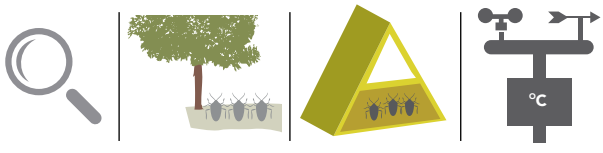
While macadamias have evolved ways to resist endemic pests and diseases, they may not have mechanisms to resist exotic threats they have not encountered in the wild. An example is *Phytophthora cinnamomi*, the water mould that causes trunk canker and root rot, which is not native to Australia. Trees planted in waterlogged and wet environments that favour the growth of Phytophthora can be productively hampered and, in severe cases, die.

Another example is macadamia seed weevil *(Kushchelorhynchus macadamiae)*. Although it is native to Australia, it evolved in a markedly different woodland and grassland environment in the tropical rainforests of far north Queensland more than 1,500 km to the north of macadamia growing areas. This means that macadamia seed weevil, which arrived in northern NSW some time ago, has no natural predators so acted like an exotic pest causing significant economic damage. A similar situation has occurred in Hawaii where macadamia felted coccid from Australia has arrived without any of its control agents and consequently it is out of control. Essentially, our commercial orchards are unnatural settings which aren't afforded nature's evolved balance.

Monitoring - an essential element

Monitoring is essential to identify pests and diseases that are present in the orchard, and to understand their ecology, levels present and thresholds that require intervention.

Monitoring differs for different pests and disease and is a skill that needs to be developed. Four types of monitoring are used in the macadamia industry:



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Visual monitoring is the technique most growers are familiar with. It involves walking around the orchard visually inspecting trees, usually with a hand lens, for the presence of pests or disease. This type of monitoring works well for relatively 'static' pests, such as felted coccid or lace bug which are less mobile. Visually monitoring for more mobile pests, such as spotting bug, often involves looking for the damage they cause. Spotting bug are generally well camouflaged, higher up in the canopy and actively hide from people. However, feeding damage on nuts can readily be seen and their numbers inferred.

Disease monitoring relies heavily on skilled visual identification of damage characteristics.



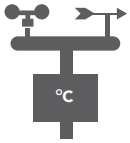
Knockdown monitoring is a useful tool for mobile pests, like spotting bug, particularly after the damage they cause becomes less obvious e.g., after shell hardening when damaged nuts don't drop until harvest. Knockdown monitoring involves pegging a large sheet or tarp to the ground under the tree, then spraying with a fast-acting contact pesticide and waiting to see what falls out. This monitoring method is labour intensive and has not been favoured in Australia but it is a highly effective method of monitoring for pests such as late spotting bug.



Trap monitoring is an under utilised tool in Australia but it is popular in other origins. There are many ways of trapping, but they usually involve something such as a sticky trap in a grid pattern throughout the orchard or at known pest entry points. Some traps use an attractant, usually a pheromone, to draw the pest to the trap where it is caught. A spotting bug trap is available in Australia, but it is only effective for banana spotting bug *(Amblypelta lutescens),* which is mainly found in Queensland. While these traps can be expensive to deploy en masse in the orchard, a few strategically placed traps can be highly effective as monitoring tools.

Trap crops are plants that are attractant to pests and specifically planted to monitor pests or provide a breeding ground for beneficial insect establishment.

The final type of monitoring helps growers observe and predict the last part of the pest and disease triangle which must be present for the pest and disease to survive and multiply, the environment.



Environmental monitoring looks at the climate to predict a pest or more commonly a disease infestation and development. For example, dry flower (caused by *Neopestalotiopsis macadamiae sp. nov.* and *Pestalotiopsis macadamiae sp.*) occurs throughout the flowering stages and can infect nutlets. This widespread disease is most prevalent when dry warm conditions follow a rainfall event at any time during flowering. By using a weather station situated close to the orchard and understanding dry flower's infestation and development conditions, it is possible to predict when the disease is likely to occur and take preventive control measures.

Using ecophysiology to underpin integrated pest and disease management

Integrated pest and disease management (IPDM) is a holistic approach to prevent, monitor and control pests, disease and weeds by using a broad range of strategies designed in part to take account of how macadamias evolved. These strategies aim to eliminate or negate one or more elements of the pest and disease triangle.

Growers who use IPDM don't rely on only one practice, rather they select the most appropriate tool or combinations of tools from available **cultural**, **biological** and **chemical** options. Fundamental to this holistic approach is an understanding of macadamia ecophysiology and using this to their advantage in the orchard.

Cultural controls – making the tree and/or environment less suitable

Often the neglected or undervalued component of an IPDM program, cultural controls are proactive and practical ways to stop or suppress pests and diseases. Cultural controls aim to make the tree and/or tree environment less suitable and facilitates a system that keeps pests and diseases under control. They include common orchard procedures such as mulching and disinfesting machinery. Strategically timing the mulching of prematurely fallen nuts can eliminate developing macadamia seed weevil larvae, as well as eliminate food for rats or a harbour for pests such as kernel grub.

Canopy management, which has production benefits, is also an essential cultural control tool. Pruning helps to manipulate orchard airflow, temperature, humidity, tree height and light interception. Pruned conditions lower and open canopies which are easier to monitor, reduce fungal disease development and create environments less favourable to many pests. They also allow good spray coverage, improving spray efficacy and minimising the potential for pesticide resistance.

