Final Report

Australian pollination service statistics

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Delivery partner:

AgEconPlus and Australian Bee Services

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Australian pollination service statistics (HA21005)

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Public Summary

The Australian Pollination Service Statistics project was funded by Hort Innovation, using across industry research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture. The project was to deliver a better understanding of current European honey bee and native stingless bee hive requirements in the horticulture sector. This information was to enable the forecasting of hive demand based on industry growth, as well as highlight potential hive resource gaps and allow for adequate planning and prioritisation of research.

The research team collected information on the following:

- European honey bee hives required for the Top 10 pollination-dependent horticultural industries, with differences recorded across growing systems.
- Native stingless bee hive demand across Australia and targeted industries.
- Estimated hive requirements for five-year and ten-year horizons for the horticultural industry.
- Cost per hive (average) and issues that drive pricing.
- Time of year and length of time hives are required with identified times of crop overlap.
- The biggest issue(s) with hives received (e.g., quality, disease, or general management issues).
- Impacts of climate variability/climate events on pollination service demand.

The study has shown that the Top 10 pollination-dependent horticultural industries required around 644,000 honey bee hives for pollination in 2021 and this is expected to grow to 867,000 hives in five-years and 952,000 hives in ten-years' time. The average cost per honey bee hive supplied for pollination services varies from $50/hive to supply honey bees to macadamia to $160/hive for blueberry pollination and $225/hive for avocado pollination in Western Australia. The cost of native stingless hives for pollination is typically $110/hive. Peak demand for pollination services is in August and September. At least one of the Top 10 pollination dependent horticultural crops requires pollination in each month of the year.

Keywords

Pollination, honey bees, native stingless bees, supply, demand, forecast, almond, apple, avocado, blueberry, cherry, macadamia, mango, melon, pear, pumpkin, Varroa.

Technical Summary

The Australian Pollination Service Statistics project was funded by Hort Innovation, using across industry research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture. The project aimed to deliver a better understanding of current European honey bee and native stingless bee hive requirements in the horticulture sector. The project also included modelling forecast hive demand based on industry growth estimates. This work would highlight potential hive resource gaps and facilitate industry planning and prioritisation of research.

Prior to the completion of the project, there was a lack of data on the pollination services employed in Australian horticulture. Pollination service statistics are not collected by the Australian Bureau of Statistics and the most recent AgriFutures Australia honey bee industry snapshot alluded to a potential shortfall in pollination resources (Clarke and Le Feuvre 2020).

The project developed and implemented a methodology for the collection of robust pollination service statistics and was discharged through the delivery of five tasks. The first task was a launch meeting with Hort Innovation to agree to ten priority horticultural industries for analysis along with membership of a Project Reference Group. Tasks two and three were concerned with literature review, survey design and delivery. The literature review included relevant research completed by Hort Innovation and AgriFutures Australia. Both telephone/email and electronic (Survey Monkey) surveys of horticultural growers and horticulture peak industry body staff were completed. Telephone/email surveys of beekeepers, pollination brokers, and pollination auditors were also completed. An analysis of current and future honey bee hive requirements, native stingless bee demand, cost of hives supplied, pollination scheduling across crops, issues with hive quality and the impact of climatic events on pollination was prepared. Draft material was reviewed by horticulture peak industry bodies, the Project Reference Group and Hort Innovation prior to finalisation.

The project was delivered as the 2022 Port of Newcastle Varroa mite incursion was identified and response activities were rolled out. Response has included restrictions on the movement of honey bee hives, including movement of hives to major pollination events. Varroa mite response has included managed hive destruction in NSW eradication zones and the baiting for unmanaged (feral) colonies. The pollination of crops in Australia is highly reliant on unmanaged honey bees. This project was delivered during an uncertain period for the pollination industry.

The research has shown that in 2021 (the most recent year for which data could be collected and prior to the Port of Newcastle Varroa mite incursion and it's disrupted of the 2022 pollination season), that the demand for European honey bee hives by the Top 10 pollination-dependent horticultural industries was 644,000 hives. By 2026, demand is forecast to increase to 867,000 hives and by 2031, pollination of Top 10 horticultural industries will require 952,000 honey bee hives. All three estimates were prepared assuming absence of the honey bee pest Varroa mite. Honey bee hive stocking rate varies with production system employed – higher stocking rates are required for intensive planting systems and protected cropping. The stocking rate used is also a function of the crop variety grown with some newer varieties requiring fewer honey bees for efficient pollination. Current pollination hive supply is estimated at 530,000 commercially managed honey bee hives (Clarke and Le Feuvre 2020). This study notes that not all hives are required for pollination at the same time and that given the right economic signals, beekeepers are able to increase hive supply to a limited extent.

Amongst the Top 10 pollination dependent horticultural industries, managed stingless bees currently contribute to the pollination of blueberry and macadamia. In the future, there is potential for managed stingless bees to also contribute to avocado and mango pollination. In addition to the Top 10 pollination dependent horticultural industries, managed stingless bees are also used for the pollination of lychee and some strawberries grown in protected cropping systems. Demand for native stingless bee hives is expected to increase over the medium and long term. Horticultural industries are increasingly aware of the need to have access to multiple pollination methods including more than one pollinating insect species as a form of risk mitigation.

The average cost per honey bee hive supplied for pollination services varies from $50/hive to supply honey bees to macadamia to $160/hive for blueberry pollination and $225/hive for avocado pollination in Western Australia. Cost differences are due to the time of year hives are required, the high cost of transporting hives long distances, the impact that the crop and production system has on bee health, and the availability of co-benefits for beekeepers (e.g., some crops are able to provide pollen that strengthens the colony or nectar to produce harvestable honey). The cost of native stingless bee hives for pollination is typically $110/hive.

Many beekeepers are reluctant to supply pollination services due to the risk of contracting disease when hives are in close contact with those of other beekeepers, the long distance travel required to service remote crops, supplementary feeding requirements prior to pollination, poor on farm access tracks that are unsuitable for beekeeper vehicles, increasing requirements for hive dispersal throughout the crop, unsuitable put down pads, failure to supply water for honey bees, chemical use especially fungicide while bees are on farm, and a "flat" pricing structure for pollination services that does not recognise colonies of superior quality.

The biggest issues with hives received by horticultural industries for pollination were: poor quality – hives were not strong enough to deliver an appropriate pollination service, supply – growers cannot secure enough hives at the time when they are required, cost – price is excessive, beekeeper management on site – especially hive distribution in the crop, inconsistency between honey bee needs and orchard management practices (e.g., application of agricultural chemicals that are potentially harmful to pollinating insects), and communication – beekeepers are reluctant to talk with growers about crop needs.

Extreme weather events reduce the short term (seasonal) demand for pollination services – there is less crop to be pollinated. Longer term, extreme weather may increase the demand for paid pollination as the supply of non-managed pollinators, impacted by a more variable climate, contracts. Beekeepers experiencing extreme weather events are less impacted than growers and are usually able to implement management responses that deliver a suitable supply of hives.

Pollination research priorities identified by horticultural industries and beekeepers included new strategies for the management of pesticide, fungicide, and crop production chemicals to prevent damage to pollinating insects, augmentation of the pollination of crops with low levels of nectar production, systems to better detect/manage honey bee disease during pollination, and techniques for improving insect pollination of protected crops (covered production, greenhouse grown, etc.).

In addition to this final report a two-page industry focussed factsheet was prepared. The factsheet is available on relevant websites and through Hort Innovation communication channels. Distribution of the factsheet will target Hort Innovation decision makers, pollination-dependent horticultural industries, Australian pollination service providers, state governments, and the Australian Government through the Department of Agriculture, Forestry and Fisheries (DAFF).

Industry Focussed Factsheet

European Honey Bee Hives Required – Current and Future

Honey Bee Hives Required Top 10 Pollination Dependent Hort Industries – Current and Future

Industry	Current Requirement (2021 data)	Future Requirement 5-Years' Time	Future Requirement 10-Years' Time
Almond	330,400	400,000	420,000
Apple	28,125	28,125	28,125
Avocado	65,275	130,000	130,000
Blueberry	25,000	37,500	50,000
Cherries	8,535	10,250	11,100
Macadamia	126,000	201,000	252,000
Mango	800	900	1,100
Melons	29,750	29,750	29,750
Pear	11,113	11,113	11,113
Pumpkin	18,584	18,584	18,584
Total	**643,582**	**867,222**	**951,772**

Source: AgEconPlus and Australian Bee Services analysis

Managed Stingless Bee Demand – Current and Future

Managed Stingless Bee Demand Top 10 Pollination Dependent Hort Industries – Current and Future

Industry	Current and Future Managed Stingless Bee Demand
Almond	• Currently there is no use of managed stingless bees in the almond industry. However, research is underway to investigate the potential use of stingless bees in almonds. • Almond pollination in cool areas in August may prevent use of managed stingless bees which are native to the warmer parts of Australia.
Apple	• Managed stingless bees do not currently contribute to apple pollination. Cook 2022 notes that wild stingless bee populations may be contributing to apple pollination. • Managed stingless bees require warm climates and apples are grown in cool areas.
Avocado	• Currently, wild native stingless bees contribute to avocado pollination in QLD. • Low attractiveness of avocado flower to honey bees, along with research showing the importance of unmanaged stingless bees, suggests a potential future role for managed stingless bees.
Blueberry	• Managed stingless bees currently contribute around 5% of this industry's pollination needs. • Managed stingless bees are well suited to blueberry pollination in warm growing areas including Coffs Harbour NSW where most blueberries are grown. Increased use of managed stingless bees for blueberry pollination is forecast by this study.
Cherries	• Currently managed stingless bees are not used in the cherry industry. Cook 2022 notes that wild stingless bee populations may be contributing to cherry pollination. • Managed stingless bees require warm climates and cherries are grown in cool areas.
Macadamia	• Managed stingless bees currently contribute around 10% of industry's pollination needs. • Managed stingless bees are well suited to pollination of macadamia which is grown in warm subtropical areas. Increased use of managed stingless bees for macadamia pollination is forecast by this study.
Mango	• No current use of managed stingless bees for mango pollination. • Some potential for additional use of managed stingless bees in the future but growers mostly wedded to unpaid pollination and favour use of wild blowflies.
Melons	• Managed stingless bees do not currently contribute to melon pollination. • Singh and Makinson (forthcoming) concluded that stingless native bees are not good candidate pollinators for cucurbits. Subasinghe Arachchige et al. (2022) concluded that stingless native bees have potential as watermelon pollinators.
Pear	• Presently, no growers are using managed stingless bees for pear pollination. • No change to the present situation is anticipated over either the medium of long term.
Pumpkin	• Managed stingless bees do not currently contribute to pumpkin pollination. • Singh and Makinson (forthcoming) concluded that stingless native bees are not good candidate pollinators for cucurbits. Subasinghe Arachchige et al. (2022) concluded that stingless native bees have potential as watermelon pollinators.

Source: AgEconPlus and Australian Bee Services analysis

Unmanaged (Feral) Honey Bee Reliance – Without Varroa Mite

Unmanaged (Feral) Honey Bee Reliance – Without Varroa Mite

Industry	Current Reliance on Unmanaged (Feral) Honey Bees for Pollination
Almond	• For orchards adjacent to riverine areas, unmanaged colonies that resident in river red gums augment managed pollination by hived honey bees.
Apple	• Moderate reliance on unmanaged honey bee colonies. Growers indicated up to 35% of pollination needs provided by unmanaged honey bees.
Avocado	• Some reliance on unmanaged honey bee colonies. Growers indicated around 15% of pollination needs provided by unmanaged honey bees.
Blueberry	• Growers indicate low reliance on unmanaged honey bees. However, they may not be aware of the role these insects play at Coffs Harbour NSW, a major growing area.
Cherries	• All cherry growers surveyed indicate that they are highly reliant of unmanaged honey bee colonies for the pollination of their crop.
Macadamia	• Surveyed macadamia growers indicate that around 15% of their crop pollination needs were met be unmanaged honey bees.
Mango	• There is some reliance on unmanaged honey bees for mango pollination (approximately 10%). However, other insect species dominate mango pollination.
Melons	• Growers indicated around 10% of pollination needs provided by unmanaged honey bees with some areas entirely dependent on feral honey bees for melon pollination.
Pear	• Unmanaged honey bee colonies meet more than one third of total pear crop pollination needs. Honey bees are attracted by an abundant supply of pollen.
Pumpkin	• Pumpkin growers are highly reliant on unmanaged honey bees for the pollination of their crop. Pollination occurs in warmer months which favours wild honey bees.

Source: AgEconPlus and Australian Bee Services analysis

Australian Pollination Calendar

Australian Pollination Calendar – Top 10 Pollination Dependent Hort Industries

Industry	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Almond							■	■	■			
Apple									■	■	■	
Avocado								■	■	■		
Blueberry	■	■	■	■	■	■	■	■	■	■		
Cherries									■	■		
Macadamia								■	■			
Mango							■	■	■			
Melons	■	■	■							■	■	■
Pear										■	■	
Pumpkin	■	■	■							■	■	■

Source: AgEconPlus and Australian Bee Services analysis

Average Hive Hire Cost for Pollination and Issues Driving Price

Average Cost to Growers by Industry for Hire of Honey Bee Hives for Pollination 2021

Industry	Average Hive Cost ($/hive)
Almond	$155*
Apple	$130
Avocado – East Coast	$110
Avocado – WA	$225
Blueberry	$160
Cherries	$105
Macadamia	$50
Mango	N/a
Melons	$100
Pear	$130
Pumpkin	$100

* In 2022 prices averaged $162/hive due to lockdowns triggered by the Varroa mite incursion.
Source: AgEconPlus and Australian Bee Services analysis

Price is driven by:

- Competition for hives in the pollination peak of August and September.
- High cost of preparing hives in autumn for the August and September peak.
- High cost of transporting hives long distances e.g., almond pollination.
- Opportunity cost of honey crop foregone.
- Health impacts caused by crop and production system e.g., bees lose condition in protected cropping.
- Non-fee benefits for beekeepers e.g., crop provides pollen or a valuable honey yield.

Reasons Why Beekeepers Will Not Supply Pollination Services/Biggest Issues with Hives Received

Barriers and Issues with Hive Supply

Reasons Why Beekeepers Will Not Supply Hives for Pollination	Biggest Issues with Hives Received by Growers
Biosecurity – pollinating bees are exposed to disease	Quality – beekeepers not doing hive preparation work
Distance - pollination events are remote, inconvenient	Supply – growers cannot secure enough hives
Supplementary feeding – capacity building required	Cost – price excessive for quality suppled
Honey – opportunity cost of honey crop foregone	Beekeeper behaviour – hive placement and timeliness
Farm access tracks – impede hive placement	Bee needs – inconsistent with crop management
Hive placement in crop – wide distribution is costly	Communication – beekeepers reluctant to engage with growers about crop needs
Put down pads – poor prep and microclimate	
Drinking water – not supplied or contaminated	
Agricultural chemicals – poison bees	
Flat pricing – discourages high quality hives	

Impact of Climate on Pollination and Beekeepers

Climate variability/climate events:

- Extreme weather reduces short term (seasonal) demand for pollination services.
- Longer term climate variability may decrease the supply of wild pollinating insects.
- Growers and crops impacted by extreme heat, dry, cold, rain, wind, and bushfire.
- Beekeepers and bees can use management practices to offset climate variation/climate events.

Communication Messages

The project delivered robust pollination statistics for Australian horticulture as well as a better understanding of future hive requirements. Potential resource gaps have been identified and recommendations made in relation to research priorities and communication messages.

Communication messages arising from the project are:

- Industry growth projections point to a near 35% increase in the demand for honey bee and native stingless bee hives for pollination in the five years 2021 to 2026.
- Estimates of future hive demand assume that current efforts to eradicate the Varroa mite are successful. If Varroa becomes endemic, and eliminates unmanaged (feral) honey bee colonies, the number and cost of hives required for pollination will be significantly greater.
- Additional investment in all aspects of honey bee biosecurity is needed to maintain and then expand pollination capacity – Varroa, Tropilaelaps, and tracheal mites (exotic), American Foulbrood in intensive horticultural environments, Small Hive Beetle in humid warm periods, European wasps (regional issue) and cane toads (regional issue) are all biosecurity threats that impact pollination capacity.
- Ensure the honey bee industry's research, biosecurity, and residue testing responsibilities are appropriately funded through the Commonwealth levy system. The levy legislation cannot currently capture contributions from paid pollination. If and when new legislation that supports levies on pollination services is enacted, this needs to be addressed by the honey bee industry.
- Horticultural industries are increasingly aware of the need to have access to multiple pollination methods including more than one pollinating insect species.
- The quality of hives supplied by the honey bee industry is not always appropriate. Hives are not being independently audited and where auditing is occurring it is often appraised by a broker. This is creating issues for the grower and suppressing the price received by best practice beekeepers.
- Addressing beekeeper concerns about biosecurity and the risk to their honey bees from contracting disease during pollination could be resolved through more auditing of honey bee hives supplied for pollination, a certification scheme, and use of technology to capture quality parameter data.
- Auditing and potentially certifying the quality of native stingless bee hives that are to be used for paid pollination will be an important aspect of this industry's maturation.
- Growers who purchase pollination services need to place higher importance on relatively simple management changes to improve serviceability for beekeepers. This may include improvements such as farm access roads, suitable put down pads, and the provision of clean drinking water will increase the supply of bees available for pollination.
- Ongoing grower education is required on the importance of paid/managed pollination and the high-risk nature of reliance on incidental pollination from wild (feral) honey bee populations.

