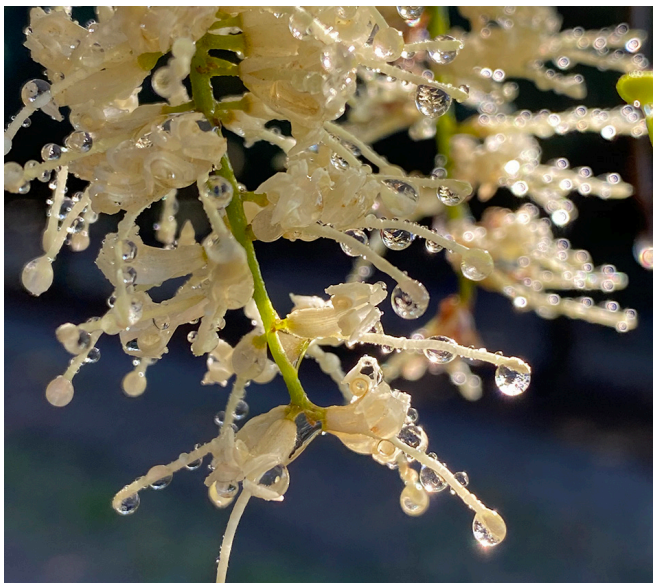
Fact sheet

POLLINATION

AUSTRALIAN MACADAMIA SOCIETY

Pollination by agents such as insects underpins production in many crops, including macadamias. Ensuring efficient and effective pollination is one way that growers can increase nut yield in orchards. This fact sheet summarises current knowledge about pollination in macadamias and suggests how this knowledge can be applied in the orchard to help improve production.



What is pollination?

Pollination involves the movement of pollen from the anthers of a flower to the stigma of the same or a different flower.

Self-pollination occurs where pollen is moved within and between racemes of the same macadamia cultivar by a pollinator such as a honey bee or native bee.

Cross-pollination occurs where pollen is moved by a pollinator from one macadamia cultivar onto the flowers of a different, compatible cultivar.

An important element in the process of macadamia pollination is fertility.

Self-fertile trees can pollinate themselves or trees from the same cultivar and produce nuts (called "selfing"). Self-sterile trees cannot pollinate themselves or trees from the same cultivar to produce nuts, rather they need to be cross-pollinated.

Fast facts

- Good pollination is essential to achieving good nut set and production in macadamias
- While some cultivars can self-pollinate, DNA paternity testing has consistently shown that most nuts come from cross-pollination, highlighting the importance of including pollination strategies in your orchard management plan
- The most important macadamia pollinators are the honey bee followed by the native stingless bee, although a variety of other naturally occurring species have been identified as macadamia pollinators of lesser importance, including rhinid flies and lycid beetles
- It is important to monitor pollinator insects in your orchard so you can determine how pollen is being moved between trees and whether there is potential to improve opportunities for cross-pollination
- Strategies to improve cross-pollination include: distributing hives of honey bees or native stingless bees or both through the orchard, incorporating multiple cultivars in each orchard block, encouraging foraging by bees by managing the flowering canopy to allow longer periods of sunlight, and yield monitoring to correlate potential yield decline due to under pollination.

Self-incompatibility means that there is some constraint that stops self-fertilisation.

Although macadamias are thought to be partially self-incompatible, i.e. they favour fertilisation by pollen of another cultivar over its own pollen, research and grower experience have shown that they can produce some nuts through self-pollination. Despite this ability for some cultivars to self-pollinate, DNA paternity testing by three different research teams in Queensland and New South Wales has consistently shown that most nuts come from cross-pollination. DNA paternity testing has also shown that the nuts produced by self-pollination are often smaller, with lower kernel mass and lower kernel recovery, than the nuts produced by cross-pollination.

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Potential for production

Macadamia trees can produce a lot of flowers – about half a million a year, per tree.

If every one of those flowers produced a 7 g nut, each tree would yield around 3,500 kg of nuts. More realistically, if one in 100 of the flowers on a tree produced nuts, the result would be 35kg of nuts per tree. Currently, average industry production per tree is between 8 and 9 kg of nuts.

Why are trees not reaching their potential production, and is poor pollination one of the causes?

(Source: Trueman and Wallace, 2020)

Macadamia flowers, fertility, weather conditions and pollinators

Important elements that affect pollination and fertility, hence nut set and production are:

- the nature of the macadamia flower
- floral health
- weather conditions during flowering
- the presence of pollinators and their dietary diversity.

While it was once thought that wind was important for pollination, research has shown that it is not likely to play a significant role. This is in part because macadamia pollen is released in sticky lumps, which are not easily blown around by wind, and because of the small surface size of the stigma.

The macadamia flower. With their large racemes, production of nectar and pollen and their structure, macadamia flowers are designed to attract pollinators, which contact the stigma and transfer pollen to it.