Tree shaking is a cultural control that drops nuts that, left in the tree, can be a resource to a range of pests and 'cleans' trees of stick tights and old wood. The practice provides a critical break in the cycle of pests

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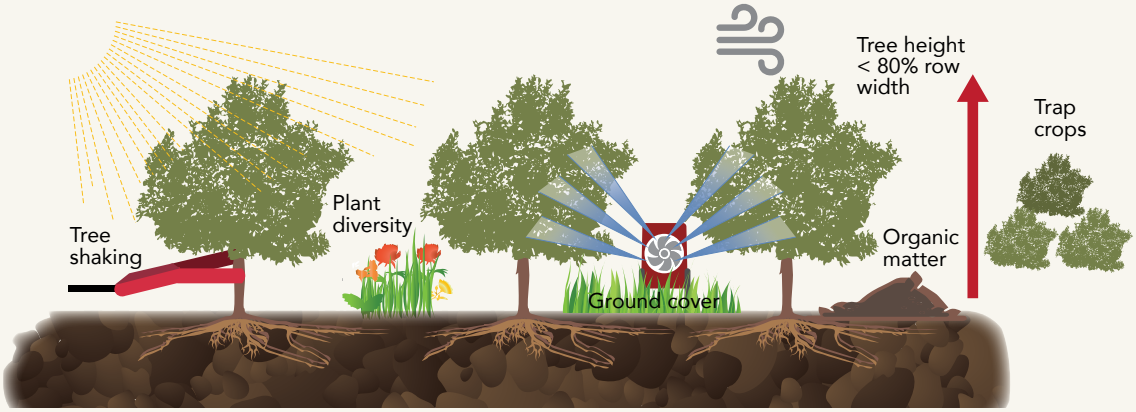
and diseases that overwinter in trees and proliferate in warmer spring conditions.

Trap crops are specifically planted to lure pests to somewhere they can be easily monitored. They can act as an early warning of an impending pest incursion, used as insectaries in which to raise beneficial insect predators or can be chemically controlled.

The benefits of cultural controls are cumulative, and all practices improve the efficacy of other controls.

Examples of macadamia orchard cultural controls

Canopy management for ventilation, light interception, spray penetration & coverage



Orchard floor management for pest/disease suppression, root health, nutrient uptake, water holding capacity, aeration, infiltration, drainage and soil resilience

Chemical control – understanding the broader impacts

In contrast to cultural controls, chemical controls are often relied on too much for pest and disease management. IPDM depends on the judicious use of chemical options as part of a holistic approach, rather than using them solely. This is because chemical controls can unbalance the orchard system. As a result, it is important that they be timed correctly, applied effectively and rotated to avoid resistance.

Thresholds are intervention triggers often for chemical controls. Thresholds are not standard across all of the industry, despite pest and disease research into the pest populations that can be tolerated in an orchard before causing economic damage. Growers should set thresholds for their context depending on crop stage, cultivar, farm resources and orchard infrastructure.

Fundamental to using chemical controls as part of IPDM is understanding the impact of each chemical on the broader environment as well as the pest or disease itself as some chemicals have a bigger impact on natural systems than others. All have varying withholding periods and use patterns and these factors need to be considered in any IPDM program.

The preferred chemical options within any IPDM program begins with 'softer' chemistry at the start of the season and reserves the use of more disruptive broad-spectrum options for the end of the season and only if required.

Targeted and safer chemistry is being introduced into the macadamia industry. Importantly, it often requires even more precise timing than with traditional chemistry, usually within a specific crop stage, pest life cycle stage or weather window. If a chemical control is incorrectly applied, it may only kill a proportion of the pests, leaving some organisms unaffected. These then breed, and if incorrect spray use continues, over time selection pressure leads to resistance.

Biological controls – a natural way

Biological controls use living organisms such as parasitoids or entomopathogens to control pests and disease. Biological controls use a natural resource and have minimal environmental impact. Their development is usually slow because of the extensive research required and, in many cases, such as with insect biologicals, a rearing system must be developed.

Natural biological controls can be encouraged or established in the orchard. Populations of apex predators like spiders and other generalist predators such as assassin bugs and lacewings are often already present. They can be helped to flourish by treating them as crucial farm workers, cultivating their working conditions and recognising their invaluable contribution.

Other biological agents can be introduced into the orchard, usually to control a specific pest. As they are living organisms it is essential to deploy them correctly, by considering hatching/survival conditions and where/when they are best released. Of course, chemical controls will likely impact these newly introduced workers and care should be taken with any chemical choice that its impact is understood.

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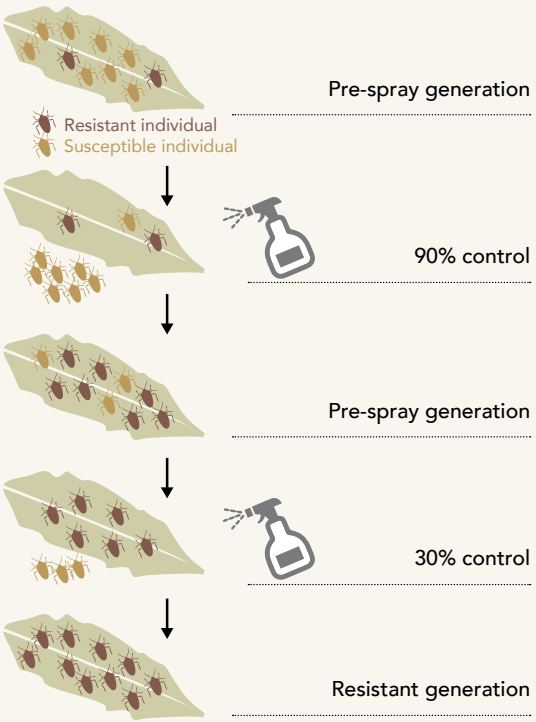
Questions to ask before using any chemicals control options:

- What cultural and biological controls can I use instead or in support of a softer chemical option?
- What is the active ingredient of the pesticide?
- What is the chemical group of the pesticide and how can I rotate chemical groups?
- What rate should the pesticide be applied at and is it required only in sections of the orchard?
- Am I timing application so that it is most effective?
- Is it a contact or systemic chemical?
- Should the pesticide be applied under a specific set of conditions, crop or pest stage or other mandatory use pattern?
- How am I going to avoid any off-target impacts?
- How will I evaluate the use efficacy after spraying?