Introduction to the Project

Background and Project Scope

Project Background

Prior to the completion of this project, there was a lack of robust data on the pollination services employed in Australian horticulture including the supply of honey bee hives for pollination services and the hives demanded by the horticultural sector. This data is not collected by the Australian Bureau of Statistics (ABS), and the latest honey bee snapshot from AgriFutures Australia has shown that: *Australia-wide, there are approximately 530,000 commercially managed hives available to deliver paid pollination services; this number has been relatively static for some years. In 2019, the almond industry, Australia's largest user of paid pollination services, hired 180,000 hives for crop pollination. Hives used per crop cannot be estimated from existing data. Crop dependence on insect pollination is known from the literature (albeit reliant on relatively old data); actual use of hives on crops, other than almond, is not known* (Clarke and Le Feuvre 2020)*.*

Project Scope

Consequently, this research project developed and implemented a methodology to collect robust pollination statistics for Australian horticulture. The scope of this work was limited to the European honey bee and managed native stingless bees used for paid pollination services. The project was to collect data on the current use of hives for pollination in Australian horticulture and the preparation of a snapshot that reports:

- European honey bee hives required for the Top 10 pollination dependent horticultural industries with differences recorded across growing systems (open field vs protected cropping).
- Native stingless bee hive demand across Australia and targeted industries.
- Estimated hive requirements for 5-year and 10-year horizons for the horticultural industry.
- Cost per hive (average) and issues that drive pricing.
- Time of year and length of time hives are required with identified times of crop overlap.
- Biggest issue(s) with hives received (e.g., quality, disease, or general management issues).
- Impacts of climate variability/climate events on pollination service demand.

The project delivery team was required to design how the data was to be collected and ensure access to any required databases. The Australian Horticulture Statistics Handbook 2020/21 (Hort Innovation 2022) was to provide the latest comprehensive data on Australian horticulture and industry growth trends. A Project Reference Group (PRG) was to be assembled and approved by Hort Innovation.

Study Objective

The key objective of this project was to collect robust pollination service statistics for Australian horticulture. Through the use of the data, this project was to create a better understanding of current hive requirements and allow for the possibility of modelling forecast hive demand based on industry growth. This analysis was to highlight potential future hive resource gaps and allow for adequate industry planning and prioritisation of research.

Method Used for Project Delivery

The project was delivered through five tasks. The first task was a launch meeting to finalise project scope. The 16 June 2022 launch meeting was used to confirm the Top 10 pollination dependent industries for analysis (Table 1) and the composition of the PRG (Table 2).

Table 1: Top 10 Pollination Depend Horticultural Industries

Industry	Dependence on Insect Pollination (%)#	Production Area 2020/21 (ha)
Almond	100	59,000
Apple	100	9,375
Avocado	100	18,650
Blueberry	100	2,500
Cherries	90	2,845
Macadamia	100	36,000
Mango	90	15,764
Melons	70	8,500
Pear	50-100	3,175
Pumpkin	100	4,646

Refers to all insect species not just honey bee
Source: Hort Innovation 2022, Clarke and Le Feuvre 2020, Monk *et al* .2008, grower, and beekeeper advice.

Table 2: Project Reference Group Composition

Name	Relevance to Horticultural Pollination
Fiona Chambers	Chief Executive Officer (CEO), Wheen Bee Foundation (WBF), well connected industry professional currently driving development of a bid for a Cooperative Research Centre (CRC) for Pollination Security.
Stephen Hodge & Jason Ezra	Department of Agriculture, Fisheries, and Forestry (DAFF) Horticultural Policy, Agricultural Policy Division.
Rachel Mackenzie	CEO Berries Australia, blueberries are an expanding user of pollinator services including use in protected cropping systems.
Trevor Monson	Leading Australian pollination broker, has driven development in honey bee pollination services since the late 1970s. CEO Monson's Honey and Pollination.
Dr Doug Somerville	Retired Technical Specialist Honey Bees, NSW Department of Primary Industries (DPI), Retired Chair AgriFutures Australia Honey Bee and Pollination Program Advisory Panel, beekeeper, pollination service provider, and pollination auditor.
Ashley Zamek	Hort Innovation R&D Manager, Manager of the Hort Frontiers Pollination Fund, current member AgriFutures Honey Bee and Pollination Program Advisory Panel.

The second and third tasks were concerned with literature review, survey design and delivery. A list of references consulted is included at the end of this report along with copies of the final survey instruments employed for data collection. Those who were contacted to participate in project surveys are also identified at the end of the document.

Surveys were completed for both horticultural growers and suppliers of pollination services. Surveys completed with growers spanned the different production systems within each of the Top 10 pollination dependent industries. Interviews included researchers working in horticulture, and grower Peak Industry Bodies (PIBs). Beekeeper, pollination broker, and pollination auditor surveys spanned beekeepers who provide pollination services, those who will not supply pollination, as well as industry leaders. Project interviews were augmented with electronic surveys of growers. The electronic survey was distributed by Hort Innovation via the Growing Innovation newsletter, 3 August 2022.

The fourth project task included analysis of current and future honey bee hive requirements, native stingless bee demand, the cost of hives supplied, the supply calendar, reasons why beekeepers wont supply pollination services, issues with the quality of hives supplied and the impact of climatic events on pollination service demand. The final project task was reporting including preparation of relevant summaries for publication. Draft report and summaries were reviewed by the PRG, Hort Innovation and pollination dependent peak industry bodies.

Project deliverables included:

- A grower questionnaire focussed on pollination service demand.
- A beekeeper questionnaire focussed on pollination service supply.
- A draft project report "Australian Pollination Service Statistics".
- A final project report incorporating PRG, and Hort Innovation comment on the draft and prepared in the relevant Hort Innovation template.
- Research priorities and communication messages arising from the project.
- A two-page industry focussed factsheet.
- A monitoring and evaluation (M&E) Report.

The Pollination Process

Pollination is the movement of male pollen grains from the anthers of a flower to the female stigma of the same or a different flower. Once on the stigma the pollen grain must germinate, and the resulting pollen tube must break through the stigmatic tissue and down through the style to reach the ovule. The genetic material in the pollen tube then combines with an ovule to create a fertilised seed. For a commercial crop this needs to happen reliably and often (Goodwin 2012).

Some flowers will be pollinated by the movement of pollen in the wind, but for many crops the pollination rate is much higher when insects visit flowers and move pollen on their bodies. Honey bees are very important flower visitors, but a range of other native bees, flies and beetles can also be important. A few crops benefit from bird or bat pollination (Clarke et al. 2017).

European Honey Bees

The honey bee provides pollination services to around 35 Australian crops through both the supply of hived colonies from beekeepers and incidental pollination provided by unmanaged (feral/wild) colonies. In the absence of the pest *Varroa destructor* (Varroa mite), Australian horticulture benefits hugely from the incidental pollination provided by unmanaged honey bees. The extent of benefit is location specific and dependent on the close proximity of tree hollows suitable for unmanaged honey bee colonies (Whitehouse et al. 2021) and the population of the honey bee pest, Small Hive Beetle (*Aethina tumida).* Small Hive Beetle is more prevalent in humid areas.

Native Stingless Bees

Australia has about 1,650 named native bee species, which are found across all regions and climatic zones. The vast majority are solitary or semi-solitary. There are eleven described species of highly social (eusocial) native stingless bees, belonging to two genera, *Tetragonula* and *Austroplebeia* in the tribe *Meliponini* (Reynolds and Robinson 2022).

Native stingless bees (sugar bag bees) are found throughout the northern parts of Australia in the desert areas above a line from about Perth to southern QLD and coastal areas to Bega on the NSW south coast. They live in nests made of wax, bitumen and propolis and have a social structure like honey bees, consisting of a queen, workers and drones. Their nests persist for many years. Native stingless bees mass provision their young rather than progressively feeding them (Goodwin 2012).

Native stingless bees are efficient pollinators where they occur in the northern regions of Australia. The current main use for native stingless bees is as a commercial pollination service for fruit and nut growers, with macadamia, native to eastern Australia, the most pollinated commercial crop. While there are other crops that are under investigation (e.g., Hort Frontiers Pollination Fund project '*Stingless bees as effective managed pollinators for Australian horticulture*' (PH16000)) or are known to be pollinated by stingless bees, they are at the early stage or are not known to be actively utilised. Reynolds and Robinson 2022 identify seven prospective horticultural crops for native stingless bee pollination -Figure 1.

Figure 1: Crops with Potential for Native Stingless Bee Pollination

Fruit	Native bees
Avocado	*Lasioglossum (Chilalictus)* spp., *Meliponini* spp., *Tetragonula carbonaria*, *Xylocopa* sp.
Blueberry	*Exoneura* spp., *Lasioglossum* spp., *Meliponini* spp., *Tetragonula carbonaria*
Lychee	*Meliponini* spp., *Tetragonula* spp.
Macadamia	*Lasioglossum (Chilalictus) polygoni*, *Tetragonula carbonaria*
Mango	*Tetragonula* spp.
Strawberry	*Tetragonula carbonaria*, *Tetragonula hockingsi*
Tomato (greenhouse)	*Amegilla (Notomegilla) chlorocyanea*, *Amegilla (Zonamegilla) pulchra* (previously *A. homelsi*), *Xylocopa (Lestis) aerate*, *Xylocopa (Lestis) bombylans*

Source: Reynolds and Robinson 2022

The leading non-European honey bee pollinator candidates are native stingless bees, which live in large colonies like honey bees, pollinate a wide variety of plants, and can be kept in managed hives. The main native stingless native bee species used for crop pollination are *Tetragonula carbonaria* and *Tetragonula hockingsi. Tetragonula* species are used to pollinate crops in India and Thailand. Current Hort Innovation project PH16000 is examining *Tetragonula* pollination of almond, avocado, lychee, macadamia, mango, and vegetables grown in field and glasshouse conditions. Early findings show that in 'smart glass' greenhouses that cut out ultraviolet light, stingless bees perform well, while honey bee navigation is adversely impacted (University of Western Sydney (USW) website August 2022).

Solitary Bees

While most commercial pollination potential appears to lie with social, stingless bees, several groups of solitary and semi-social bees, including the *Amegilla* (blue-banded/banded bees and teddy bear bees), *Xylocopa* (carpenter bees) and numerous *halictids* (sweat bees) such as *Lipotriches*, "buzz" pollinate and show potential for *Solanaceae* crops such as eggplants, chillies and tomatoes, as well as *Ericaceae* species such as blueberries and cranberries. Honey bees cannot perform "buzz" pollination. A current Hort Frontiers project, 'Development of Blue-Banded Bees as Managed Buzz Pollinators' (PH19001), is investigating optimising breeding and management of disease in blue-banded bees (Reynolds and Robinson 2022).

Top 10 Pollination Dependent Industries

Chapter 2 provides an analysis of Australian horticulture's Top 10 pollination dependent industries. For each industry, the following has been addressed:

- Industry profile
- Production systems employed
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Almond Pollination

Industry Profile

Almonds are grown mainly in the south-east of Australia, with most production occurring in three growing regions, Sunraysia (VIC), Riverland (SA) and the Riverina (NSW) and a single enterprise in Western Australia (WA). The industry has a strong export market focus. Nationally there are less than 200 growers with 40 large corporates producing 90% of Australia's almonds. For the year ending 30 June 2021, Australian production was 124,439 tonnes kernel weight with a farmgate value of $721.6 M[1]. Between 2019 and 2020 production grew 10% with a further 9% growth in 2021 (Hort Innovation 2022).

The industry has actively promoted best management practice for honey bee health in almond orchards and has over 50% of the industry certified under the WheenBee Bee Friendly Farming program. The Almond Board of Australia (ABA) has prioritised the establishment of close-working relationships with beekeeper associations and provides financial assistance and support for honey bee industry initiatives and administrative capacity (Deidre Jaensch, Industry Development Manager, ABA, pers. comm., January 2023).

Production Systems Employed

Almonds are grown on a large scale and range of planting densities with ongoing research targeting high density, early cropping orchards. Almonds are not grown in covered production systems.

Honey Bee Hive Requirements

Almond fruit set and hence production is dependent on honey bee pollination. Generally, the main cultivars are self-incompatible. Therefore, there is a need for the pollen of one cultivar to be transferred to the stigma of another cultivar, this is also known as cross-pollination. Almond plantings are characterised by alternating rows of pollinator varieties with Nonpareil the main eating variety. Only honey bees that carry pollen from one cultivar to another receptive flower contribute to fruit set.

Honey bee hive stocking rates for almonds have been quoted at between 4 and 10 hives/ha. The Australian literature notes that between 5 and 7 strong colonies per hectare are required for maximum production of almonds. Monk et al. 2008 estimated hive requirements for almonds at between 3 and 5 hives/ha. Pollination broker Trevor Monson suggests 5 hives/ha in mature almonds. The Almond Board of Australia (ABA) estimated 4.6 hives/ha in 2021.

The survey completed as part of this study found an average stocking rate of 5.6 hives/ha in 2021. Data on peak pollination month was sourced from the literature and beekeepers supplying almond pollination services.

Table 3: Almond Pollination Service Requirements 2021

State	Pollination Peak Month	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
VIC	August	36,176	5.6	202,588
NSW	August	10,661	5.6	59,700
SA	August	11,905	5.6	66,670
WA	August	257	5.6	1,442
Total		**59,000**		**330,400**

Source: project survey results and Keogh et al. 2010.

This study estimates that 330,400 hives are required for almond pollination in 2021.

[1] 2020 farmgate value was $982.6M and 2019 farmgate value was $838.7M (Hort Innovation 2022).

Native Stingless Bee Demand

Use of native stingless bees for almond pollination is under examination as part of Hort Frontiers project PH16000. Almond pollination in cool areas in August may prohibit the use of managed stingless bees which require warm climates. At the current time there are no almond growers using native stingless bees to pollinate their crop.

Hive Demand in 5- and 10-Years' Time

In 2022, more almonds are being planted in Australia's south-east. Almonds are a highly mechanised crop, and the industry is growing in preference to more labour-intensive horticultural enterprises, such as asparagus.

ABA crop production data and forecasts through to 2030 are shown in the table below. A production estimate for 2031 has been prepared by this study.

Table 4: Almond Forecast Production and Honey Bee Hive Requirements 2019 - 2031

Year	Production – Tonnes Kernel Weight (t)	Honey Bee Hive Requirements (no.)
2019	104,441	180,000 (ABA Almond Insights 2018-19).
2020	114,427	
2021	124,439	330,400 (see table above estimated as part of this study)
2022	145,000	
2023	165,000	
2024	175,000	
2025	185,000	
2026	190,000	400,000 (estimated by this study)
2027	195,000	
2028	200,000	
2029	205,000	
2030	210,000	
2031*	212,000	420,000 (estimated by this study)

Source: Tim Jackson, CEO ABA, presentation to 4th Aust Bee Congress June 2022 * Estimate prepared by this study.
https://australianalmonds.com.au/wp-content/uploads/2021/08/2021_Almond_Insights_soft_copy.pdf

Growth in demand for honey bee hives will not be directly proportional to the growth in almond production. For example, self-fertile almond varieties which are now being introduced to the industry will require fewer honey bees for pollination. Taking account of future efficiencies, industry demand is estimated to be 400,000 hives in 5-years' time, and 420,000 hives in 10-years' time.

What about Varroa mite? If Varroa mite, a serious pest of honey bees becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will have some impact on almond industry hive demand and will significantly impact hive supply and availability. For orchards adjacent to riverine areas, unmanaged colonies resident in river red gums augment managed pollination.