The flowers on the raceme do not open at the same time, rather it takes between 6 and 12 days for this to occur. Most flowers open over two days, and they can only be pollinated when they are fully open. Research has shown that each flower is attractive to pollinators for about three days.

Macadamia flowers do not all open at the same time and can only be pollinated when fully open. It is important to know when your flowers will be opening so you can manage activities such as spraying and scheduling contract hive hire to maximise opportunities for pollinators to work safely and effectively in the orchard.

Floral health. Successful pollination depends on managing factors that are within your control, e.g. pests and diseases. Potential pests that can devastate flowers include macadamia lace bug and macadamia flower caterpillar and these need to be monitored closely as flowering approaches and progresses.

Most professional pest scouts will also monitor for floral diseases that cause some or all the flower to die thus leaving fewer flowers to pollinate, e.g. *Botrytis*, *Pestalotiopsis* and *Cladosporium*. These diseases can be hard to diagnose. A professional consultant can identify and recommend pest and disease management strategies, which will include biological and cultural controls.

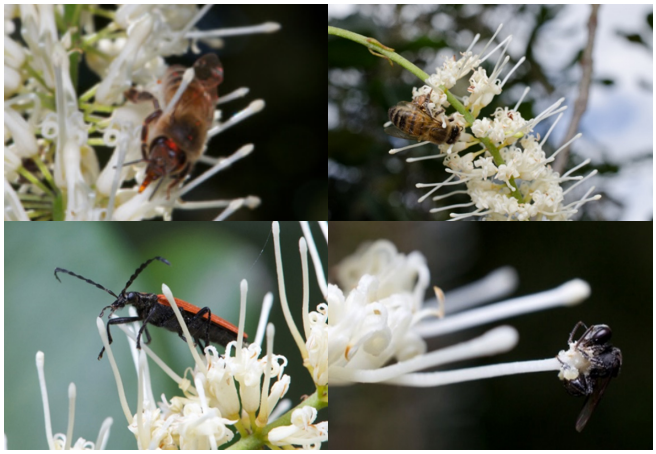
Floral health and development are underpinned by general tree health, available carbohydrates and adequate soil moisture. Managing boron, which supports functional floral growth, before open flowering has been shown to increase both yield and kernel quality. An integrated and professionally developed ground-based and foliar nutrition program is recommended. The use of rain-fast adjuvants is not advised during flowering as it may inhibit pollination.

Weather conditions during flowering. Flower initiation occurs in April and May and buds remain dormant for between 50 and 90 days. Warmer winter and early spring conditions will cause earlier flower emergence; conversely, cooler conditions will delay flowering.

Optimal floral growth occurs at cooler temperatures (12 to 18°C); high temperatures and low humidity will affect development. Rainy conditions during open flowering are not ideal for pollination, particularly in overgrown orchards with low light and limited air flow.

Presence of pollinators. The most important macadamia pollinators are European honey bees, *Apis mellifera* and native stingless bees, e.g. *Tetragonula carbonaria*. Along with *T. hockingsi,* they are the only pollinators that can be managed, i.e. in hives, that are used in macadamia orchards.

A variety of other naturally occurring species have been identified as macadamia pollinators including rhinid flies *(Stormorhina discolor)* and lycid beetles *(Metriorrhyncus rhipidius)*. These natural beneficial insects need biodiverse areas within or on the edges of the orchard in which they can be supported.



Many insects can pollinate macadamia including (clockwise from top left) rhinid flies, honey bees, stingless bees and lycid beetles. Source: Macadamia News Bulletin vol 46:2 August 2018, photos by Brian Cutting.

Dietary diversity. Honey bees and native stingless bees are healthier when they have a diverse "diet" supplied through a range of floral sources. This means that it is important to have a plant habitat inside and around orchard blocks that includes a variety of flowering plants.

This highlights the importance of orchard management that:

- enables a productive habitat for beneficial insects as a way of maximising pollinator populations
- uses an active pollination service through managed hives.

What we know about pollinators

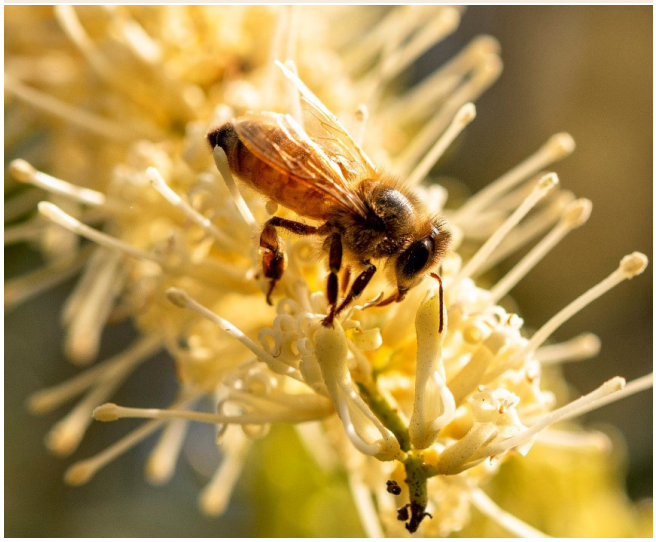
There have been several research projects into pollination for macadamias. The key findings as they relate to orchard management and improving production are summarised below.