Concept of resistance



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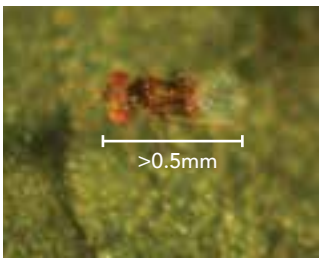
MacTrix wasp – our industry's biological good news story

The macadamia industry has an excellent example of biological control being used as part of an IPDM program to manage a major industry pest - MacTrix wasp.

In the 1990s and early 2000s, the main insect problem for the industry was macadamia nut borer *(Cryptophlebia ombrodelta)*, a moth pest that had been solely managed using chemical options as natural predators did not appear effective. When the parasitoid wasp *(Trichogrammatoidea cryptophlebiae)*, shortened to MacTrix, arrived in Australia from Southern Africa it quickly became naturalised on the Sunshine Coast where its potential as a control agent for nut borer was realised.

After much research, commercially viable ways to rear and dispatch the parasitoid to growers were developed. Within a few years, releases of MacTrix had reduced nut borer from a major to a minor pest. As with most control measures, correct timing is crucial to ensure maximum efficacy. In the case of nut borer, MacTrix are released into both the orchard and surrounding habitat before the nut borer moths start to appear in large numbers.



These releases in the bush help suppress any overwintering population, particularly in warmer climates. Cards containing hundreds of wasp parasitised eggs must be strategically distributed throughout the orchard. They are so tiny they can only fly with the wind, not against it, so cards are best placed on the upwind edges of the orchard, about 50 m apart and in shade if conditions are likely to reach 35^{0}C (this is because wasps will not survive in higher temperatures, unlike nut borer, which can survive temperatures up to 40^{0}C).

MacTrix wasp timing with phenology

Nut set and growth	Nut shed	Oil accumulation	Maturity and harvest stage
Order MacTrix wasps in August/early September. Start monitoring for MNB eggs.	Initial wasps releases should be made around orchard periphery and in bush to suppress nut borer population that has overwintered or is establishing.	Weekly releases of at least 1,000 parasitised eggs per ha is recommended or cards every 50 metres on the upwind periphery. Starting just before nut shed through to the end of December.	Consider putting out MacTrix past nut maturity if you: • Have thin shelled cultivars • Grow in southern regions or • If the temperature reaches 35^{0}C at which stage MacTrix die.

Adult MacTrix wasps are easily killed by many chemical sprays. The developing MacTrix larvae inside the parasitised nut borer egg are relatively safe. The least disruptive chemical options when spraying for other pests such as fruit spotting bug will ensure the viability of MacTrix in the orchard

A sustainable future using today's knowledge

IPDM and more environmentally sensitive crop protection methods are being adopted in the industry and included in control strategies, with many growers seeking softer and more environmentally sustainable options. This is in part driven by improvements in knowledge and in part by community and consumer demand.

As the industry expands, threats will inevitably come from new, exotic pests and diseases. In this context, understanding the ecophysiology of macadamias and how they evolved will be more important than ever. By applying this knowledge and adapting management practices we will continue to find even more innovative and sustainable growing solutions.

There is nothing more important to the communities in which we farm and the markets we supply than our crop protection practices and environmental stewardship.

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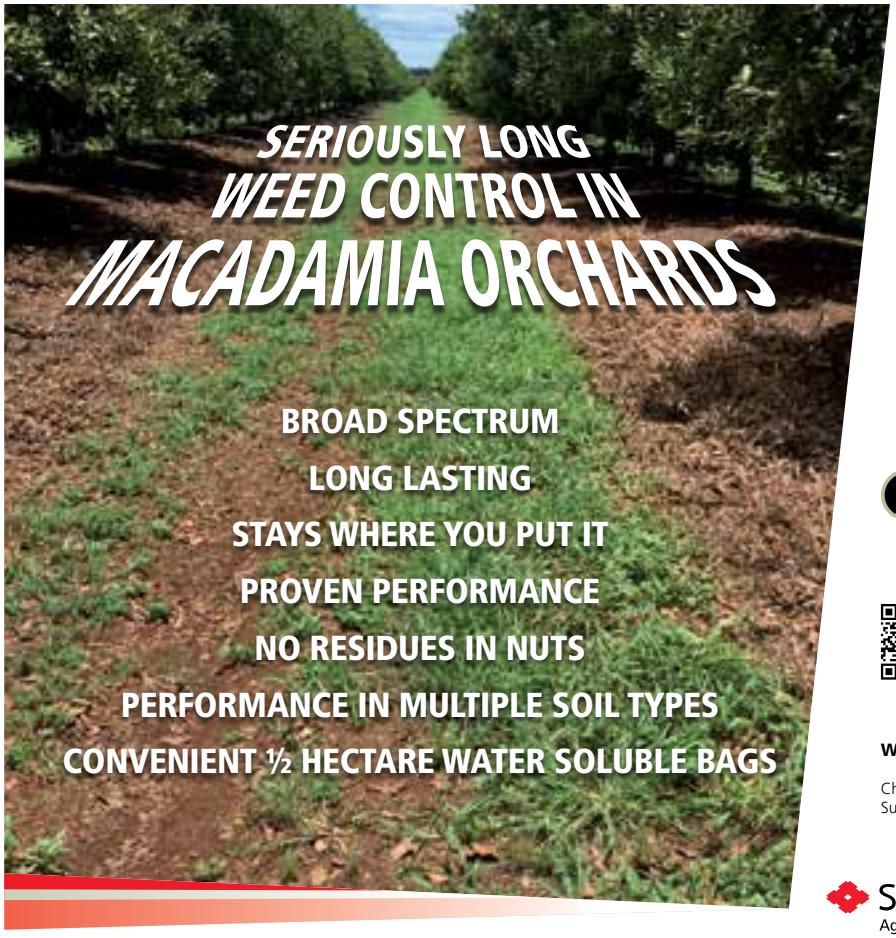