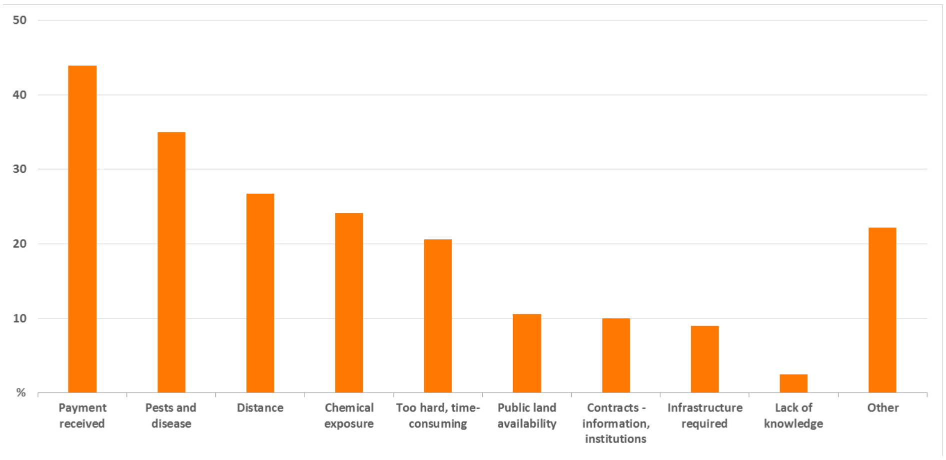
Competition for Honey Bee Supply and the Biggest Issues with Hives Received

The Australian almond industry is dominated by major corporate entities which seek efficiency in all aspects of production. It is likely that further KPIs around quality and timing will be introduced for honey bee pollination (Tim Jackson, CEO ABA, presentation to 4th Aust Bee Congress June 2022).

Application of chemical sprays while honey bees are in almond orchards has been a longstanding issue of concern for beekeepers and a reason why some apiarists will not supply pollination services. In 2021, it was estimated that 30% of almond growers did not spray almonds while honey bees were pollinating.

The most recent, but now dated ABARES survey of the honey bee industry, identifies payment received (relative to earnings from a honey crop), pest and disease risk, and distance to orchards as the major reasons beekeepers do not commence or expand paid pollination services – Figure 2.

Figure 2: Impediments to Beekeepers Providing Paid Pollination Services



Source: ABARES 2016

The almond grower survey revealed that the biggest issues with honey bee hives received by growers, in priority order, were:

- Cost – hive prices are too high.
- Supply – being able to source appropriate and sufficient hive numbers to meet demand.
- Quality – hives supplied did not meet expectations for hive strength.

Growers also identified border closures associated with the Varroa mite incursion in 2022 as a major issue. Victorian almond growers were particularly impacted as 49% of hives required to service Victoria were supplied by NSW beekeepers that were not able to cross the border.

Average Cost of Hives and Issues Driving Price

In 2020, with honey bees in short supply following extensive east coast bushfires, beekeepers were offered up to \$180/hive for almond pollination and in May 2020 the price had settled out at \$150/hive (Wayne Fuller, Commercial Beekeeper, NSW, pers. comm., May 2020) (Clarke and Le Feuvre 2020).

In 2021, the average price paid for honey bee hives to pollinate almonds was \$155/hive. In 2022, and post the Varroa mite incursion, closure of state borders, and limits on the availability of honey bee hives for almond pollination, beekeepers and pollination brokers reported actual payments averaging \$162/hive (with a range of between \$155 and \$170/hive).

Time of Year and Length of Time Hives are Required

Honey bee hives for almond pollination are required in late July and August. Honey bee colonies should be in the orchard at the beginning of flowering and should remain until flowering of the main cultivar has ended. Flowering is usually complete by late August to early-September.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Grower identified climate variability/adverse climatic events that are most likely to impact pollination services include:

- Extreme cold/frost/rain during pollination– pollinating honey bees are less likely to fly and pollinate the almond crop.
- Extreme wind events that impact both the honey bee's ability to pollinated and the impact on the flowering tree.

- Almond pollination is unlikely to be impacted by extreme dry (drought), the industry has been established on permanent irrigated water supply. However, growers did identify drought as having an impact on the quality of bee hives supplied for pollination services.

Research Priorities

The almond grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Honey bee health and management research to ensure the highest quality and consistent hives are supplied for pollination.
- Understanding the future supply and demand for almond (and competing crop) pollination and what implications this might have for hive pricing.
- Alternatives to insect pollination including research into better self-compatible cultivars and mechanical pollination techniques.
- How to attract and manage multiple pollinating species for efficient pollination.
- Research to document and understand the impact of lighter hive stocking rates in 2022 caused by lockdowns associated with the Varroa mite incursion e.g., impact on industry yield.

Deidre Jaensch, ABA (pers. comm., January 2023) reported that the ABA Pollination Committee identified the following RD&E priorities:

- Better understanding lethal and sub-lethal chemical impacts.
- Better understanding of the interaction between floral resources, supplementary feeding and bee nutrition for the benefit of pollination efficiency.

Several growers identified the need for the honey bee industry to attract younger people. Growers observed an ageing demographic which raised concerns around future industry viability.

Apple Pollination

Industry Profile

Apple production occurs across all states of Australia. Apple harvesting is between February and May and is largely manual, hand picking. Year-round availability of apples for consumers is made possible using controlled atmosphere storage technology. Nationally there are over 500 apple growers. For the year ending 30 June 2021, Australian production was 280,274 tonnes with a farmgate value of $620 M. Between 2019 and 2020 production shrank by 3% and in 2021 it declined by a further 7% (Hort Innovation 2022). Apple production has declined on a consistent basis since 2016-17 (Apple Strategic Investment Plan (SIP) 2022-26).

Production Systems Employed

Modern apple orchards may be grown under netting (hail, birds, and frost protection) with high density plantings. High density plantings on dwarf rootstock can be up to 2,000 trees/ha. Growers surveyed as part of this project tended to have a mix of traditional uncovered crop, medium density uncovered crop, and high density covered production. Large capital costs associated with high density covered production has slowed the adoption of this production system.

Honey Bee Hive Requirements

Apple crop yield benefits from cross-pollination. Of the ten available ovules in each fruit, the greater the number that are fertilised, the greater the likelihood that a particular fruit will compete successfully for available nutrients and will develop into a harvestable item. In addition, high seed numbers ensure better shaped fruit and improved keeping qualities. The movement of pollen across varieties most often happens when insects forage for nectar and pollen and fly from one tree to another. Australian studies have shown that this is most often accomplished by honey bees (Keogh et al. 2010).

This study found that apple growers using traditional uncovered cropping systems stocked managed honey bees at 1.5 to 2 hives/ha, medium density uncovered production was at 2 hives/ha, and high density covered production averaged a little over 4 hives/ha with a range between 2-6.5 hives/ha.

Research on the optimal stocking rate for honey bees in apple orchards suggests anything from 1 to 12.5 hives/ha is required with an average stocking rate across the literature of 2 to 4 hives/ha. Three to five hives per hectare should be used with high density plantings (Keogh et al. 2010). Monk et al. 2008 estimated hive requirements for apple at between 4 and 12.5 hives/ha. Goodwin 2012 suggests 4 hives/ha. Beekeeper advice is that there is a high reliance on incidental pollination, provided by unmanaged honey bees, native insects and wind dispersal of pollen, in the Australian apple industry. It is noted that an increase in the area of apples under netting may increase grower willingness to pay for honey bee hives (Clarke & Le Feuvre 2020).

Potential honey bee pollination requirements for apple in 2021 are summarised in the table below.

Table 5: Apple Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	September	29,558	989	3	2,966
WA	October	28,691	960	3	2,879
NSW	October	38,283	1,281	3	3,842
VIC	October	127,939	4,279	3	12,838
TAS	November	29,015	971	3	2,912
SA	October	26,788	896	3	2,688
Total		**280,274**	**9,375**		**28,125**

Source: Hort Innovation 2022, Area of production estimated from PHA data for 2018-19. Hive stocking rate from Keogh et al. 2010.

Nationally, this study estimates that 28,125 honey bee hives are required for apple pollination in 2021.

Native Stingless Bee Demand

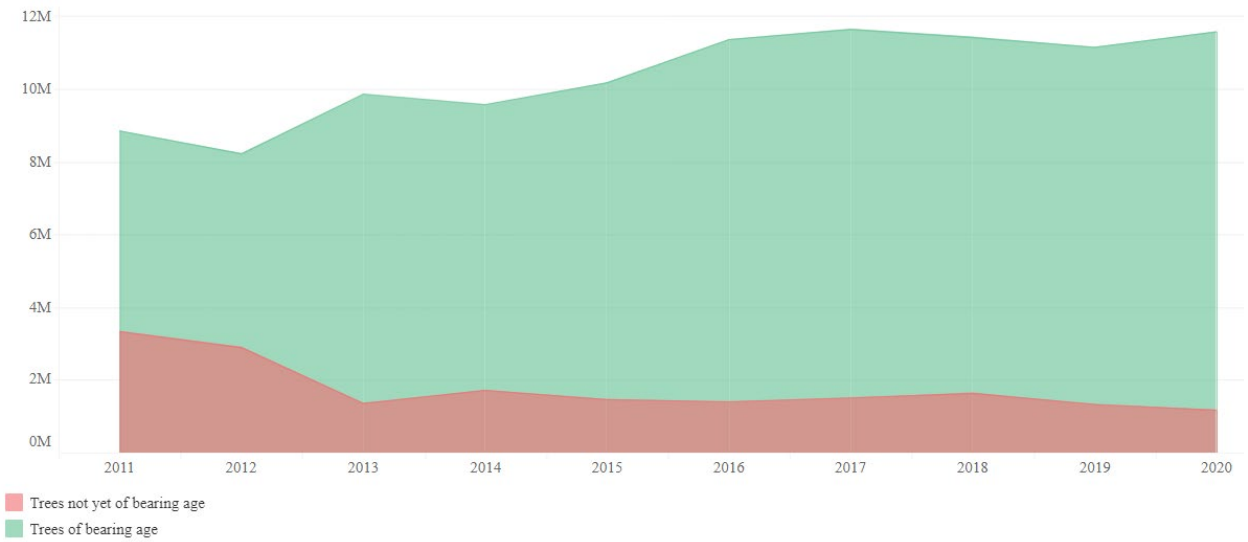
Research completed as part of the Rural R&D for Profit (RND4P) project, Securing Pollination (Whitehouse et al. 2021) showed that on surveyed apple farms, honey bees were the most common visitors. However, solitary native bees such as read bees and furrow bees were also common. In Stanthorpe (QLD), where apples are grown under hail netting, only honey bees pollinated the crop. The apple orchards studied in the Adelaide Hills (SA), Huon Valley (TAS) and Yarra Valley (VIC) were predominantly unnetted and had a higher diversity and abundance of insect visitors. In the Huon Valley of TAS, honey bees dominated pollination with some hoverflies and reed bees. Bumblebees were absent. In Bilpin (NSW), apples were pollinated by sweat bees. In Orange (NSW), there were no stingless bees, and the addition of managed honey bees for pollination is essential. It is important for growers to have access to multiple species to ensure adequate crop pollination (Ashley Zamek, Hort Innovation, pers. comm., 16 June 2022).

In eastern Australia, semi-social carpenter bees offer potential for pome orchard pollination (Brown, Barton and Cunningham 2020). Cook (2022) found that some native bees are as good as honey bees in pollinating apples at the individual insect level and noted that wild stingless bees may already be playing a role in apple pollination in Bilpin and Orange NSW. Managed stingless bees are not being used for apple pollination and this study notes that managed stingless bees require warm climates and consequently they may not be suitable for apple pollination as apples are grown in cooler areas.

Hive Demand in 5- and 10-Years' Time

The Australian apple industry is mature. Production of 280,274 tonnes in 2021 is similar to production of 276,400 tonnes in 2006. A wave of new orchard investment in the first decade of this century is complete and the share of non-bearing to bearing age trees has declined – see figure below.

Figure 3: Apple Tree Distribution by Age 2011 – 2020



Source: Apple and Pear Australia Limited (APAL) https://apal.org.au/programs/industry-data/industry-stats/

Production is flat and industry trends are towards new varieties and more intensive planting (Adam Briggs, Head Data and Insights, Hort Innovation, pers comm., June 2022). This study estimates that the demand for honey bee hives for pollination in both 5-years' and 10-years' time will be similar to 2021. (NB: An increase in the area of apples under netting may increase grower willingness to pay for honey bee hives – Clarke & Le Feuvre 2020).

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will increase apple industry hive demand. The apple industry benefitsfrom unmanaged (feral) honey bee pollination. Apple growers contacted for this study indicated that between 13% and 35% of their pollination needs were provided by unmanaged honey bees.

Average Cost of Hives and Issues Driving Price

The survey completed as part of this study showed that the average cost to apple growers of hiring honey bees for pollination was $130/hive. Price is driven by competition from avocado, blueberry, cherry, pear and macadamia growers as well as alternative income sources. Spring is, for many regions, the largest honey production period creating opportunity cost issues for beekeepers. Surveyed apple growers did not use commercial hive managed stingless bees.

Time of Year and Length of Time Hives are Required

Honey bee hives for apple pollination are required in September in QLD and November in TAS. All other states require hives for pollination in October (end of September to early November). Survey respondents indicated that hives should remain in the apple orchard for 3 to 4 weeks, Guy Graeta, Chair NSW Farmers Horticulture Committee uses 50 hives for a 3-week period to pollinate apples and cherries (The Guardian Australia 28 June 2022).

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

More than 80% of apple growers surveyed had no issues with hives supplied by beekeepers for pollination. Secondary issues identified by these and other apple growers, in priority order, were:

- Managing the needs of beekeepers and their bees – the management of onsite bees is not always consistent with the need to use chemical sprays.
- Cost – price demanded by beekeepers is too high.
- Quality – hives are not strong enough to do the job. There is limited auditing, and it is difficult to assess the results of managed pollination on apple yield.
- Beekeeper management when on site – hives are not placed in the right locations or dispersed appropriately through the orchard.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Apple growers identified the extreme climate variations/events most likely to impact the pollination of their crop as extreme cold, extreme rain, and extreme wind. Surveyed apple growers had not noticed changes in seasonal patterns impacting on the supply of pollination services.

Research Priorities

The apple grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Understanding supply and demand balances including future costs.
- Attracting and managing native pollinators to fill the honey bee pollination gap.
- Effective and efficient pollination in protected cropping systems.
- Managing multiple species for efficient pollination.
- Alternatives to insect pollination – mechanical pollination, new crop varieties.
- Honey bee management and efficiency.

Multiple apple growers noted the need for sound, long-term working relationships with local beekeepers. The need to be able to officially make use of bumblebees was noted as being a priority by one TAS apple grower.

Avocado Pollination

Industry Profile

Avocado harvest occurs mainly in QLD and northern NSW during the winter, and WA during the summer. Nationally there are approximately 850 avocado growers. For the year ending 30 June 2021, Australian production was 78,049 tonnes with a farmgate value of $489 M. Between 2019 and 2020 production grew 2% before declining 11% in 2021 due to adverse seasonal conditions (Hort Innovation 2022).

Production Systems Employed

Avocado plantings occur at either high or low density. High density planting starts at 300 trees/ha with thinning to 170 trees/ha on maturity. High density planting generates greater cash flow in the early years of the orchard. Low density orchards are planted at 150 trees/ha and are not thinned at maturity. Covered production is limited. There is one commercial avocado orchard under covered production in Tasmania, an experimental orchard in Kingaroy QLD and approximately 30 ha in SA (Simon Newett, Avocado Extension Officer, QLD Department of Agriculture and Fisheries (QDAF), pers. comm., August 2022 and Danny Le Feuvre, Australian Bee Services, pers. Comm., January 2023).

Honey Bee Hive Requirements

Although avocado flowers are self-fertile, the entire breeding system of the tree has evolved to reduce the amount of self-pollination that occurs. Cross-pollination increases the chances of successful pollination and improves final yields. Cross-pollinated fruit are less likely to be dropped early during periods of stress (Plant & Food NZ 2020).

Avocados require insect pollination. The consensus of various researchers who have studied the flowering and fruiting of the avocado is that only honey bees are always sufficiently abundant on the blossoms to set satisfactory crops of fruit. However, the attractiveness of the avocado flower to honey bees is low and honey bees are disinclined to pollinate avocado when alternative sources of pollen and nectar are available.

Avocado growers surveyed as part of this study indicated that they believed pollination of their crop was from the following sources:

- 40% managed honey bees.
- 15% unmanaged honey bees.
- 45% unmanaged native insects.

The literature suggests a honey bee hive density for avocado pollination of between 2 and 3 hives/ha. Increasing hive density from 2 to 3 hives/ha has been shown to increase average fruit weight (Keogh et al. 2010). McGregor (1976) concluded that a density of 2-10 hives/ha is required, with the actual number of hives depending on the amount of competing bloom. Monk et al. 2008 estimated hive requirements for avocado at between 5 and 8 hives/ha. Goodwin 2012 also proposed between 5 and 8 hives/ha. Plant & Food NZ (2021) also estimated a hive stocking rate of between 5 and 8 hives/ha.

Simon Newett (Avocado Extension Officer, QDAF, pers. comm., August 2022) notes that honey bee stocking rates in avocado vary from 2 to 10 hives/ha. Two hives being used when there are unmanaged honey bee populations, native bee and blowfly populations available to the grower. The industry survey completed as part of this study revealed an average honey bee hive density of 3.5 hives/ha.