Efficiency vs effectiveness. There is a difference between efficiency and effectiveness of pollinators. Efficiency is the rate of pollen deposited onto the stigma per minute by one pollinator; effectiveness is the number of stigmas that receive pollen in an orchard in an hour from all individuals of a pollinator species. This means that a pollinator species may not be as efficient as another but if there are more of them, they could be more effective.

Studies looking at the efficiency and effectiveness of different pollinators have consistently shown that stingless bees are the most efficient pollinators. They deposit more pollen per visit than other insects, contact more stigmas and visit more racemes per minute, and deposit pollen on stigmas more often than honey bees. Honey bees are the next most **efficient** pollinators after stingless bees, but they are the most **effective** pollinating species in most orchards because there are a lot more of them compared with stingless bees and other insects.

Plant & Food Research estimated that 78 % of pollination in Australian orchards is performed by honey bees and 13 % by stingless bees.

The key message is that honey bee hive populations are much higher than those of native stingless bee hives, so it is essential that they be included in any pollination management strategy.



Honey bees underpin pollination in macadamias.

Pollen collecting activity of honey bees decreases with distance from hives as they are central-place foragers. This means that placing hives evenly throughout the orchard in groups of two to four is more effective than placing hives along boundaries. As a guide, stocking rate of between five and eight honey bee hives/ha is recommended depending on competing floral resources.

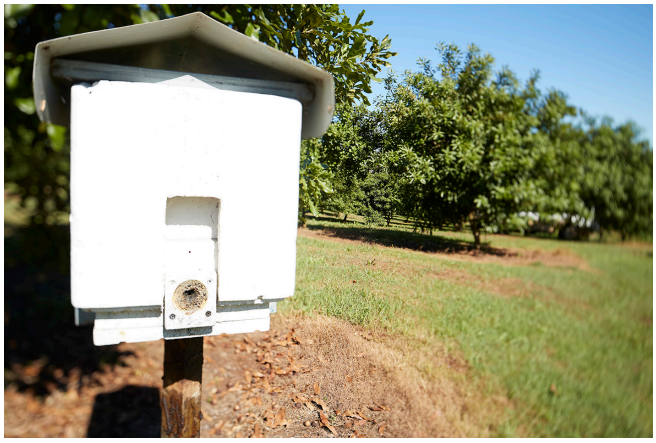
Honey bees, unlike stingless bees, need water, which should be available close to hives.

Work with your beekeeper. Not all beehives are the same; those best for pollination are managed differently from those used for collecting honey. As well, both honey bees and stingless bees have limited movement ranges and patterns of dispersal in orchard blocks. Work with your beekeeper to make sure that you are getting enough hives for pollination and spread the hives throughout your farm to promote pollination in all areas.

Working with your beekeeper can also help to avoid problems with accidental pesticide exposure and ensure your apiarist is familiar with the biosecurity code of practice – preventing spread of honey bee and plant diseases.

A detailed pollination agreement between the grower and apiarist is useful to ensure both are clear on services expected.

It should include the period hives will be in the orchard, apiarist access, hive distribution, timeous communication about any chemical applications and remuneration if applicable.



Spread stingless beehives throughout your farm to promote pollination.

A honey bees hive should contain more than 30,000 bees.

Be careful with chemical application. Check toxicity of all agricultural chemicals to bees and use those that are less likely to impact beneficial insects. If possible, apply them when the crop is not in flower and not at peak flowering. If the crop is in flower and you need to spray, apply chemical in the evening when bees are no longer foraging.

Cultivar and cross pollination. Research has shown that while cultivars differ in fertility, most nuts are cross-pollinated. From DNA paternity studies, cultivars such as 814, 816, 842, 849, A4, A16, A38, A203, Daddow and MCT1 are self-sterile and need pollen from another cultivar to produce good nut set.

Other cultivars such as 660, 741 and 791 seem to be self-fertile, and selfing rates (the percentage of self-pollinated nuts that reach maturity) of up to 40 % have been measured. Note, that this was only on individual trees in a regional variety trial and more work needs to be done before any conclusions can be drawn.