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Macadamia Change Makers take centre stage in new campaign

Jacqui Price, Market Development Manager, AMS
P: 02 6622 4933 **E:** jacqui.price@macadamias.org

Marc Harrison is a 'wood whisperer'. A problem solver, artist and furniture maker, he turns macadamia shell and timber into desirable, beautiful objects that have become icons of Australia under his brand Husque.

It's Marc's story that is launching Australian Macadamias' new consumer campaign. Called Macadamia Change Makers, it will shine a spotlight on Australian brands and achievers using macadamias in creative and life-enriching ways.

Feeding a hungry audience

Fans of Australian Macadamias are eager to be informed and inspired about the macadamia experience. Our Australian audience in particular is not afraid to experiment, explore and embrace the new, and they're seeking brands they can believe in, and products they feel good investing their energy, interest and money in.

This new campaign, which will run in Australia, Japan, China, Taiwan and South Korea, is an invitation for consumers around the world to discover, uncover and explore, as we share stories of people and brands that are breaking new ground with macadamias.

Learning about an Australian icon

Originally from New Zealand, Marc Harrison came to Australia aged 14, dreaming of adventure. It was here he had his first encounter with a macadamia tree, while renovating a house as a tradesman in Brisbane.

"There was a macadamia tree there, and that's when I first experienced how hard the shell is. I began by trying to crack it with a rock, graduating to a hammer and then finally a ring spanner. I eventually understood the point of it all when I experienced how amazing the nut tastes," Marc recalls.





Marc Harrison's work as an artist and furniture maker features in a new consumer campaign by Australian Macadamias.

This first encounter helped Marc understand the importance of macadamias to the Australian psyche. Then a residency with a furniture manufacturing company opened his eyes to the incredible possibilities of macadamia shell as a material.

"I was always very interested in doing things a little bit differently," he says. "I wanted to try and combine art and manufacturing together and see if we could come up with some unusual solutions."

The shaping of a new icon

Marc knew that Spanish companies were using waste almond shells to make coffins, so when a supplier showed him some pure macadamia shell powder he began experimenting. He combined the powdered macadamia shell with resin to create a beautiful smooth material that he shaped into his signature macadamia-shaped bowls that are now icons of Australian design.



Marc Harrison combines powdered macadamia shell with resin to create his signature macadamia-shaped bowls.

"The macadamia shell has great thermal quality, so it's nice to touch. It adjusts to your body temperature when you're holding it. That gives it a certain tactile quality," he explains.

Made by hand in Marc's studio, the bowls are for sale through Husque and local galleries. Oprah Winfrey was presented with one as an official gift when she toured Australia in 2010.

The macadamia wood project

Marc's current project uses macadamia tree wood to craft beautiful and unique furniture handles. Many growers appreciate the beautiful grain in the macadamia wood that they prune from their orchards, but Marc says it's a challenging material to work with.



Macadamia timber has a beautiful grain, as many growers appreciate.



Macadamia wood is challenging to work with, but Marc Harrison has developed techniques to turn it into beautiful objects.

"Within a matter of days and weeks the timber starts to split, making it very hard to actually do anything with. It doesn't season nicely and evenly," he explains. Marc had to develop techniques that would work with very short, thick and gnarly bits of wood, and that's where his creativity as an artist came in.

"The real breakthrough came when I looked at veneering the timber while it's still green, before it's even had a chance to dry out. Eventually I got to a point where I could cut a branch off the macadamia tree in the morning, and have this veneered, moulded handle by the afternoon. A tree limb the size of my arm can yield between 20 and 40 handles."



Marc Harrison uses macadamia tree wood to craft beautiful and unique furniture handles.

Art meets industry

Although Marc's products are at the forefront of industrial design, he approaches his work as an artist and maker first, letting the materials speak to him as he works with them. It's that hands-on creativity that has allowed Marc to innovate so successfully with macadamias.

"Macadamias are a big part of Australia, and they're becoming a big part of the world," he says. "They're a big part of my life too. In fact, I would say that Husque is my life's work."

Watch the video of Marc's story on our YouTube channel (YouTube.com/AustMacadamias) and stay tuned for more Macadamia Change Makers coming soon.

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Kernel quality: remaining cream of the crop

Kim Jones, Director, Cropwatch Independent Laboratories, **M:** 0488 340 808 **E:** kim.jones@westnet.com.au

Kim Jones from Cropwatch Independent Laboratories presents an analysis of the 2021 season based on the samples received from all major growing regions and summarises the key grower practices that underpin quality.

The 2021 season

This 2021 analysis is based on samples from Rockhampton in the north to Nambucca Heads in the south. While it is limited to samples submitted to our laboratory, it is a good representation of the results for the Australian industry for the year. The analysis is split into regions - Central Qld (Rockhampton to Maryborough), SE Qld (Gympie and G/H Mountains) and NSW (Northern Rivers to Nambucca Heads). The data compares 2021 averages to last season's for the same districts.