Potential honey bee pollination requirements for avocado in 2021 are summarised in the table below.

Table 6: Avocado Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	August	54,685	13,067	3.5	45,735
WA	September	13,547	3,237	3.5	11,330
NSW	September	7,418	1,773	3.5	6,204
VIC	September	1,599	382	3.5	1,337
SA	September	800	191	3.5	669
Total		**78,049**	**18,650**		**65,275**

Source: Hort Innovation 2022. Hive stocking rate from 2022 industry survey, production area from UNE AARSC (2022) Australian Tree Crop Map, July 2022.

Nationally, 65,275 honey bee hives are required for avocado pollination. Hives required for avocado pollination in QLD, NSW, VIC must compete for hives with crops that flower at the same time (e.g., canola).

Native Stingless Bee Demand

A wide variety of insects like flies, beetles, and bees pollinate avocado flowers. The main pollinators can vary greatly between regions (Plant & Food NZ 2021). Avocado insect visitors varied by region, in Bundaberg QLD wild, native stingless bees and honey bees were most common, whereas in Sunraysia VIC, flies were dominant (Whitehouse et al. 2021).

Current WSU research (PH16000) shows flies, rather than honey bees are the major pollinator of Australian avocados (WSU website accessed August 2022). However, when large numbers of honey bees are used, honey bees will dominate pollination and ensure a successful crop (Plant & Food NZ 2021). The low attractiveness of avocado flower to honey bees, along with research showing the importance of unmanaged stingless bees, suggests a potential future role for managed stingless bees.

The efficiency of alternative avocado pollinators, measured in terms of how much pollen they deposit on stigmas is shown in the table.

Table 7: Efficiency of Different Avocado Pollinators

	Bristle flies	Blow flies	Hover flies	Lady beetles
Number of insects equivalent to 1 honey bee	1	2	3	3

Source: Plant & Food NZ 2021

Average Cost of Hives and Issues Driving Price

The survey completed as part of this project showed that the average cost to avocado growers of hiring honey bees for pollination was $110/hive. Price is driven by competition from alternative pollination opportunities, the high cost of preparing hives for pollination early in the year, and alternative income sources Spring is, for many regions, the largest honey production period creating opportunity cost issues for beekeepers. Surveyed avocado growers did not use hive managed native bees.

In Western Australia, beekeepers report current hire fees for avocado pollination are $225/hive. This cost is much higher than the Australian east coast and reflects direct competition for hives for the production of high-priced Jarrah honey. Beekeepers currently receive $35/kg farmgate for Jarrah honey (Dr Rob Manning, researcher, beekeeper, queen breeder, pers. comm., November 2022).

Hive Demand in 5- and 10-Years' Time

The avocado industry is in a strong growth phase and is expected to continue to grow at a rapid rate over the next five years based on the area planted across the nation. About half of all plantings are yet to come into full production with large increases in supply expected in north QLD, central QLD, and WA. Over the next five years, it is estimated that the industry will need to increase both domestic and international markets to consume an additional 90,000 tonnes, more than double the production volume in 2021 (Avocado SIP 2022-2026).

Australian avocado production is forecast to increase strongly over the next few years, with an average of around 170,000 tonnes per annum expected to be produced by 2026 (Avocados Australia 2021).

Honey bee hive demand is forecast to increase to 130,000 hives in 5-years' time and remain at this level in 10-years' time. Some offset in honey bee demand may be possible with increased use of managed stingless bees.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it may increase avocado industry demand for managed honey bee hives. Avocado growers indicate that around 15% of pollination is currently supplied by unmanaged honey bee colonies.

Time of Year and Length of Time Hives are Required

Honey bee hives for avocado pollination are required in August in QLD and September in other Australian states and regions. Honey bee hives for avocado pollination are required in October (Danny Le Feuvre, Australian Bee Services, The Guardian Newspaper, 28 June 2022).

Avocado Extension Officer Simon Newett, QDAF (pers. comm., August 2022) reports that honey bee hives are required for avocado pollination:

- Far North QLD – peak demand in August.
- South East QLD – mid September.
- Tri-state/Murray River – peak demand October.
- South West WA – October to November.

Honey bee hives remain in the avocado orchard for approximately six weeks.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

Avocado growers will need to compete for honey bees with the growers of other horticultural crops and the opportunity to capture a honey crop. Avocado pollination coincides with peak honey production periods in many regions providing alternative sources of beekeeper income.

In the Atherton Tablelands Far North QLD, availability of honey bee hives is limited by competition from nearby blueberry farms which have secured long-term pollination contracts. Furthermore, expansion of citrus orchards in the Atherton area is attracting honey bees away from avocado farms (Jim Kochi, Avocado Grower, Atherton Tablelands, pers. comm., August 2022).

Approximately one third of avocado growers surveyed had no issues with hives supplied by beekeepers for pollination. Issues identified by other growers included:

- Cost – price demanded by beekeepers is not reasonable ("but I pay more for better hives").
- Supply – can't secure enough hives when I need them.
- Quality - hives are not strong enough to do the job (limited auditing).
- Beekeeper management when on site e.g., hives not dropped in the right locations.
- Communication with beekeepers can be difficult. Working with the beekeepers to keep bee sites away from each other and meet their biosecurity requirements can be a challenge.
- Beekeeper/bee needs are not consistent with the management of my orchard e.g., cannot use production sprays.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

All extreme weather events impact avocado pollination (heat, dry, cold, rain, wind, bushfire). In particular, a warm spring which seems to be becoming more prevalent, will bring flowering forward and if a cold snap follows the flower will die. Avocados need three days with temperatures >10^{o}C for the Hass variety and >14^{o}C for the Shepard variety for a successful "Pollination Event" to occur. While avocados will flower every three weeks, a cold snap that kills avocado flowers will set production back and diminish total saleable yield (Simon Newett, Avocado Extension Officer, QDAF, pers. comm., August 2022).

Research Priorities

The avocado grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Native pollinators to fill honey bee pollination gap (e.g., development of pollination meadows/planting, managing all types of beneficial insects – pest predators and pollinators).
- Managing multiple species for efficient pollination (especially alternative pollinators – flies, and love bugs (*Plecia nearctica*).
- Managing citrus blossom bug and pollination – a new pest of avocado that requires spraying during flowering which also affects insect pollinators.
- Robust data to show best stocking rate and layout.

One grower noted "I think flies offer the best opportunity for low-cost pollination in conjunction with bees. Refining and developing species and commercial rearing and release or in-field breeding of flies is important".

Blueberry Pollination

Industry Profile

Blueberry production is centred in the northern NSW region of Coffs Harbour. A number of other blueberry production regions across Australia allow for close to year-round availability. Nationally, there are approximately 300 blueberry growers. For the year ending 30 June 2021, Australian production was 23,451 tonnes with a farmgate value of $411 M. Between 2019 and 2020 production grew 9% with a further increase of 14% in 2021 (Hort Innovation 2021, Hort Innovation 2022).

Hort Innovation 2022 reports the total area of Australian blueberry production at 1,375 ha. This estimate is shown as static since 2019 (and is unlikely to be accurate). PHA 2019 estimates blueberry production area at 2,500 ha with output of 19,008 tonnes. Berries Australia advice is that the PHA area of production estimate is more likely to be accurate (Rachel Mackenzie, Executive Director, Berries Australia, pers. comm., August 2022).

Production Systems Employed

Most Australian blueberry farms use protective covers such as plastic poly-tunnels and woven hail or bird netting to enhance blueberry growing conditions and protect the crop from damage. These covers may disrupt normal pollinator behaviour. Honey bees forage less under netted covers and can lose hive strength under such conditions. If possible, blueberry growers should delay covering their crops until the pollination period is over. Alternatively, and given that honey bees forage less widely under covered production, growers are advised to increase honey bee stocking rates (Plant & Food Research NZ 2020). It also needs to be noted that while blueberry produces nectar, it produces very little pollen and is not that attractive to bees. This also needs to be considered when planning blueberry pollination (Dr Doug Somerville, pers. comm., January 2023).

Covered production systems vary by region. Poly-tunnels are easier for honey bee and other insect pollination. Hives are placed outside the tunnel and bees have access to other sources of nutrition (e.g., weeds, native vegetation). On the NSW north coast, the preference is for large, structured nets to protect the crop from hail and birds. Pollination is more challenging under these conditions.

Honey Bee Hive Requirements

Blueberry pollen does not readily travel by wind, so pollinators are needed for adequate fruit set to occur. Most Australian blueberry cultivars are either 'highbush' – highly dependent on cross-pollination supplied by pollinators, or 'rabbiteye' – moderately dependent on cross-pollination (Plant & Food Research NZ 2020). Both overseas and Australian studies have shown that blueberry plants benefit from visitation by honey bees with greater fruit set, increased fruit numbers, and more fruit by weight than plants caged to prevent access by bees and larger insects. Insect pollinated fruit has been found to mature 4-12 days earlier and be up to 50% larger than fruit where insect access has been restricted (Keogh et al. 2010).

Blueberry growers surveyed as part of this study indicated that they believed pollination of their crop was from the following sources:

- 95% managed honey bees.
- 5% managed native stingless bees.

There is considerable variation in the number of honey bee hives required to pollinate blueberries. According to the plant variety and pollination requirements, hive density in blueberry crops varies between 1.25 and 10 hives/ha (Plant & Food Research NZ 2020). Two to 5 hives/ha should be adequate for most blueberry crops and can be introduced at or before 5% flowering (Keogh et al. 2010). Monk et al. 2008 estimated hive requirements for blueberry at between 2.5-10 hives/ha. Goodwin 2012 suggests that 8 or more hives/ha would be appropriate for most blueberry crops.

North coast NSW beekeeper Steve Fuller who supplies 2,500 hives per annum for blueberry pollination reports one hive is required per 1,000 blueberry plants (pers. comm., November 2022).

Blueberry Industry Development Officer Melinda Simpson (pers. comm., August 2022) reports that honey bee hive density requires further research. Melinda indicated that published information suggests around 6-10 hives/ha but that some industry representatives suggest up to 20 hives/ha. A survey of growers completed as part of this study, across uncovered, netted and poly-tunnel production systems, showed an average stocking rate of 10 hives/ha.

Potential honey bee pollination requirements for blueberry in 2021 are summarised in the table below.

Table 8: Blueberry Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	August	879	94	10	937
WA	September	504	54	10	537
NSW	September	20,075	2,140	10	21,401
VIC	September	469	50	10	500
TAS	October	1,407	150	10	1,500
SA	September	117	12	10	125
Total		**23,451**	**2,500**		**25,000**

Source: Hort Innovation 2022, hive stocking rate from industry survey 2022.

Nationally, 25,000 honey bee hives were required for blueberry pollination in 2021 if an average stocking rate of 10 hives/ha is applied. It is important to note that honey bee hives used to pollinate covered blueberry crops are "swapped out" every three weeks so the actual number of hives rotated through blueberries may be greater. Pollination broker Trevor Monson (presentation to the 4th Bee Congress, June 2022) estimated that the demand for hives for blueberry pollination in QLD, NSW, and VIC was 114,000 hives in 2021 and this estimate may recognise hive rotation.

The bumble bee *Bombus terrestis*, is an introduced species to Tasmania, and on some farms, it can be the primary pollinator of blueberries. Bubble bees and carpenter bees can sometimes struggle to reach pollen in the base of blueberry flowers and chew holes in the base of the flower to reach nectar. Studies have shown that even these robbing visits add to pollination and fruit set (Plant & Food Research NZ 2020).

Native Stingless Bee Demand

A variety of pollinators visit blueberry flowers these include stingless bees, native and non-native 'buzz' pollinators, honey bees, flies, butterflies, beetles and birds (Plant & Food Research NZ 2020).

Stingless bees are frequent visitors to blueberry flowers in mainland Australia. These small bodied native bees make good contact with stigmas while foraging and are likely to be efficient pollinators for blueberries. Stingless bees are social and in warmer regions managed hives are available for hire (Plant & Food Research NZ 2020).

Research has shown that honey bees may not be the most efficient pollinators of blueberry and that other insects and smaller native bees may also assist in pollination. While honey bees were the most common visitors to the blueberry farms studied, other native and other wild bees were also common (Whitehouse et al. 2021).

In 2020, blueberry flowers were surveyed for insect visitors on farms in TAS, NSW, and QLD. In TAS, honey bees accounted for 76% of visitation with bumblebees (19%) accounting for most of the rest. In NSW, honey bees and wild stingless bees (*Tetragonula carbonaria*) accounted for 99% of blueberry flower visitation. In Walkamin QLD, managed honey bees contributed 95% of flower visitation for blueberries grown in poly-tunnels. The success of pollination by unmanaged stingless bees is highly dependent on the presence of woody native vegetation for nesting within 200 metres of the crop (Whitehouse et al. 2021).

Managed stingless bees are well suited to blueberry pollination in warm growing areas like Coffs Harbour where most blueberries are grown. Increased use of managed stingless bees for blueberry pollination is forecast by this study.

Hive Demand in 5- and 10-Years' Time

The trend towards healthy eating, the rise in popularity of fruit for 'snacking' purposes, the classification of blueberries as a 'superfood', and the versatility of berry products suggest increased domestic and global berry consumption and a corresponding opportunity for Australian blueberry growers. Growth in the domestic market will continue. Growers will increase their strategic focus on export opportunities (Blueberry SIP 2022-2026).

In 5-years' time, production will be 50% greater than the industry's current 23,451 tonne output and in 10-years' time it will be double current output. Over the last 5 years blueberry production has experienced a 9% year-on-year increase in volume and 15% increase in value. Honey bee hive demand will increase in line with production projections, i.e., 37,500 hives in 5-years and 50,000 hives in 10-years' time.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will not impact blueberry industry hive demand but will significantly impact hive supply and availability. Limited blueberry pollination is provided by unmanaged honey bees. Blueberries are mostly serviced by managed honey bees and, to a lesser extent, managed native stingless bees. As an aside it is noted that blueberry growers in Coffs Harbour, which is a major blueberry production area, may not be aware that their area has a significant unmanaged (feral) honey bee population (Dr Doug Somerville, pers. comm., January 2023).

Average Cost of Hives and Issues Driving Price

The average cost to blueberry growers of hiring honey bee hives for pollination across four large growers (Mountain Blue, Driscolls, Perfection Fresh and Costa) was $160/hive and an average hire is for two months. Blueberry Industry Development Officer Melinda Simpson reports that honey bee hire costs range between $75 and $85/hive/month (pers. comm., August 2022). North coast NSW beekeeper Steve Fuller reports a minimum charge of $90/month (pers. comm., November 2022). Price is driven by the high cost of preparing honey bee hives for pollination early in the year, competition from alternative paid pollination, and alternative income sources i.e., honey flows from native vegetation.

The cost of hiring native stingless bee hives for blueberry pollination was $110/hive and hives were kept in the crop for approximately 10 weeks. Most users of native bees had their own hives or had them provided by the native bee keeper at no cost to the grower.

Time of Year and Length of Time Hives are Required

Blueberry Industry Development Officer Melinda Simpson (pers. comm., August 2022) reports that honey bee hives are required for blueberry pollination:

- Early season blueberries – April to June.
- Mid-season blueberries – August to September.
- Late season blueberries – September to October.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

Honey bee hives are required for blueberry pollination in winter and early spring when bees have low populations. Blueberry growers need to compete for honey bees with winter/early spring flowering crops and the opportunity to capture a honey crop. Native stingless bees are not available for pollination in August and September but may be available in October in warmer climates such as Coffs Harbour.

The blueberry grower survey revealed the biggest issues with honey bee hives received were (in priority order):

- Supply – growers cannot secure enough honey bee hives when they need them – major industry issue.
- Biosecurity incursion impacting the supply of hives – surveying coincided with Varroa detection at the Port of Newcastle, 22 June 2022.
- Beekeeper management when on site e.g., hives not dropped at the right locations.
- Quality – hives are not strong enough to do the job (there isn't enough auditing of what is supplied).
- Lateness - hives arrive late and miss the peak blueberry flowering window.
- Pests and diseases – fear of pests and diseases is keeping beekeepers away (also related to supply)

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Blueberry growers identified extreme rainfall as the climatic event most likely to impact pollination of their crop – "when it is overcast and raining honey bees will not pollinate". On the back of two major NSW floods in 2022, blueberry growers indicated that climate change was leading to an increase in extreme rainfall events and a decrease in pollination efficiency.

Research Priorities

The blueberry grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Better understanding of the pollination requirements for different blueberry varieties as well as the stocking rates for these varieties.
- Managing multiple species for efficient pollination.
- Honey bee management and efficiency – especially hive densities.
- Native pollinators to fill honey bee pollination gap.
- Pollination in protected cropping.
- Alternatives to insect pollination (mechanical pollination, new crop varieties).