While some cultivars do self, in general, cross-pollination is likely to improve nut set in all cultivars, so the key message is to take advantage of this by including more than one variety in orchard blocks if you are planting out new areas or rejuvenating older orchards. It is also a good idea to ensure different cultivars are close to each other, e.g. in alternate rows. The evidence so far suggests that, with most pollen parents of cross-pollinated nuts often being the closest neighbours, pollination mainly occurs over short distances.

Research in a large 27 row block of A16, with 344/741 on one side and A4 on the other, identified that between 80 and 100% of A16 nuts were cross-pollinated. The project found that only 10 to 14% of nuts were self-pollinated in the middle of the 27-row block of A16 trees.

In another example, research in a large pure block with 42 rows of 816 trees next to 48 rows of Daddow trees found that more than 90% of the nuts were cross-pollinated. For 816, 94% of harvested nuts were cross-pollinated and only 6% self-pollinated. Even in the middle of the block, 84% of nuts were cross-pollinated. For Daddow, 98% of harvested nuts were cross-pollinated and only 2% were self-pollinated. Even in the middle of the block, 96% of nuts were cross-pollinated. Self-pollination contributed less than 0.2t/ha NIS to yield.

Improving pollination outcomes

More research is needed into pollination in macadamias, whether some cultivars are better pollinators than others, whether pollination issues are involved in early nut-drop in macadamias and the suspected significant role of self-sterility and poor cross-pollination in limiting yield. The advances in understanding mean that there are some things that can be done to improve pollination in the orchard.

Orchard design. Incorporating multiple cultivars in the one block greatly increases the chance of cross-pollination. When planting a new block or selectively replacing trees, consider differing cultivars, ensuring that timing of flowering and nut drop are well matched. Planting different cultivars within rows should assist cross pollen movement as pollinators do not have to fly so far between tree gaps across the rows, but there are orchard management considerations that need to be taken into consideration when implementing this within-row cultivar change.

Canopy management. Encourage bee foraging by managing the canopy to allow longer periods of sunlight, and in turn more pollination visits.

Hive placement. Bees are managed species whose foraging ranges differ. Distributing hives evenly and within their specific foraging distances will assist pollination.

Increasing biodiversity. Creating a biodiverse orchard conducive to natural pollinators and being mindful of orchard operations which impact these populations.

Monitor your pollinators. It is important to monitor the presence of pollinators. Becoming familiar with them in your orchard is an important step to understanding what may be moving pollen, and how cross-pollination could be improved.

Examining your trees in fine warm weather between 10am and 2pm is useful to assess pollinator activity. It will also allow you to make decisions about your need for additional pollinators. A suggested technique is to walk around 6 to 10 trees throughout the orchard and count the flower-visiting insects. Spend about two minutes per tree. On average, orchards have been found to contain three to four bees per tree, so it is good to aim for a higher count than this. If your counts are low or uneven, then introducing more managed bees (honey bees or stingless bees) may be necessary.

Tailor your pollination management. Macadamia pollination can be subject to many factors and varies from farm to farm, but by building your knowledge of what is happening in your orchard (including yield monitoring), you will be able to better understand which factors are the most important for you. You can then tailor your management strategy. This will help to safeguard your production against environmental changes, and develop an active pollination management strategy to ensure your farm is getting the highest possible yields.

Matched flowering. The guide below is a general indication of the main flowering of standard industry cultivars. It is important to ensure that new orchard blocks have cultivars which flower at similar times ie. the start, middle or end of the flowering period. Individual flowering times and length will depend on growing region, seasonal changes and range of other orchard management factors.

Some cultivars like 246 have an extended flowering period and often early out of season flowering.

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Acknowledgments

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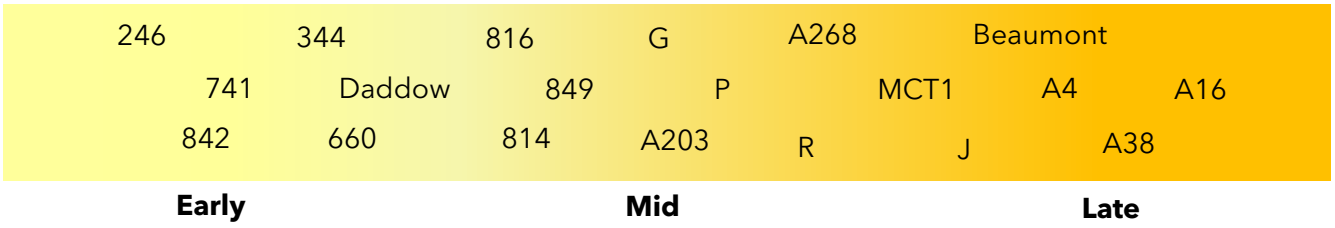
Further Information

For more information on this topic, please contact the AMS Industry Development Manager and/or your consultant/grower liaison officer.

Indicative Macadamia Cultivar Main Flowering Guide



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