Overall, in terms of grower kernel quality, 2021 seems to be an average season. Total kernel recovery (TKR) is slightly down compared to 2020, which was above average for all growing regions, as seen in Figure 1.

The TKR for Central Qld appears to be slightly higher for 2021 (Fig 1A), but the change in harvesting practices in Central Qld, with a greater portion of the crop being sprayed with Ethrel and shaken, has brought the crop forward and given the impression of a higher TKR this season. The average though for the season to date in Central Qld is down from 38.8% in 2020 to 38.0% this year.

TKR generally increases in all districts as the season progresses with the lowest TKR in March. The season TKR for both NSW and SE Qld are down from 37.5% to 35.5% and from 37.6% to 35.2% respectively.

While TKR is down, the percentage of premium kernel is higher for both Qld districts due to a reduction in commercial and reject grades as seen in Figure 2. The premium kernel percentage in NSW is lower, down from 31.5% in 2020 to 29.9% this season, mainly driven by lower TKR but also by an increase in internal discolouration.

Internal discolouration in Central Qld was exceedingly high in February with some consignments having over 10% rejects due to internal discolouration. The incidence of the defect in Central Qld declined as the season progressed, except for another small spike in May. As in previous years SE Qld has the lowest occurrence of internal discolouration as seen in reject breakdowns in Figure 3, with a season average of 0.5%.

NSW had higher levels of the discolouration defect and a season average of 0.7%, up from 0.5% in 2020, but averages only tell part of the story. In NSW, some of the highest levels of internal discolouration occurred in May

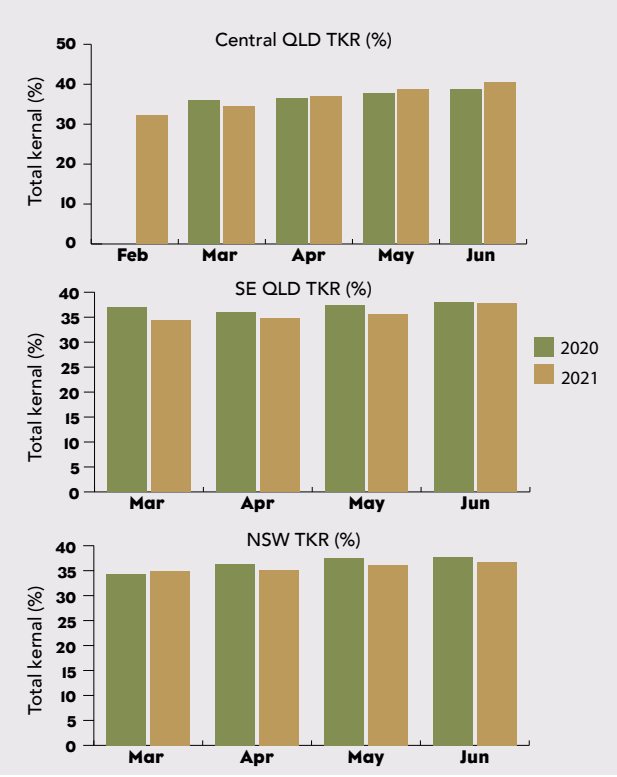

Figure 1. Total kernel recovery (TKR) for 2020 and 2021 seasons.

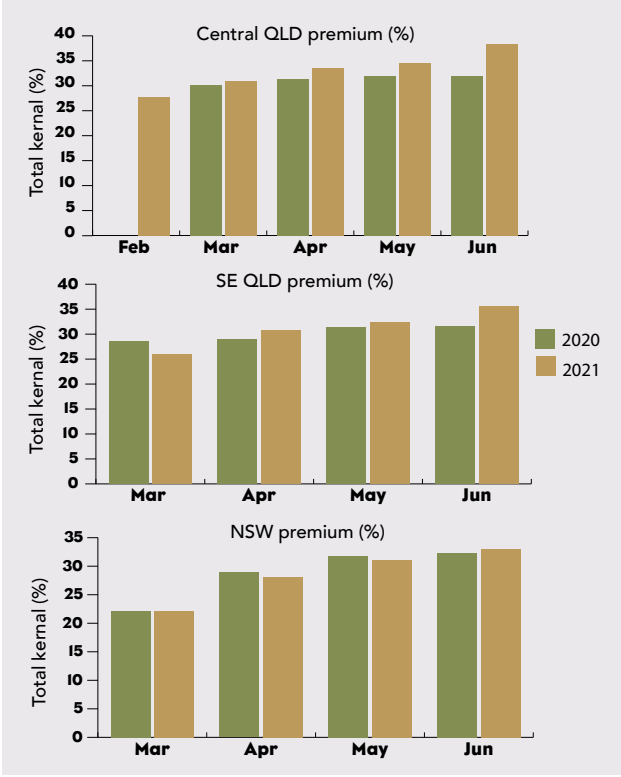

Figure 2: Premium kernel percentage for 2020 and 2021 seasons.