Cherry Pollination

Industry Profile

Cherries are produced during the summer months, with most production occurring in the southern states of Australia. Nationally there are approximately 700 cherry growers. For the year ending 30 June 2021, Australian production was 20,073 tonnes with a farmgate value of $231 M. Cherry production volumes fluctuate from year to year due to climatic factors. Between 2019 and 2020 production shrank by 27% but increased 36% in 2021 (Hort Innovation 2022).

Production Systems Employed

Cherries are a high value crop and are mostly grown in some form of protected production systems. Netting is used for hail, birds, and frost.

Honey Bee Hive Requirements

Cherries require insect delivered cross-pollination to secure a satisfactory crop. Multiple studies have shown increased fruit set and resultant production when using managed honey bees at suitable stocking rates for pollination. One study showed yields for caged cherry trees which could not be visited by honey bees of 1.9 kg of cherries per tree while trees exposed to honey bees yielded 35.2 kg/tree (Keogh et al. 2010).

A stocking rate of 2 to 3 hives/ha is generally regarded as adequate for the pollination of most cherry varieties. Cherry blossom is very attractive to honey bees. Some researchers contend that a higher stocking rate may occasionally be desirable. Monk et al. 2008 estimated hive requirements for cherry at between 2.5 and 5 hives/ha. Goodwin 2012 recommends that up to 10 hives/ha be used for cherry pollination.

Potential honey bee pollination requirements for cherry in 2021 are summarised in the table below.

Table 9: Cherry Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Producing Trees (no)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	September	50	5,440	7	3	21
WA	September	622	67,675	88	3	264
NSW	September	5,550	603,856	787	3	2,360
VIC	September	5,661	615,933	802	3	2,407
TAS	October	5,038	548,149	714	3	2,142
SA	September	3,152	342,947	447	3	1,340
Total		**20,073**	**2,184,000**	**2,845**		**8,535**

Source: Hort Innovation 2022, Production area based on Cherry Growers Australia Inc. data for 2018-19. Hive stocking rate from Keogh et al. 2010.

Nationally, 8,535 honey bee hives are required for cherry pollination.

Native Stingless Bee Demand

Research completed as part of the RND4P project, Securing Pollination (Whitehouse et al. 2021) showed that on the cherry farms surveyed in SA and VIC, honey bees were the most common visitors. However, read bees and furrow bees were also common. Cook (2022) found that some native bees are as good as honey bees in pollinating cherries at the individual insect level and noted that wild stingless bees may already be playing a role in cherry pollination in Bilpin and Orange NSW. Managed stingless bees are not being used for cherry pollination and this study notes that managed stingless bees require warm climates and consequently they may not be suitable for cherry pollination as cherries are grown in cooler areas.

Hive Demand in 5- and 10-Years' Time

The cherry industry is in a strong growth phase with increased plantings occurring predominantly in Tasmania and Victoria. The orchards are being developed to service the anticipated demand increase from China, Korea, Japan, and the United Kingdom following completion of Free Trade Agreements (Cherry SIP 2022-2026).

This study estimates a 20% increase in Australian cherry production in 5-years' time and a 30% increase on 2021 levels in 10-years' time. These increases will have a corresponding impact on hive demand i.e., 10,250 hives in 2026 and 11,100 hives in 2031.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will increase demand for managed honey bee hives for cherry pollination. All growers surveyed estimated they had a heavy reliance on the feral honey bee populations. The Young District of NSW is a major cherry growing area and is well supported by unmanaged honey bee colonies (Dr Doug Somerville, pers. comm., January 2023).

Average Cost of Hives and Issues Driving Price

The survey completed as part of this project showed that the average cost to cherry growers of hiring honey bees for pollination was $105/hive for the duration of flowering. Some growers commented that honey bees hired for other crops, such as apples and pears, were also used to simultaneously pollinate their cherries.

Price is driven by competition from alternative pollination and honey production opportunities during spring. Spring is, for many regions, the most productive honey producing period creating opportunity cost issues for beekeepers.

Time of Year and Length of Time Hives are Required

Honey bee hives for cherry pollination are required in late September on the mainland and early October in the colder Tasmanian regions. Honey bee colonies should be placed in the orchard when 5% of the blossom is ready. Guy Graeta, Chair NSW Farmers Horticulture Committee uses 50 hives for a 3-week period to pollinate apples and cherries (The Guardian Australia, 28 June 2022).

Typically survey respondents expected honey bee hives to be required for a three-to-four-week period which is shorter than many other crops.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

All cherry growers surveyed stated they had no issues sourcing bee hives and were happy with their relationship with their beekeeper. The short flowering period does make it critical to place the bees in orchards on time.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Surveyed cherry growers identified cold, wet and windy weather during pollination as having significant impacts of pollination success. One grower identified that certain varieties perform better under adverse weather conditions than others. Another grower commented that he thinks the effects of windy weather during pollination is not understood well enough and believes wind alone can have significant impacts of pollination efficacy.

Research Priorities

All growers prioritised research into native pollinators as a honey bee alternative and managing multiple pollinating species in crop. Growers also wanted research into managing honey bees in protected cropping and to understand the future supply, demand and consequential impacts on pricing for pollination services.

Macadamia Pollination

Industry Profile

Macadamia production occurs mainly in northern NSW and Bundaberg QLD. The macadamia industry has a strong export market focus with 79% of production shipped overseas. Nationally there are around 800 macadamia growers. For the year ending 30 June 2021, Australian macadamia production was 51,000 tonnes (in-shell weight at 3.5% moisture) with a kernel weight of 16,830 tonnes and a farmgate value of $339.1 M. Production increased by 5% between 2019 and 2020 and a further 13% between 2020 and 2021 (Hort Innovation 2022).

Production Systems Employed

Orchard design usually favours long hedgerows to maximise land use and machinery operation. Planting distance can vary from high density (6 x 3m) to lower density (10 x 4m) depending on tree variety, soil conditions and topography (Keogh et al. 2010). Production is mostly low density with 312 trees/ha. Covered production is not used in this industry (Leoni Kojetin, Industry Development Manager (IDM), Australian Macadamia Society (AMS), pers. comm., August 2022).

Honey Bee Hive Requirements

Macadamia has bi-sexual flowers that are partially self-compatible. However, the initial nut set of many commercial cultivars is reduced when self-pollination is compared with cross-pollination. The literature concludes that given the small size of the stigma, the sticky pollen and the absence of wind-borne pollen, insect pollination is critical. In Australia, the major pollinators of macadamia are honey bees and native bees of the genus *Tetragonula* (Keogh et al. 2010).

Macadamia growers surveyed as part of this study indicated that they believed pollination of their crop was from the following sources:

- 40% managed honey bees.
- 10% managed native stingless bees.
- 15% unmanaged honey bees.
- 35% unmanaged other insects.

There is no industry standard for honey bee hive stocking rates for macadamia pollination and the AMS loosely recommends stocking rates of between 2 and 5 hives/ha (Leoni Kojetin, IDM, AMS, pers. comm., August 2022). The literature indicates that optimal honey bee stocking rates are between 5 and 8 hives per hectare (Keogh et al. 2010, Plant & Food Research Australia 2020). Sub-optimal stocking rates provide a honey crop for beekeepers.

Some beekeepers report honey crops from macadamia and this is reflected in the price paid to beekeepers by growers. When stocked at the higher recommended densities nectar is dissipated amongst the pollinating bees reducing any economic gain from honey production for the beekeeper.

Potential honey bee pollination requirements for macadamia in 2021 based on the average of survey results, are summarised in the table below.

Table 10: Macadamia Pollination Service Requirements

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	August	9,593	20,520	3.5	71,819
NSW	August	7,069	15,121	3.5	52,923
WA	September	168	359	3.5	1,258
Total		**16,830**	**36,000**		**126,000**

Source: Hort Innovation 2022. Hive stocking rate from 2022 industry survey, production area from UNE AARSC (2022) Australian Tree Crop Map, July 2022.

Nationally, this study estimates that in 2021 approximately 126,000 honey bee hives were required for macadamia pollination. Keogh et al. 2010 estimated macadamia hive requirements of 104,000 hives based on production from 14,900 ha. Pollination broker Trevor Monson estimated the QLD and NSW total for 2021 at 138,000 hives (presentation to the 4th Bee Congress, June 2022).

Native Stingless Bee Demand

Jolyon Burnett, CEO, AMS noted that the macadamia industry is more fortunate than other industries with respect to the Varroa incursion but is still quite reliant on honey bees to make sure of a strong pollination and hence a good crop. Coastal NSW macadamia orchards were often near bushland which has populations of various insect types to help pollinate crops. "Here in the Northern Rivers of NSW, the average orchard is somewhere between 10 ha and 15 ha, and it is often surrounded by bits of remnant bush and a wide variety of other vegetation and other crops, and there are a lot of indigenous insects that contribute to pollination. It could be a different story for some bigger QLD orchards. In Bundaberg QLD the orchards are usually between 80 ha and 100 ha and cropping is extensive throughout the region. There is less remnant vegetation so we do expect that if Varroa gets out and does have an impact on honey bees, then the impact on the crop in Bundaberg would be more severe" (ABC Rural, 29 June 2022).

Research completed as part of the RND4P/PH16004 project, Securing Pollination (Whitehouse et al. 2021) showed that for macadamia in Bundaberg, honey bees accounted for between 80-90% of pollination visits. A range of flies, beetles and moths were also observed.

Use of native stingless bees for macadamia pollination is under examination as part of PH16000. Macadamia is the most advanced Australian horticultural industry in the use of native stingless bees for pollination. Macadamia's use of native stingless bees has been assisted by macadamia being a native species with which native bees have co-evolved. In many instances, macadamia growers own their own native stingless bee hives and keep them in the plantation year-round.

Stingless bees can be great pollinators for macadamias if hives are spaced close enough to the crop to ensure good flower visitation. Stingless bee pollination can be further enhanced by retention of native vegetation within close proximity of the macadamia plantation. Other beetles (e.g., net winged beetle, soldier beetle) and birds can also help with macadamia pollination (https://beeaware.org.au/wp-content/uploads/2018/03/Macadamia-pollination-brochure.pdf).

Managed stingless bees are well suited to pollination of macadamia which is only grown in warm tropical and subtropical areas. Increased use of managed stingless bees for macadamia pollination is forecast by this study.

Hive Demand in 5- and 10-Years' Time

The industry has expanded significantly over the past four years from 19,000 ha of macadamia tree plantings in 2017 to present plantings of approximately 36,000 ha, with greatest growth in and around the Bundaberg region and most holdings being medium to large operations (Macadamia SIP 2022-26).

The forecast increase in macadamia production and honey bee hive demand from 2021 to 2030 is shown in the table below.

Table 11: Macadamia Forecast Production and Honey Bee Hive Requirements 2021 – 2030

Year	Production – in-shell weight (t)	Honey Bee Hive Requirements (no.)
2021	51,000	126,000
2022	57,634	
2023	63,038	
2024	69,215	
2025	76,218	201,600
2026	83,364	
2027	90,630	
2028	97,880	
2029	105,062	
2030	112,156	252,000

Source: Mayer 2022 and project analysis of honey bee hive requirements

This study estimates a 60% increase in honey bee hive demand for macadamia production in 5-years' time and a 100% increase in 2021 levels in 10-years' time.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will remove approximately 15% of macadamia industry pollinators, increasing demand for both managed honey bees and managed native stingless bees. Potentially, additional measures will be required to increase the population of alternative, unmanaged insect pollinators.

Average Cost of Hives and Issues Driving Price

The average cost to macadamia growers of hiring honey bee hives for pollination across survey respondents was estimated at $35/hive. Macadamia IDM Leoni Kojetin (pers. comm, August 2022) reports that honey bee hire costs are typically $50/hive but that few growers pay for hives. Suboptimal stocking rates with beekeepers securing a high value macadamia honey crop is assumed.

North Coast NSW beekeeper Steve Fuller reported that macadamia growers are willing to pay for robust honey bee hives to secure pollination and that $60/hive is achievable for his bees (pers. comm., November 2022).

Hiring native stingless bee hives for pollination is more expensive than honey bee hive hire at $110/hive. Potentially this is due to the absence of a supplementary honey crop. Native stingless bees are relatively small producers of harvestable honey.

Time of Year and Length of Time Hives are Required

Macadamia IDM Leoni Kojetin (pers. comm, August 2022) reports that honey bee hives are required for macadamia pollination:

- NSW – week 3 of August for about 7 weeks.
- QLD – week 2 of August for about 6 weeks.

This advice was consistent with information provided by survey respondents.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

Very few macadamia growers pay for hives. Consequently, macadamia growers who are willing to pay for pollination are prioritised by beekeepers (Leoni Kojetin, Macadamia IDM, pers. comm., August 2022).

Approximately one third of survey respondents indicated that hives supplied by beekeepers had no issues and that the service provided was appropriate. Of those growers who did have issues with hives received, the biggest issues were (in priority order):

- Quality – hives are not strong enough to do the job (limited auditing).
- Beekeeper management when on site e.g., hives not dropped at the correct locations.

- Can't secure enough hives when I need them (supply).
- Hives arrive late and miss the peak flowering window.
- Beekeeper/bee needs are not consistent with the management of my orchard (e.g., cannot use production sprays).
- A biosecurity incursion and closure of state borders.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Macadamia growers identified extreme rainfall as the climatic event most likely to impact pollination of their crop. This is to be expected given two major east coast floods in 2022. Growers also noted that they are "seeing more warm autumns and that this reduces flowering in some varieties".

Research Priorities

The macadamia grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Native pollinators to fill the honey bee pollination gap.
- Managing multiple species for efficient pollination.
- Alternatives to insect pollination (mechanical pollination, new crop varieties).
- Honey bee management and efficiency – especially hive densities.
- More research on flies for pollination.
- Robust data to show best stocking rate and layout.

Mango Pollination

Industry Profile

Mango is a tropical fruit whose production occurs mainly in QLD and the Northern Territory (NT) – approximately 96% of total production originated from these jurisdictions in 2019-20. Nationally there are around 800 Australian mango growers. For the year ending 30 June 2021, Australian mango production was 51,528 tonnes with a farmgate value of $167.4 M. Production decreased by 4% between 2019 and 2020 and a further 28% between 2020 and 2021 (Hort Innovation 2022). Mangoes have a tendency toward bi-annual bearing which impacts production and industry value.

Production Systems Employed

Mango crops are usually laid out in rows with tree planting density dependent on the variety being grown. Historically, industry dominating Kensington Pride has been spaced 12 X 12 metres due to its vigorous growth. More recent plantings of new varieties are spaced 4 X 7 metres (Keogh et al. 2010). Covered production is not employed on this tree crop and one aspect of the industry's research program is focussed on higher density plantings.

Honey Bee Hive Requirements

There is a lack of agreement on the pollination of mangoes. The literature does not conclusively indicate that honey bees significantly add to pollination. However, there is a definite need for pollen to be transferred to the stigma by a pollinating agent. The Department of Agriculture and Food in WA (DAFWA) identified a role for honey bees in mango pollination and recommended a honey bee hive density of between 8 and 15 hives/ha depending on the mango variety being grown (DAFWA 2005).

Advice from Martina Matzner (Mango IDO, pers. comm., August 2022) was that in the late 1990s, managed honey bees were used to pollinate mangoes but that this is no longer common practice. When honey bees are present there appears to be more flowers pollinated. Unfortunately, the holding capacity of fruit on most mango varieties is quite low with Kensington Pride at only 0.8 fruit per panicle. Consequently, there is no benefit from added insect pollination. Furthermore, mango trees are usually sprayed with pesticides during their flowering window, and this can affect the health of honey bees brought in for pollination. In the NT there are few beekeepers and few hives available even if mango growers chose to use them.

In the Mareeba District of QLD some growers continue to use managed honey bee hives for pollination. Perfection Fresh has a mango production area of 200 ha across QLD and the NT and managed honey bee hives account for 10% of their pollination needs. Honey bee hives are used in their Lakeland QLD operation. Marto's Mangoes at Bowen QLD with a production area of 142 ha has successfully trialled managed honey bees for pollination and believes unmanaged hives make a 15% contribution to crop pollination. Stocking rates for these two large growers were approximately 2.5 hives/ha. Other growers surveyed do not use any managed honey bees for pollination. Overall, mango growers surveyed as part of this study indicated that they believed pollination of their crop was from the following sources:

- 2% managed honey bees.
- 10% unmanaged honey bees.
- 88% unmanaged other insects including various species of fly.

Consequently, this study estimates that only a small number of managed hives are used across Australian mango production and an estimate of total use in 2021 is made on the following basis:

- 15,764 ha of mango production (UNE AARSC 2022).
- 2% of production area using managed honey bees.
- 2.5 hives/ha stocking rate.

Approximately 800 honey bee hives were used for mango pollination.

Native Stingless Bee Demand

Rader, Robson, and Cunningham completed an analysis of mango pollination in Mareeba QLD in 2017 and found at least 15 different insect types visited mango flowers. The six most important were stingless bees (18% of visits), blowflies (17.6%), rhinid flies (17.3%), bibionid flies (14.4%), honey bees (11.7%), and hoverflies (8.9%). Stingless bees and honey bees moved well within a single tree while blowflies moved well between trees (Whitehouse et al. 2021).

Analysis of mangoes in Bundaberg QLD showed that the rhinid fly accounted for 46% of flower visits and that honey bees were also important (22% of visits). Stingless bees accounted for approximately 5% of flower visits (Whitehouse et al. 2021).

Makinson and Singh completed analysis of mango pollination in Darwin and Katherine NT in June and July 2019 and found that stingless native bees were the dominant flower-visiting group comprising almost half of total insect visitation. They were surprised to note that only a few honey bees were observed during their surveys, which suggests that mango flowers may not be a first-choice food for honey bees (Whitehouse et al. 2021).

Owing to their small size, stingless bees fit completely inside the middle of mango flowers, and they repeatedly walk around and across the flowers with their abdomen and legs making contact with reproductive parts of the flowers. Makinson and Singh observed a positive relationship between fruit set and visitation by stingless bees and blowflies and that insect visitations significantly increase fruit set in mango orchards (Whitehouse et al. 2021).

This study finds that there is some potential for additional use of managed stingless bees in the future. However, mango growers are mostly wedded to unpaid pollination and favour use of wild blowflies.

Hive Demand in 5- and 10-Years' Time

The volume of mangoes produced in Australia increased by 25.9% between 2013 and 2020 with production value growing by 26.7%. Annual growth of approximately 3% (value and volume) is forecast for both the medium (5 year) and longer (10 year) period (Mango SIP 2022-26). On this basis, demand for honey bee hives might climb to 900 hives in 2026 and 1,100 hives in 2031.

What about Varroa mite? If Varroa mite, becomes endemic in northern Australia and eliminates unmanaged (feral) honey bee colonies, it is possible that additional managed honey bee hives will be required for mango pollination. However, it is more likely that measures will be put in place to encourage alternative pollinators including various species of fly.

Average Cost of Hives and Issues Driving Price

There were insufficient users of managed honey bee hives to estimate an average cost of hives. Industry consultation and survey did not identify any current use of managed stingless bees for mango pollination.

Time of Year and Length of Time Hives are Required

Honey bee hives for mango pollination are required in September. Survey respondents indicated:

- Bowen QLD - Week 1 July to Week 1 August.
- Yeppoon QLD – Week 2 August to Week 4 September.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

The mango grower survey revealed the biggest issues with honey bee/stingless bee hives received were:

- Supply - finding enough hives to meet mango pollination needs in northern Australia.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Mango growers identified extreme cold and extreme rain as the climatic events most likely to impact pollination of their crop – "when temperature falls below 7°C pollination stops" and "incessant rain results in anthracnose and flower rot at pollination". Growers believed that northern QLD had become warmer and wetter over the last twenty years.

Research Priorities

Mango growers identified improving the effectiveness of native insect pollinators as their industry's highest priority for pollination research.

Melon Pollination

Industry Profile

The Australian melon category includes watermelons and muskmelons such as rockmelons and honeydew. Melons are grown Australia wide, with most production occurring in NSW and QLD. Nationally, there are approximately 140 melon growers (Jonathon Davey, Melons Australia, pers. comm., February 2023). For the year ending 30 June 2021, Australian production was 182,572 tonnes with a farmgate value of $149 M. Between 2019 and 2020 production increased by 5% before declining by 2% between 2020 and 2021 (Hort Innovation 2022).

Production Systems Employed

Watermelons are field planted in rows with enough space so that vehicles can access between them. There are many different growing practices, with some dense row groupings pending size and scale of machinery (Jonathon Davey, Melons Australia, pers. comm., February 2023). A portion of the Australian watermelon crop is grown in poly-tunnels (Singh and Makinson forthcoming).

Honey Bee Hive Requirements

Seedless watermelon (99% of Australian production) is sterile and therefore pollinator plants are required, generally in a ratio of 1 to 3 plants along each row (Jonathon Davey, Melons Australia, pers. comm., February 2023). Muskmelons are andromonoecious and have individual plants that bear both male and hermaphrodite flowers. Muskmelon flowers can be considered self-fertile but not self-fertilising. Melon pollen is sticky and must be transferred from the anthers to the stigma by insects. Flowers that do not receive adequate insect pollination will be misshapen or aborted. Cross-pollination has been shown to produce heavier, more marketable fruit.

Growers in the Waroona areas of WA have reported that using honey bees as pollinators increased production of rockmelon by up to 40%, from 600 to 1,000 cartons per acre annually. Further studies found that pollination of rockmelon using honey bees improved percentage fruit set and fruit weight significantly. It has been shown that honey bees are also the most abundant pollinators of watermelon with lack of pollination linked to poor yields and thus low incomes for growers. Recent studies have further demonstrated the benefit, with crops pollinated with honey bees producing significantly higher numbers of mature fruits and seed yields, as compared with caged plants which failed to produce any fruit at all (Bee Aware website).

Melon growers surveyed[2] as part of this study indicated that they believed pollination of their crop was from the following sources:

- 90% managed honey bees.
- 10% unmanaged honey bees living wild near the crop.

It has been shown that honey bees are the most abundant pollinators of melons. The density of hives required for melon pollination ranges from 2.5 hive/ha to 7.5 hives/ha (Keogh et al. 2010). Recommendations for the number of hives per hectare for watermelon, rockmelon and honeydew vary from 2 to 5 hives per ha (Bee Aware website). Monk et al. 2008 proposed 3.5 hives/ha for watermelon. Joanna Embry Melons Australia (pers. comm., August 2022) reported hive stocking rates of 1 to 5 hives/ha. The survey completed as part of this study revealed an average honey bee hive density of 3.5 hives/ha.

Potential honey bee pollination requirements for melon in 2021 are summarised in the table below.

[2] Includes both growers whose names are listed at the end of this report plus anonymous growers who responded to the Hort Innovation online survey.

Table 12: Melon Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD#	July	62,479	2,909	3.5	10,181
WA#	May	25,560	1,190	3.5	4,165
NSW	December	51,524	2,399	3.5	8,396
VIC	December	4,327	201	3.5	705
SA	October	2,502	116	3.5	408
NT#	May	36,180	1,684	3.5	5,896
Total		**182,572**	**8,500**		**29,750**

Source: Hort Innovation 2022, Area of production estimated is from Melons Australia website, Hive stocking rate from industry survey.
Northern WA, NT, and Far North QLD need pollination during the winter months (Jonathon Davey, Melons Australia, pers. comm., February 2023).

Nationally, this study estimates that 29,750 honey bee hives are required for melon pollination.

Native Stingless Bee Demand

Research completed as part of the RND4P/PH16004 project, Securing Pollination (Whitehouse et al. 2021) showed that honey bees were the most common visitor to watermelon flowers in the five regions studied, i.e., Riverina NSW, Coffs Harbour NSW, south east QLD, far north QLD, and Katherine in the NT, though a range of native bees were also found. Subasinghe Arachchige et al. (2022) confirmed these findings and concluded that pollination service delivery could be increased by deploying managed populations (e.g., native stingless bee colonies), employing pollinator-safe land management practices as well as exploring methods for increasing the efficiency of managed honey bee colonies.

Melon flowers are attractive to a range of insects including native stingless bees, solitary native bees, flies, and beetles which add to the essential pollination required by honey bees. Native pollinators can complement honey bees because they are active at times when honey bees are not (Bee Aware website). Goodwin noted that native stingless bees are useful pollinators of cucurbits (Goodwin 2012). Stingless native bees currently support melon pollination (Jonathon Davey, Melons Australia, pers. comm., February 2023). Watermelons in open fields and poly-tunnels were mainly visited by honey bees and native halictid solitary bees (Singh, G and Makinson, J forthcoming).

While small insects like native stingless bees can move pollen between male and female flowers, they do not distribute pollen as evenly on the stigma as larger bees like honey bees. Because of this, more visits may be needed to get evenly shaped fruit (Bee Aware website).

Hive Demand in 5- and 10-Years' Time

Melons are an annual crop whose production is mature. This study estimates that the demand for honey bee hives for pollination in both 5-years' and 10-years' time will be similar to the number of hives required in 2021.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will impact melon growers. Melon growers surveyed as part of this study indicated that a portion of their pollination needs are met by unmanaged honey bees. Furthermore, it is understood that in some areas of NSW and VIC melon growers are almost entirely reliant on unmanaged honey bees for the provision of pollination services.

Average Cost of Hives and Issues Driving Price

Melon growers surveyed as part of this study indicated that the average cost of honey bee hives for pollination was $50 per month for an average of two months in 2021 and 2022. This cost ($100/hive) is lower than some other horticultural industries and is due to melon pollination falling outside the peak demand window driven by almond pollination and the high cost of hive preparation for this event. NB: beekeepers who supply pollination services often charge a daily rate of $1/day for melon pollination.

Time of Year and Length of Time Hives are Required

Honey bee hives for melon pollination are required from May in northern WA and the NT which is only possible given a warmer climate and opportunity for honey bee build up in these environments at this time. Hives should be placed between rows and no more than 100 metres away from each other. Joanna Embry, Melons Australia (pers. comm., August 2022) reported that hives are required approximately 40 days after the melon crop is planted. Survey results indicated that pollination can occur between October and March and hives may remain in the crop for between eight and twenty weeks.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

About a third of melon growers responding to the survey indicated they had no issues with honey bee hives supplied for pollination. Amongst growers who did have issues, problems included:

- Supply – can't secure enough hives when I need them. Industry commented that this is a significant issue. Production is in remote locations, there is a high cost for delivery, and beekeeper service is inconsistent.
- Pests and disease – fear of pests and disease is keeping beekeepers away from pollination.
- Beekeeper/bee needs are not consistent with the management of my crop (e.g., cannot use production sprays).

Melon growers were also concerned about:

- Varroa mite and what this will do to honey bee hive supply and price.
- Honey bees can potentially spread some plant diseases, including cucumber green mottle mosaic virus (CGMMV). NB: work has been completed by Hort Innovation detailing how beekeepers can minimise biosecurity risks associated with CGMMV when their hives are introduced to cucurbit crops (see Finlay-Doney 2022).

Beekeepers interviewed as part of the study indicated that melons are routinely sprayed with fungicide and there appears to be some evidence that fungicide damages both larvae and the queen.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

All extreme weather events impact melon pollination (heat, dry, cold, rain, wind, and bushfire). Hail is problematic as are temperatures that are too low for bees to activate. In relation to changes in seasonal patterns that impact the supply of pollination services, one melon growers noted that "I haven't noticed changes in seasonal patterns that impact the supply of pollination services. Perhaps the change has been too gradual."

Research Priorities

The melon grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Managing multiple species for efficient pollination ("We need greater understanding of alternative insect pollinators – we have a looming threat from Varroa. Research ways farmers can manage local beneficial pollinating insect species- this is something I will be doing on my own farm").
- Honey bee management and efficiency ("Research to improve honey bee disease control and improve quarantine". "Not really any effective alternative to the honey bee").

Pear Pollination

Industry Profile

While pears are grown in all Australian states, the vast majority are grown in the Goulburn Valley VIC. Harvesting typically occurs between February and April. Year-round availability is made possible using controlled atmosphere storage technology. Nationally there are 255 pear growers. For the year ending 30 June 2021, Australian production was 124,338 tonnes with a farmgate value of $140 M. Between 2019 and 2020 production grew by 4% and between 2020 and 2021 it increased by a further 5% (Hort Innovation 2022).

Production Systems Employed

The most common tree arrangements for intensive pear production are single row or open tatura trellis (double row) systems. Modern pear orchards are focussed on varieties and rootstocks that deliver increased densities with earlier production and yield. Low density is generally anything less than 1,000 trees/ha with high density between 2,500 and 5,000 trees/ha and very high density more than 5,000 trees/ha. Some orchards are grown under netting for hail, birds, and frost protection.

Honey Bee Hive Requirements

Most pear cultivars are self-incompatible and require cross-pollination to secure an optimal crop. The literature gives credit to several pollinating insects including *hymenoptera, diptera*, and *coleoptera*, however it has been well established that honey bees are the primary pollinators of pears. Honey bee pollination has been shown to increase yield, fruit shape/quality and shelf-life.

Despite pears being reliant on honey bee pollination, the crop is not very attractive to honey bees. This is because of the low volume of nectar secreted from the crop's flowers. This is somewhat compensated by the abundance of attractive pollen.

The density of hives required for pear pollination ranges from 1 hive/ha for low-density orchards to 5 hives/ha for high density pear plantings. Higher stocking rates are needed if more attractive flowering species are present. Goodwin 2012 suggests a hive stock of between 1.2 and 5 colonies per hectare.

Potential honey bee pollination requirements for pear in 2021 using advice from the literature and grower consultation are summarised in the table below.

Table 13: Pear Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	October	339	9	3.5	30
WA	October	4,396	112	3.5	393
NSW	October	248	6	3.5	22
VIC	October	112,507	2,873	3.5	10,055
TAS	November	1,171	30	3.5	105
SA	October	5,677	145	3.5	507
Total		**124,338**	**3,175**		**11,113**

Source: Hort Innovation 2022, Area of production estimated from PHA data for 2018-19. Hive stocking rate from Keogh et al. 2010.

Nationally, this study estimates that 11,113 honey bee hives are required for pear pollination.

Native Stingless Bee Demand

Research completed as part of the RND4P project, Securing Pollination (Whitehouse et al. 2021) showed that on surveyed pear farms, honey bees were the most common visitors. However, a total of 16 species of insect visitor have been identified in pear orchards in Australia.

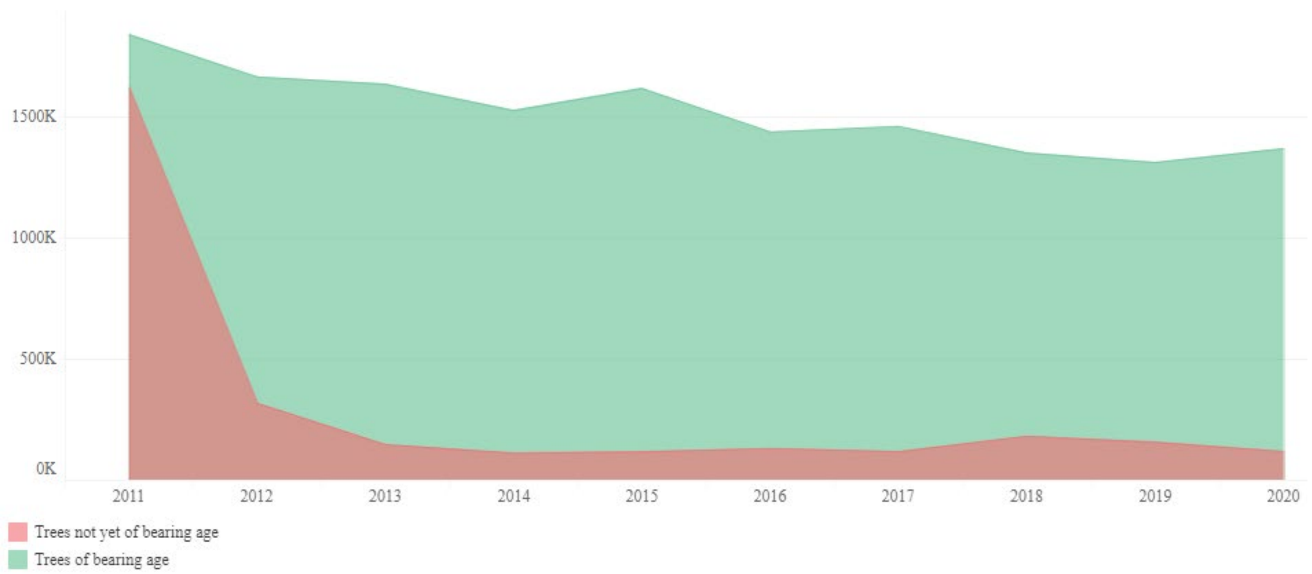
In eastern Australia, semi-social carpenter bees offer potential for pome orchard pollination (Brown, Barton and Cunningham, 2020).

Presently, no growers are using managed native stingless bees for pear pollination and no change is anticipated over either the medium of long term.

Hive Demand in 5- and 10-Years' Time

Pear production has declined significantly since the mid-2000s reflecting the shift away from lower value, large processing volumes to higher value fresh varieties and rising exports. The pear industry is now mature and characterised by consistent production volumes and gradually increasing production value (Pear SIP 2022-26). A wave of new orchard investment in the first decade of this century is complete and the share of non-bearing to bearing age trees has declined since 2011 – see figure below.

Figure 4: Pear Tree Distribution by Age 2011 – 2020



Source: APAL Industry stats | Apple & Pear Australia Ltd (APAL)

This study estimates that the demand for honey bee hives for pollination in both 5-years' and 10-years' time will be similar to 2021.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will increase pear industry hive demand. The pear industry benefits from unmanaged honey bee pollination. Unmanaged honey bees contribute up to 35% of total pear crop pollination. Honey bees are attracted by an abundant pollen supply which offsets limited nectar production.