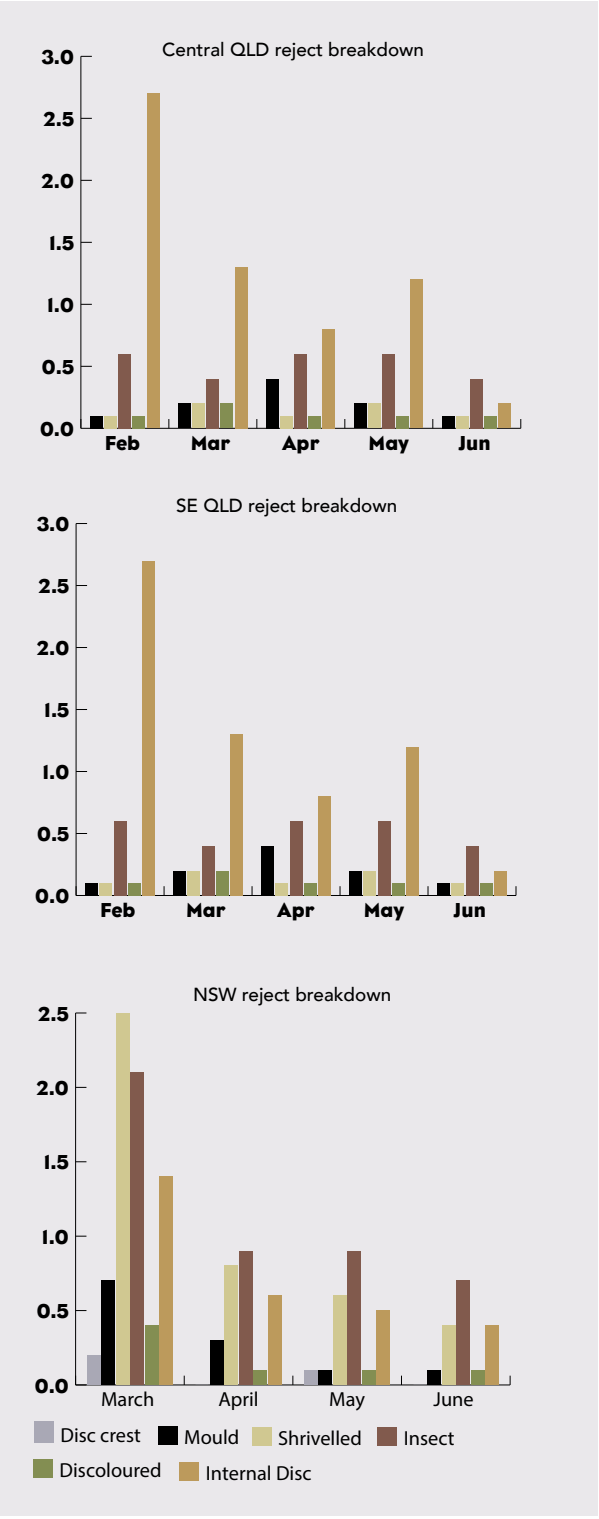

Figure 3. 2021 reject breakdowns by region.

and June. While many farms had zero brown centres, many recorded more than 3% internal discolouration in May and June.

In NSW, the cultivar 246 has had high levels of shrivelled kernel throughout the season. One sample from 246 that was harvested and delivered at the end of June had over 3% reject shrivelled kernel and a further 6.5% commercial grade shrivelled kernel. With a TKR of only 30%, this equates to 10% of the consignment rejected and a further 20% being downgraded to commercial grade.

On farm practices that underpin quality and the consumer experience

Prior to crop maturity, good farming practices including pest and disease control, nutrition, canopy management, irrigation and orchard floor management determine kernel quality. Once the crop has matured, there is nothing that a grower can do to improve quality. From this point it's all downhill. Significant losses in quality can occur due to poor harvest and post-harvest practices. At today's prices, every 1% increase in reject kernel costs the grower approximately 14 cents/kg NIS.

What can growers do?

Research conducted by the Australian industry over the years has identified and quantified many on-farm practices that impact kernel quality. Here are some key results from past research projects.

Harvest frequency: Short harvest intervals improve quality. The Adoption of Quality Management Systems project (Quinlan et al 2008) found that on average, growers who harvested every four weeks or more often had 2.6% more sound kernel than growers who harvested less frequently than every four weeks. At today's prices, the average lost income suffered by growers who harvested less frequently than every four weeks equates $364/tonne NIS at 10%. The reduction in quality was mainly due to increases in mould, germination and discolouration. Frequent harvests (when weather permits) give the best chance of optimising quality.

On farm storage: Nut in shell moisture content must be reduced to below 10% within two weeks of harvest to retain maximum quality. Most Australian on-farm storage systems are outdoor silos which are not designed as macadamia drying or curing systems and if nuts are held in these vessels for extended periods, significant kernel quality can be lost. In addition, nuts must be dehusked before any storage and preferably within 24 hours of harvest.

Post-harvest losses in quality are directly related to moisture content, length of time in storage and temperature. Early season harvests are particularly at risk as nuts are harvested at high moisture content, often above 25%, and daytime ambient temperatures frequently in the high 20's or even low 30's. With the high moisture and high temperatures, nut in shell will rapidly decline in quality.

Research by Kowitz et al (1996) showed that nuts stored for just two weeks at 25° C and 15% moisture had significantly poorer quality than nuts that had been dried to 3.5% and stored in ideal conditions.

The appearance, flavour and shelf life of raw kernel were all negatively impacted after NIS was stored for two weeks at 25° C and 15% moisture. The higher the moisture content, the quicker the decline, especially in relation to raw kernel flavour.

Hidden quality losses

Reduced flavour and shelf life is not measured by processors on delivery so these ''hidden" quality losses do not directly impact the grower's return. However, it is incumbent on growers to do everything they can to ensure quality kernel with long shelf life is delivered to the processor. This is particularly important in a market that may have excess stock from the previous season.

We know that good quality macadamias can be stored for several years without quality decline under the ideal conditions of low moisture, low temperature and low oxygen levels.

As world macadamia markets tighten up with increasing supply, kernel quality becomes more important in maintaining prices. The Australian macadamia industry has always prided itself as having the best kernel quality in the market, but this is no time to rest on our laurels. Supplying poor quality kernel to the consumer will impact repeat purchases and result in potential downward pressure on the price.