Average Cost of Hives and Issues Driving Price

The survey completed as part of this study showed that the average cost to pear growers of hiring honey bees for pollination was $130/hive. Price is driven by competition from apple, avocado, blueberry, cherry, and macadamia growers as well as alternative income sources. Spring is, for many regions, the largest honey production period creating opportunity cost issues for beekeepers. Surveyed pear growers did not use managed stingless bees.

Time of Year and Length of Time Hives are Required

Honey bee hives for pear pollination are required in October in all states except TAS where they are required in November. Honey bee colonies should not be placed in the orchard too early as honey bees may abandon the crop for more attractive alternative floral resources. Hives should be brought in in two waves at approximately five-day intervals. Hives are required for a 3-week period to pollinate pears.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

Most pear growers interviewed had no major uses with hives supplied by beekeepers for pollination. Secondary issues identified by these growers and those identified by other pear growers were:

- Managing the needs of beekeepers and their bees – the management of onsite bees is not always consistent with the need to use chemical sprays.
- Cost – price demanded by beekeepers is too high.
- Quality – hives are not strong enough to do the job. There is limited auditing, ant it is difficult to assess the results of managed pollination on pear yield.
- Beekeeper management when on site – hives are not placed in the right locations or dispersed appropriately through the orchard.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

Pear growers identified extreme cold, rain, and wind as the seasonal events most likely to impact pollination. Surveyed pear growers had not noticed changes in seasonal patterns likely to impact pear pollination.

Research Priorities

The pear grower survey revealed the most pressing research priorities in relation to pollination of their crops were (in priority order):

- Understanding supply and demand balances including future costs.
- Attracting and managing native pollinators to fill the honey bee pollination gap.
- Effective and efficient pollination in protected cropping systems.
- Managing multiple species for efficient pollination.
- Alternatives to insect pollination – mechanical pollination, new crop varieties.
- Honey bee management and efficiency.

Pumpkin Pollination

Industry Profile

Pumpkins are grown Australia wide, with most production occurring in NSW and QLD. For the year ending 30 June 2021, Australian production was 115,983 tonnes with a farmgate value of $89.4 M. Between 2019 and 2020 production decreased by 1% with a similar decline between 2020 and 2021 (Hort Innovation 2022).

Production Systems Employed

Large-fruited pumpkins (e.g., QLD Blue/Grey) are field grown in rows 1.8 to 3 metres apart, with a distance of 1 to 3 metres apart within the rows. Butternuts and small-fruited pumpkins are planted at 1.5 to 2.5 metres apart with a distance of 0.6 to 1 metre within the rows. All Australian pumpkins are field grown. Pumpkins are not grown in covered production systems.

Honey Bee Hive Requirements

Pumpkins are monoecious and have separate male and female flowers on the same plant. For pollination to occur, pollen must be transferred from the male flowers to the female flowers via a transport vector, usually honey bees. Efficient pollination and fruit set depends on both male and female flowers being present on a vine and sufficient pollinating insects foraging during bloom. Fruit set and seed number have been shown to increase as the number of honey bee visits to flowers increases. A large honey bee population helps ensure maximum flower visitation, pollen deposition and crop yield.

Most pumpkin growers surveyed as part of this study made use of managed honey bee hives to boost the pollination efforts of local unmanaged honey bee colonies. Others relied solely on unmanaged honey bee colonies.

Pumpkin flowers produce abundant nectar and pollen which is available in quantities sufficient to sustain pollinating honey bee colonies. The density of hives required for pumpkin pollination ranges from 2 hive/ha to 6 hives/ha (Keogh et al. 2010). Potential honey bee pollination requirements for pumpkin in 2021 are summarised in the table below.

Table 14: Pumpkin Pollination Service Requirements 2021

State	Pollination Peak Month	Production (t)	Area (ha)	Average Hive Density (h/ha)	Estimated Number of Hives Required
QLD	December	55,092	2,207	4	8,827
WA	December	20,344	815	4	3,260
NSW	December	32,712	1,310	4	5,241
VIC	December	3,479	139	4	557
TAS	December	551	22	4	88
SA	October	1,740	70	4	279
NT	December	2,065	83	4	331
Total		**115,983**	**4,646**		**18,584**

Source: Hort Innovation 2022, Area of production estimated is for 2020, Hive stocking rate from Keogh et al. 2010 and project consultation.

Nationally, this study estimates that 18,584 honey bee hives are required for pumpkin pollination.

Native Stingless Bee Demand

Keogh et al. (2010) reports that honey bees are the most widely used commercial pollination agents available to pumpkin growers in Australia. Goodwin noted that native stingless bees are useful pollinators of cucurbits (Goodwin 2012). Subasinghe Arachchige et al. (2022) concluded that pollination service delivery could be increased for cucurbits by deploying managed populations (e.g., native stingless bee colonies), employing pollinator-safe land management practices as well as exploring methods for increasing the efficiency of managed honey bee colonies.

Hive Demand in 5- and 10-Years' Time

Pumpkin is an annual crop whose production has been static for some time. This study estimates that the demand for honey bee hives for pollination in both 5-years' and 10-years' time will be similar to 2021.

Average Cost of Hives and Issues Driving Price

Pumpkin growers surveyed as part of this study indicated that the average cost of honey bee hives for pollination was $50/hive per month for an average of two months in 2021 and 2022. Average cost is $100/hive.

Time of Year and Length of Time Hives are Required

Honey bee hives for pumpkin pollination are required in December in all states except SA where hives are required in October. Hives should be placed throughout the crop at the start of flowering. Growers and beekeepers providing pollination services surveyed as part of this study indicated that planting was staggered as was pollination and pollination might span the period October to March.

What about Varroa mite? If Varroa mite, becomes endemic and eliminates unmanaged (feral) honey bee colonies, it will impact pumpkin growers. Many in this industry rely on incidental pollination and flowering occurs in late spring and summer when unmanaged honey bees have had an opportunity to build their numbers.

Competition for Honey Bee Supply and the Biggest Issues with Hives Received

Pumpkin growers surveyed as part of the study indicated that use of managed honey bees often relied on a local source of supply – prices paid were insufficient to attract beekeepers from further afield. Pumpkin growers were satisfied with the quality of honey bee hives supplied.

Impacts of Climate Variability/Climate Events on Pollination Service Demand

All extreme weather events impact pumpkin production (heat, dry, cold, wind, and bushfire). Growers report that honey bees will not pollinate in extremely hot, extremely wet or even very cloudy, humid days. Extreme dry and extreme humidity result in the plant shedding its crop of small, non-viable pumpkins.

Research Priorities

A single research priority for pumpkin was identified by growers:

- Definitive research that quantifies the benefit, or establishes that no benefit exists, from the addition of managed honey bee hives for pollination.

Growers felt that crop pollination was a relatively minor issue for their business and that there were no deficiencies in the pumpkin yields being achieved.

Pollination of Australian Horticulture

Chapter 3, pollination of Australian horticulture, provides an analysis of:

- Honey bee hives requirements Top 10 pollination dependent horticultural industries - current and future
- Managed stingless bee demand Top 10 horticultural industries - current and future
- Australian pollination calendar
- Average hive cost and issues driving price
- Reasons why beekeepers will not supply pollination services
- Biggest issues with hives received by growers
- Impact on beekeepers of climatic events
- R&D priorities

Honey Bee Hive Requirements – Current and Future

Data from the previous chapter has been summarised in the table below to provide a robust estimate of current honey bee hive requirements for the Top 10 pollination dependent industries along with potential demand, in 5- and 10-years' time. Future demand for honey bee hives is based on forecast industry growth.

Table 15: Honey Bee Hives Required Top 10 Pollination Dependent Horticultural Industries – Current and Future

Industry	Current Requirement (2021 data)	Future Requirement 5-Years' Time	Future Requirement 10-Years' Time
Almond	330,400	400,000	420,000
Apple	28,125	28,125	28,125
Avocado	65,275	130,000	130,000
Blueberry	25,000*	37,500	50,000
Cherries	8,535	10,250	11,100
Macadamia	126,000	201,000	252,000
Mango	800	900	1,100
Melons	29,750	29,750	29,750
Pear	11,113	11,113	11,113
Pumpkin	18,584	18,584	18,584
Total	**643,582**	**867,222**	**951,772**

* NB: honey bee hives used to pollinate covered blueberry crops are "swapped out" every three weeks so the actual number of hives rotated through blueberries each pollination season will be greater than the estimate shown.
Source: AgEconPlus and Australian Bee Services analysis

Current and future demand for honey bee hives for pollination shown in the table is in strong contrast to Clarke and Le Feuvre 2020 which estimated a total population of managed honey bee hives of 530,000. However, it is important to note that demand for pollination hives does not all occur at the same time (see Australian Pollination Calendar below). Also, that the honey bee industry has some capacity to increase the number of hives available to meet forecast demand assuming the cost benefit is attractive to beekeepers.

Managed Stingless Bee Demand – Current and Future

Current and future managed stingless bee demand for Top 10 pollination dependent industries is summarised in the table below.

Table 16: Managed Stingless Bee Demand Top 10 Pollination Dependent Horticultural Industries – Current and Future

Industry	Current and Future Managed Stingless Bee Demand
Almond	• Currently there is no use of managed stingless bees in the almond industry. However, research is underway to investigate the potential use of stingless bees in almonds. • Almond pollination in cool areas in August may prevent use of managed stingless bees which are native to the warmer parts of Australia.
Apple	• Managed stingless bees do not currently contributed to apple pollination. Cook 2022 notes that wild stingless bee populations may be contributing to cherry pollination. • Managed stingless bees require warm climates and apples are grown in cool areas.
Avocado	• Currently, wild native stingless bees contribute to avocado pollination in QLD. • Low attractiveness of avocado flower to honey bees, along with research showing the importance of unmanaged stingless bees, suggests a potential future role for managed stingless bees.
Blueberry	• Managed stingless bees currently contribute around 5% of this industry's pollination needs. • Managed stingless bees are well suited to blueberry pollination in warm growing areas including Coffs Harbour NSW where most blueberries are grown. Increased use of managed stingless bees for blueberry pollination is forecast by this study.
Cherries	• Currently managed stingless bees are not used in the cherry industry. Cook 2022 notes that wild stingless bee populations may be contributing to cherry pollination. • Managed stingless bees require warm climates and cherries are grown in cool areas.
Macadamia	• Managed stingless bees currently contribute around 10% of this industry's pollination needs. • Managed stingless bees are well suited to pollination of macadamia which is grown in warm subtropical areas. Increased use of managed stingless bees for macadamia pollination is forecast by this study.
Mango	• No current use of managed stingless bees for mango pollination. • Some potential for additional use of managed stingless bees in the future but growers mostly wedded to unpaid pollination and favour use of wild blowflies.
Melons	• Managed stingless bees do not currently contribute to melon pollination. • Singh and Makinson (forthcoming) concluded that stingless native bees are not good candidate pollinators for cucurbits. Subasinghe Arachchige et al. (2022) concluded that stingless native bees have potential as watermelon pollinators.
Pear	• Presently, no growers are using managed stingless bees for pear pollination. • No change to the present situation is anticipated over either the medium of long term.
Pumpkin	• Managed stingless bees do not currently contribute to pumpkin pollination. • Singh and Makinson (forthcoming) concluded that stingless native bees are not good candidate pollinators for cucurbits.

Source: AgEconPlus and Australian Bee Services analysis

Amongst the Top 10 pollination dependent horticultural industries, managed stingless bees currently contribute to the pollination of blueberry and macadamia. In the future, there is potential for managed stingless bees to also contribute to avocado and mango pollination.

In addition to the Top 10 pollination dependent horticultural industries, managed stingless bees are also used for the pollination of lychee and some strawberries grown in protected cropping systems.

Unmanaged (Feral) Honey Bee Reliance – Without Varroa Mite

Current reliance on unmanaged (feral) honey bee colonies by Top 10 pollination dependent industries is summarised in the table below.

Table 17: Unmanaged (Feral) Honey Bee Reliance – Without Varroa Mite

Industry	Current Reliance on Unmanaged (Feral) Honey Bees for Pollination
Almond	• For orchards adjacent to riverine areas, unmanaged colonies that resident in river red gums augment managed pollination by hived honey bees.
Apple	• Moderate reliance on unmanaged honey bee colonies. Growers indicated up to 35% of pollination needs provided by unmanaged honey bees.
Avocado	• Some reliance on unmanaged honey bee colonies. Growers indicated around 15% of pollination needs provided by unmanaged honey bees.
Blueberry	• Growers indicate low reliance on unmanaged honey bees. However, they may not be aware of the role these insects play at Coffs Harbour NSW, a major growing area.
Cherries	• All cherry growers surveyed indicate that they are highly reliant of unmanaged honey bee colonies for the pollination of their crop.
Macadamia	• Surveyed macadamia growers indicate that around 15% of their crop pollination needs were met be unmanaged honey bees.
Mango	• There is some reliance on unmanaged honey bees for mango pollination (approximately 10%). However, other insect species dominate mango pollination.
Melons	• Growers indicated around 10% of pollination needs provided by unmanaged honey bees with some areas entirely dependent on feral honey bees for melon pollination.
Pear	• Unmanaged honey bee colonies meet more than one third of total pear crop pollination needs. Honey bees are attracted by an abundant supply of pollen.
Pumpkin	• Pumpkin growers are highly reliant on unmanaged honey bees for the pollination of their crop. Pollination occurs in warmer months which favours wild honey bees.

Source: AgEconPlus and Australian Bee Services analysis

The industries that are most reliant of feral colonies are apple, cherry, pear, and pumpkin.

Australian Pollination Calendar

Time of year and length of time hives are required for pollination for Top 10 pollination dependent industries is shown in the Figure 5. Length of time required for pollination of each crop is shown at the 'upper end' as it reflects the full range of geographic areas in which each crop is grown.

Figure 5: Australian Pollination Calendar – Top 10 Pollination Dependent Horticultural Industries

Industry	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Almond							■	■	■			
Apple									■	■	■	
Avocado								■	■	■		
Blueberry	■	■	■	■	■	■	■	■	■	■		
Cherries									■	■		
Macadamia								■	■			
Mango							■	■	■	■		
Melons	■	■	■							■	■	■
Pear										■	■	
Pumpkin	■	■	■							■	■	■

Source: AgEconPlus and Australian Bee Services analysis

Peak demand for pollination services is in August and September. At least one of the Top 10 pollination dependent horticultural crops requires pollination in each month of the year.

Average Hive Hire Cost for Pollination and Issues Driving Price

The table below summaries average cost to growers of hiring honey bee hives for pollination in 2021. Some average cost data for hive hire in 2022 was also collected. These data were deemed to be atypical due to disruptions caused by state border closures resulting from the 22 June 2022 Port of Newcastle Varroa incursion.

Table 18: Average Cost to Growers by Industry for Hire of Honey Bee Hives for Pollination 2021

Industry	Average Hive Cost ($/hive)
Almond	$155*
Apple	$130
Avocado – East Coast	$110
Avocado – WA	$225
Blueberry	$160
Cherries	$105
Macadamia	$50
Mango	N/a
Melons	$100
Pear	$130
Pumpkin	$100

* In 2022 prices averaged $162/hive.
Source: AgEconPlus and Australian Bee Services analysis

Differences in hive hire cost reflect competition between individual growers and industries in peak pollination periods (e.g., August when the almond industry requires 330,400 hives), the damage that the crop and production system does to the bees (e.g., bees lose condition in covered blueberry crops), as well as other benefits received by beekeepers from provision of pollination services (e.g., some crops such as macadamia, provide beekeepers with a valuable honey crop in certain situations).

Beekeepers and industry leaders interviewed as part of this study identify the following issues driving the price of hive hire for pollination:

- Strong competition for hives in August and September.
- High cost of preparing and delivering hives for pollination – labour for hive manipulation prior to pollination, supplementary feeding to bolster hive strength prior to pollination, and the cost of transporting hives long distance, especially for almond pollination.
- Opportunity cost of a honey crop foregone – in both the autumn prior to spring pollination and in late winter and spring when eucalypts and canola are in flower. Hives required for spring pollination are rested in autumn so that colonies are sound for the following spring.

What about Varroa mite? If Varroa mite becomes endemic and commercial beekeepers are forced to treat for the pest, average hive cost will significantly increase. Beekeepers will incur additional hive management costs as well as the cost of chemical treatment. Beekeepers will also benefit from additional demand for pollination services as growers who currently benefit from unmanaged honey bee pollination are forced to purchase pollination services.