Repeat purchase is largely determined by the consumer experience of the product even more than the price. With increasing world competition, the best way to ensure a sustainable high price is to ensure that the consumer has an enjoyable experience when they consume Australian macadamias. Quality control must start on the farm and extend through the whole supply chain.



Quality control and ultimately the consumer experience starts on farm.

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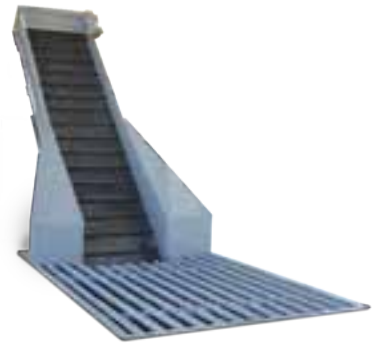
The Aspirator is used to separate out light debris and to grade nuts by weight. It is available in 24", 36" & 48" widths.



The Pit Elevator is the first stage of many cleaning plants. Savage makes them in several sizes.



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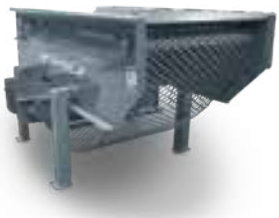
The Stone Remover has two stages: one that removes heavy debris and one that takes out light debris. Available in 36" and 48" widths.



The sorting table is availabe in various sizes. This one includes the Vision, dual-spectrum sorter, capable of sorting 15,000 pounds per hour.



This pre-cleaning assembly incorporates a Pre-vac, Stick Remover, Sizer/Cleaning Reel, and a Trash Conveyor. It is available in three different size configurations.



The Stick Remover uses a rotating sizing chain to remove sticks from the harvested nuts. It is available in 36", 48" & 60" widths.

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New macadamia rootstocks worth a crack

Malcolm Smith, Plant Breeder and Project Leader,
Department of Agriculture and Fisheries Queensland **E:** malcolm.smith@daf.qld.gov.au

There are a handful of new macadamia rootstocks that warrant wider industry testing according to the results from a Hort Innovation funded large rootstock field experiment near Bundaberg. Project leader Malcolm Smith suggests growers should stick with what they know but also include some of this promising genetic material in any new plantings. Malcolm believes the Australian industry has been well served by rootstocks like H2 and Beaumont, but we need to be on the lookout for something better. That was the purpose of the field experiment planted in 2007 with more than 200 different potential new rootstocks.

How important are rootstocks in macadamia orchard performance? This question is a topic of ongoing debate and sits at the heart of the *MC16000 Innovative rootstocks for the Australian macadamia industry* project. The project led by plant breeder Malcolm Smith from the Department of Agriculture and Fisheries, aims to identify new rootstocks with potential to improve orchard productivity.

The project team's approach was to plant as many genetically diverse cultivars as possible as rootstocks in the field experiment, to maximise the chances that some interesting results would emerge. With nearly 2,000 trees in the experiment and 10 years of yield assessments, there are some promising signs.

New scion cultivars are always going to be the main drivers of improved productivity in macadamia and that is why rootstock research should never be more than a minor component of breeding activity. However, scion cultivars generally need to be grafted onto rootstocks, so it makes sense to use the best rootstocks available.

Finding new rootstocks for tree crops is never easy because of 'background noise' in the data. There can be enormous variability in performance between two trees growing side-by-side. This is the case even when rootstocks are identical (clonal), but in macadamia, the rootstocks are segregating seedlings, which adds to the problem. Segregating seedlings are seedlings resulting from the crossing of two different parents (cultivars), making them inherently more variable.

Contrary to popular belief, using cuttings or tissue culture does not solve this problem because high variability remains, and a new problem of tree stability and potential 'wind-blows' is created. One answer is to find a few promising seed parent cultivars and to focus more attention on these, with higher replication and more testing sites. That is the stage we have currently reached in the experiment.

Growers who test some of the suggested rootstock cultivars from this research will be able to compare new rootstocks with the industry standards (H2 and Beaumont) under their own production conditions.

Malcolm Smith, who leads the project from the Bundaberg Research Facility, said that the rootstock cultivars need to be trialled under different growing conditions.



Malcolm Smith from DAF Queensland says the top performers in the experiment include A268, Own Venture and A4.



With nearly 2,000 trees in the experiment and 10 years of yield assessments, there are certainly some signs of promise.

"We need to see larger numbers of these trees tested under a wider range of conditions before deciding how much better they are than the existing standard rootstocks," he said.

"We think there is an opportunity to boost industry productivity with no additional inputs."

Malcolm added that new rootstock cultivars which have shown to be within the top performers in the experiment and worth testing on farm include A268, Own Venture and A4.

The existing field trial will continue to be monitored for productivity, tree health and vigour while a new rootstock experiment is currently being propagated and will include all the promising material identified from the first trial. This new trial will be planted on a grower's property where it can be evaluated under commercial conditions.

"Now that we have a handle on the better seed parents, we want to replicate them in greater numbers and start to examine the contribution of the pollen parent to rootstock performance," Malcolm said.

For anyone who still thinks that rootstocks are not important in macadamia production and just want to use any old seed they can find, Malcolm has some clear advice.

"Don't! If there is one thing that is very clear from our testing of more than 200 cultivars as rootstocks, it is that some of them are a disaster. Stick with what you know already works, while trying some of these new possibilities on perhaps 10-20% of new plantings," he said.

Acknowledgement:

Our thanks to FNC Plantations and Manager Adrian Walsh for hosting the trial.

This work is part of the project *MC16000 Innovative rootstocks for the Australian macadamia industry.*



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Rootstock field trial established at Nambour

Dr Mobashwer Alam[1], **Dr John Wilkie**[2], **Grant Bignell**[2], **Professor Bruce Topp**[1] **E:** m.alam@uq.edu.au

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As part of the National Tree Crop Intensification in Horticulture project, a rootstock trial has been established at Maroochy Research Facility at Nambour. The aim of the trial is to test 21 rootstocks for their effect on precocity, yield, flowering, tree vigour and structure and to identify characteristics of ungrafted rootstocks that are associated with scion performance.

The trial was planted in April 2017 and consists of 22 seedling and cutting rootstocks grafted with HAES 741 scion. The rootstocks under test include 11 elite selections from the national breeding program, two accessions of wild *Macadamia tetraphylla*, an accession of the wild species *M jansenii*, and eight cultivars (H2, Beaumont, Daddow, Renown, A4, A16, A268 and HAES842). The breeding program elites in this trial include four selections which are 30-50% of standard tree size.

In 2020, as three-year-olds, 45% of the trees produced nuts with a mean yield of 0.3 kg per tree. Harvesting has been completed for the 2021 crop. The scion HAES 741 was chosen for this trial because it is a common cultivar in both Queensland and New South Wales orchards and has low precocity. Rootstock effect on precocity will be amplified with the use of this scion.

A unique feature of the trial is the planting of an ungrafted rootstock adjacent to each grafted tree. For example, where H2 has been used as a cutting rootstock grafted with HAES 741, an ungrafted H2 cutting is planted along-side. The purpose of this design is to allow identification of characteristics in the ungrafted rootstock that may be associated with its performance as a grafted tree. This will assist in future research for selection of new rootstocks.



Measurement of trunk circumference in rootstock field trial at Nambour.



Dr Alam stands next to an M. jansenii *cutting. The tree to his left is a HAES 741 grafted onto the* M. jansenii *cutting.*

The trial was inspected by members of the Macadamia Industry Varietal Improvement Committee in 2019. A field day to present the 2021 yield results and allow industry inspection of the trial will occur once COVID-19 meeting restrictions are lifted. For details of the trial, please contact Dr Mobashwer Alam at m.alam@uq.edu.au

Acknowledgement

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Australian macadamia minor use and emergency permits

Current at August 2021

Chemical	Permit no.	Pest/Disease use	Application rate	Withholding period (no. days)	Minor use permits
Minor use permits					
Abamectin	PER87510	Thrips and flat or broad mites	• Product containing 18 g/L abamectin: 750 mL /ha plus 5 L summer spray oil/ha • Product containing 36 g/L abamectin: 375 mL /ha plus 5 L summer spray oil/ha	28	All states and territories except VIC
Chlorpyrifos & maldison	PER13642	Australian plague locust	• Product containing 500 g/L chlorpyrifos: 350 mL/ha • Product containing 440 g/L maldison: 1.4 or 1.9 L/ha • Product containing 500 g/L maldison: 1.2 or 1.7 L/ha • Product containing 1000 g/L maldison: 600 or 850 mL/ha • Product containing 1150 g/L maldison: 520 or 750 mL/ha • Ground application	Chlorpyrifos: 30 Maldison: Not required when used as directed	All states and territories except VIC
Diazinon	PER14276	Macadamia lace bug	• Product containing 800 g/L diazinon: 120 mL product/100 L	14	NSW, QLD & WA only
Ethephon	PER11462	Promote nut fall after maturity reached	• Product containing 480 g/L ethephon: 65–250 mL/100 L water • Product containing 720 g/L ethephon: 55–165 mL/100 L water • Product containing 900 g/L ethephon: 44–132 mL/100 L water • Do not spray stressed trees • Refer to critical comments for varietal rate adjustments	7	NSW, QLD, WA & NT only
Indoxacarb	PER86827	Macadamia seed weevil	• Product containing 150 g/L indoxacarb: 50 mL product/100 L • Product containing 300 g/kg indoxacarb: 25 g product/100 L	42	NSW & QLD only
Methomyl	PER90592	Banana fruit caterpillar	• Product containing 225 g/L methomyl: 1.5–2 L/ha • Spraying ground mulch/soil surface up to treelines only	Not required when used as directed	QLD only
Petroleum oil	PER11635	Macadamia felted coccid	• Product containing between 763 and 861 g/L petroleum oil: 1 L/100 L water	Not required when used as directed	NSW & QLD only
Trichlorfon	PER13689	Macadamia lace bug, fruit spotting bug, banana spotting bug and green vegetable bug	• Product containing 500 g/L trichlorfon: 200 mL/100 L	2	NSW & QLD only
Emergency permits					
Chlorantraniliprole	PER89353	Fall armyworm	• Product containing 350 g/kg chlorantraniliprole: 18 g product/100 L + 15 g active/100 L non-ionic surfactant/ wetting agent • Product containing 200 g/L chlorantraniliprole: 30 ml product/100 L + 5 g active/100 L non-ionic surfactant/ wetting agent	10	All states and territories except VIC
Indoxacarb	PER89278	Fall armyworm	• Product containing 300 g/kg indoxacarb: 25 g/100L	42	All states and territories except VIC
Methomyl	PER89293	Fall armyworm	• Product containing 225 g/L methomyl: 1.5–2 L/ha • Product containing 400 g/kg methomyl: 0.84–1.13 kg/ha • Spray ground mulch/soil surface only	Not required when used as directed	All states and territories
Spinetoram	PER89241	Fall armyworm	• Product containing 120 g/L spinetoram: 40 mL product/100 L	7	All states and territories except VIC

All efforts have been made to provide the most current, complete and accurate information on these permits, however, AMS and NSW DPI recommend that you confirm the details at the APVMA website portal: https://portal.apvma.gov.au/permits.

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.

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