Reasons Why Beekeepers Will Not Supply Pollination Services

The survey of beekeepers and pollination brokers completed as part of this study revealed the following reasons for beekeeper reluctance to supply honey bee hives for pollination services. Reasons are not presented in priority order:

- Biosecurity – beekeepers are concerned that their hives will contract diseases while near the hives of other beekeepers during pollination. A range of honey bee diseases can be spread from one apiary to another during pollination. Diseases include American Foulbrood (AFB), European Foulbrood (EFB), Chalkbrood, and Nosema. One beekeeper notes "If the biosecurity regulations were implemented for AFB similar to the Varroa incursion, then AFB would be cleaned up overnight. Pollination services wouldn't have any AFB concerns". Other beekeepers indicate that the almond pollination season (August) coincides with the best time of the year for brood inspection and identification of any diseases in their own hives. Consequently, it is not a convenient time to travel with hives.
- Distance to pollination events – pollination events may be remote and up to 1,000km from the beekeeper's home and usual honey harvesting range. Long distances may add cost and an unwelcome level of inconvenience to a beekeeper's business.
- Honey crop foregone – winter flowering eucalypts and acacia have the capacity to yield large volumes of honey for the beekeeper. Returns from honey sales at approximately $5-6/kg have the potential to exceed income earned from crop pollination.
- Supplementary feeding requirements – honey bee colonies are likely to require supplementary feeding late autumn and winter to be sufficiently strong for early flowering crops like almonds spring pollination. This requires skill and investment on behalf of the beekeeper and beekeepers may not be prepared to invest in capacity building and the cost of supplementary feed. Supplementary protein feeding requires research to develop best practice recommendations.
- Poor farm access tracks - that impede hive placement, flood effected tracks and bogged beekeeper vehicles. While three years of wet weather (2020, 2021 and 2022) has focussed beekeepers on the issue of bogging, poor access tracks are also an issue in dry years. Pollination service providers use large, often articulated vehicles with on-board hive moving equipment. Poor roads limit pollination service efficiency and add to the cost of providing the service.
- Hive placement in the crop – while research (e.g., Cunningham et al. 2015) suggests small loads of honey bee hives scattered throughout the crop benefit pollination (e.g., 40 to 60 hives every 400 metres in almonds), diffuse placement is a significant cost in terms of time and labour for the beekeeper. Beekeepers argue that diffuse placement of hives may be only one factor in determining pollination success and a central hive drop with a large load size (potentially 144 hives) may work just as well.
- Unsuitable put down pads – with poorly prepared surfaces and unsuitable microclimates. Beekeepers indicate that just like access roads, put down pads for pollinating hives are often congested with materials capable of puncturing vehicle tyres, uneven and not hard packed. Beekeepers comment that designated put down pads are sometimes shady so that bees lose up to half a day's pollination activity before they are warm enough to fly. Shady put down pads are offered when alternative sunny, wind free sites might be supplied with little effort.
- Drinking water for bees at put down pads – best practice growers provide clean drinking water in wheely bins with bee escapes (e.g., corks, branches) at the put down pad. On site water has two advantages. One, it avoids field bee diversion from pollination to finding drinking water for the colony. Two, it discourages bees from sourcing drinking water from farm dams and irrigation drip lines which may be contaminated with farm chemicals that impact bee health.
- Agricultural chemical application while bees are pollinating crops – while risks associated with insecticide application during honey bee pollination should be well understood, colony loss still occurs (e.g., aphid control insecticide applied during the pollination period). Losses caused by fungicide application are more insidious with impact on non-field bees (the queen, young workers, and larvae) delayed until the pollination service has been delivered. Fungicide traces deposited by hardy field bees,

contaminate pollen and royal jelly fed to non-field bees. One third of all almond growers apply fungicide during the pollination period. Boron, delivered through irrigation drippers to improve fruit set/retention, is also thought (anecdotally) to be causing the death of pollinating honey bees. Wetting agents used with chemical application are also harmful to honey bees. Pollination brokers explain that both crop agronomists and growers lack knowledge on the impact of agricultural chemicals on pollinating bees and additional education efforts are needed.

- A "flat" pricing structure for pollination services – beekeepers are typically paid a standard fee for hives used in pollination provided those hives meet a minimum standard. Beekeepers argue that payment of a premium for bees of superior strength would encourage a lift in the quality of pollination services. For payment of a premium to work, additional auditing of hives would be required. Comprehensive auditing would also help to "weed out" hives that are not meeting minimum standards for quality and hives which carry communicable disease.

Communication of these points to growers and agronomists would help ensure an adequate supply of honey bee hives for pollination into the future. Uptake might allow honey bee hive stocking rates to be reduced in the future. Most of these points are available in greater detail on the ABA website using information on pollination best practice prepared by the Almond Board of California (Dr Doug Somerville, retired Technical Specialist Honey Bees, pers. comm., October 2022).

Biggest Issues with Hives Received by Growers

Approximately one third of growers surveyed had no issues with hives supplied by beekeepers for pollination. Issues identified by other growers, in priority order across the Top 10 horticultural industries, were:

- Quality - hives are not strong enough to pollinate the crop. Poor hive quality points to the need for additional hive auditing, and potentially inadequate stocking rates/unrealistic expectations on the pollination potential of each honey bee hive. Auditors note that while corporate almond growers use auditors, many growers do not. Dr Doug Somerville (beekeeper, pollination auditor, pers. comm., October 2022) estimated 25% of hives supplied for almond pollination are audited, 25% are broker checked, and the balance are just supplied without inspection. Auditors and pollination brokers noted that in a significant number of cases, beekeepers are not completing the necessary hive preparation work required to deliver a hive of appropriate quality.

  "One of the biggest problems in pollination is the quality of the hives. The hives are not being independently audited or are inspected by the broker, which is questionable. This is creating a false availability of hives and keeping the price down. The system is unfair to the good beekeepers who put a great deal of effort into providing a quality product" (Jon Lockwood, beekeeper, pollination service provider, pers. comm., October 2022)

- Supply – growers cannot secure enough hives when they need them for pollination. Lack of supply may be linked to price paid to beekeepers for pollination services as well as the other factors identified in the section above (biosecurity concerns, distance to crop, supplementary feeding, access roads, hive disbursement throughout the crop, inadequate put down pads, clean drinking water for pollinating bees, losses due to poisoning with agricultural chemicals, and the current pricing structure). Supply was also impacted in 2022 by the Port of Newcastle Varroa mite incursion.
- Cost – price demanded by beekeepers is excessive. Some growers who identified this as an issue also noted that they are willing to pay more for better quality hives and an assured pollination outcome.
- Beekeeper management when on site e.g., hives are not dropped in the right locations, beekeepers are slow to remove hives after pollination and this prevents necessary sprays. The first issue points to the potential conflict between growers requiring a diffuse distribution of bee hives within the crop and beekeepers requiring efficient, "one stop" drop off and hive pick up. Some beekeepers use grower fields and orchards for hive storage – a convenient no-cost place to dump hives between pollination engagements or collection of a honey crop. Penalties should apply to beekeepers who use pollinated fields and orchards for hive storage.
- Beekeeper/bee needs are not consistent with the management of my orchard e.g., the grower cannot use production sprays during honey bee pollination. Once again, this issue points to the conflict between crop pest and disease control and crop management using additives such as boron and loss of bees to chemical contamination.
- Communication with beekeepers can be difficult. Working with the beekeepers to keep bee sites away from each other and meet their biosecurity requirements can be a challenge. In addition, beekeepers are not adept at communication with growers.

Impact on Beekeepers of Climate Variability/Climate Events

Chapter 2 reported the impact of climate variability/climate events on the demand for pollination services from a growers' perspective. All extreme weather events impact crop pollination (heat, dry, cold, rain, wind, bushfire). Beekeepers experiencing extreme weather events are less exposed than growers and are usually able to supply suitable hives. For example, extreme heat (heatwaves) can be managed through the provision of additional shade and water. Extreme dry (drought) may diminish the supply of nectar and pollen from native flora however this can be replaced, at a cost, via supplementary feeding. In some instances, drought may boost the flowering of eucalypt and acacia species. Extreme cold (frost) will prevent bees from flying but will not impact the hive's viability. Extreme rainfall (floods), and bushfire require the timely relocation of transportable honey bee hives.

Beekeepers note that Australia is a "boom-and-bust" climate and that there is little consistency between years. However, they also note that the frequency of extreme weather events appears to be increasing and extreme weather event records are being broken at regular intervals.

Impact of Extreme Events on Demand for Pollination Services

Extreme weather events reduce the short term (seasonal) demand for pollination services – there is less crop to be pollinated. Longer term extreme weather may increase the demand for paid pollination as the supply of non-managed honey bees contracts. Hort Innovation project PH16000 will investigate the effects of climate change on pollinators including testing how climate manipulations influence the timing and quality of nectar and pollen available to a range of bee species.

R&D Priorities

Industry specific research priorities are included in the body of Chapter 2. The following priorities are relevant to the strengthening of Australian horticulture pollination services:

- Queen bee breeding with a focus on pollination traits. Members of the honey bee industry speculated that existing queens are inbred and have not been selected for pollination. Selection for this trait could be prioritised by the NSW DPI, Plan Bee, queen breeding program.
- Examination of the full suite of options and opportunities to build bee numbers and hence hive strength prior to pollination (e.g., additional access to forested areas, bee meadows/pastures, identification of beneficial pasture species, supplementary feeding especially protein feeding).
- Protein supplementary feeding prior to pollination (young bees require protein for growth) – research and communicate best practice, superior commercial products, impact on adult bee longevity, etc.
- Sugar syrup augmentation for crops with low levels of nectar production. For crops such as almond, apple, and pear which produce limited nectar, crop pollination would benefit from strategic use of sugar syrup while honey bees are in the orchard. Research is required to understand best practice and return on investment from this activity.
- Understanding and augmenting the target crop's floral landscape. Research to understand what floral species are competing with or complementing the target crop. How can the landscape be supplemented or modified e.g., interrow planting of canola.
- Understanding honey bee hive populations to optimise pollination – is it better to have two 5-frame hives or a single 10-16-frame colony?
- Training of pollination auditors and brokers to encourage a more professional approach by beekeepers to the supply of honey bees for pollination.
- Training of agronomists to ensure they are fully aware of the potential impacts of pesticide, fungicide, and crop production chemical on pollinating honey bees.
- Training of skilled beekeepers who can prepare and deliver hives for pollination. Many skilled beekeepers have retired, and remaining apiarists find it difficult to recruit skilled staff.
- Technologies and systems to better detect/manage honey bee disease spread during pollination. Diseases of concern include AFB, EFB, Chalkbrood, and Nosema. Pest detection (e.g., Varroa mite, Tropilaelaps) may also be an issue in the future.
- Research and delivery of new strategies for the management of pesticide, fungicide, and crop production chemicals during pollination to prevent damage to pollinating insects (e.g., impact on pollinating honey bees of the fruit retention chemical boron supplied through dripper lines).
- Research to establish and communicate the link between use of fungicides in orchards during pollination and subsequent queen and brood loss.
- Opportunities for insecticide resistant honey bees – opportunity was identified as part of this project.
- Techniques for improving insect pollination of protected crops (e.g., hive management for younger bees (older bees have developed long distance foraging habits), brood top ups, regimes for hive change over). Protected crops include both netted production, and greenhouse grown commodities.
- Techniques for making horticultural crops more attractive to honey bees. Review each crop for whether bees are seeking nectar (e.g., blueberry) or pollen (e.g., almond). Develop strategies to maximise nectar and/or pollen production. These might include fertiliser, micro-nutrients, water, etc.
- Further work on "Bee Tubes" in place of full honey bee hives. Disposable mini hives that are hung from within the tree rows, still experimental but cheaper than full hives (Avocado Case Study Keogh 2010). Furthermore, an alternative to tubes and full hives might be the use of nucleus hives.
- Extension and communication program to increase grower awareness of the importance of managed pollination and the high-risk nature of ongoing reliance on unmanaged insects.

Conclusions and Communication Messages

The project has delivered robust pollination statistics for Australian horticulture as well as a better understanding of future hive requirements. Potential resource gaps have been identified and recommendations made in relation to research priorities and communication messages.

Communication messages arising from the project are:

- Industry growth projections point to a near 35% increase in the demand for honey bee and native stingless bee hives for pollination in the five years 2021 to 2026.
- Estimates of future hive demand assume that current efforts to eradicate the Varroa mite are successful. If Varroa mite becomes endemic, and eliminates unmanaged (feral) honey bee colonies, the number and cost of hives required for pollination will be significantly greater.
- Additional investment in all aspects of honey bee biosecurity is needed to maintain and then expand pollination capacity – Varroa, Tracheal and Tropilaelaps mites (exotic), AFB in intensive horticultural environments, SHB in humid warm periods, European wasps (regional issue) and cane toads (regional issue) are all biosecurity threats that impact pollination capacity.
- Ensure the honey bee industry's research, biosecurity, and residue testing responsibilities are appropriately funded through the Commonwealth levy system. The levy legislation cannot currently capture contributions from paid pollination. If and when new legislation that supports levies on pollination services is enacted, this needs to be addressed by the honey bee industry.
- Horticultural industries are increasingly aware of the need to have access to multiple pollination methods including more than one pollinating insect species.
- The quality of hives supplied by the honey bee industry is not always appropriate. Hives are not being independently audited and where auditing is occurring it is often appraised by a broker. This is creating issues for the grower and suppressing the price received by best practice beekeepers.
- Addressing beekeeper concerns about biosecurity and the risk to their honey bees from contracting disease during pollination could be resolved through more auditing of honey bee hives supplied for pollination, a certification scheme, and use of technology to capture quality parameter data.
- Auditing and potentially certifying the quality of native stingless bee hives that are to be used for paid pollination will be an important aspect of this industry's maturation.
- Growers who purchase pollination services need to place higher importance on relatively simple management changes to improve serviceability for beekeepers. This may include improvements such as farm access roads, suitable put down pads, and the provision of clean drinking water will increase the supply of bees available for pollination.
- Ongoing grower education is required on the importance of paid/managed pollination and the high-risk nature of reliance on incidental pollination.

Attachments

Persons Contacted

NAME	RELEVANCE TO HORTICULTURAL POLLINATION
Project Reference Group	
Fiona Chambers	Wheen Bee Foundation – CEO
Jason Ezra	DAFF – Policy Officer
Stephen Hodge	DAFF - Director Horticulture, Labour, and Education
Rachel Mackenzie	Berries Australia – CEO
Trevor Monson	Pollination broker – CEO Monson Honey and Pollination
Dr Doug Somerville	Pollination service provider – Retired Technical Specialist Honey Bees
Ashley Zamek	Hort Innovation R&D Manager
Almond	
Peter Cavallaro	ABA - Pollination Committee Chair
Josh Fielke	ABA - Industry Development Officer
Tim Jackson	ABA - CEO
Deidre Jaensch	ABA – Industry Development Manager
Andrew Martin	Almond grower
Brendan Sidhu	Almond grower
Luke Stoeckel	Almond grower
Ben Brown	Almond grower
Tim Preusker	Almond grower
Apple and Pear	
Joe Ceravolo	Grower
Rose Daniel	APAL – Technical Manager – Future Orchards
John Evans	Grower
Robert Green	Grower
Peter Hall	Grower
Terry Martella	Grower
Justin Smith	APAL - Industry Services & Export Manager
Avocado	
Eric Carney	Avocado grower
Simon Grabbe	Avocado grower
Ian Groves	Avocado grower
Kathy Hoare	Avocado grower and agronomist
Jim Kochi	Avocado grower
Chris Searle	Avocado industry consultant
Simon Newett	Avocado Extension Officer, QDAF
Blueberry	
Nicholas Miall	Blueberry grower - Perfection Fresh
Maurizio Rocchetti	Blueberry grower - Costa Berries
Tyler Scofield	Blueberry grower - Driscolls Blueberries
Melinda Simpson	Industry Development Officer - Blueberries
Kamaldeep Singh	Blueberry grower - Mountain Blue Blueberries
Cherry	
Joe Ceravolo	Cherry grower
Fiona Hall	VIC Cherry Growers Association
Andrea Magiafoglou	Cherry Growers Australia
Brent McClintock	Cherry grower
Nick Noske	Cherry grower

Tony Hannaford	Cherry Grower
Macadamia	
Eric Carney	Macadamia grower
Hendrik Christiansen	Macadamia grower
Leoni Kojetin	Industry Development Manager - Macadamia
Andrew Pearce	Macadamia grower
Chris Searle	Macadamia industry consultant
Trevor Steinhardt	Macadamia grower
Andrew Starkey	Macadamia grower
Mango	
Ben Martin	Mango grower – Marto's Mangoes
Martina Matzner	Industry Development Officer - Mango
Nicholas Miall	Mango grower – Perfection Fresh
Joe Moro	Mango grower – family farm
Ian Groves	Mango grower – family farm
Gavin Scurr	Mango grower – Pinata
Melon	
Johnathon Davey	Melons Australia - CEO
Brad Dawson	Melon grower – watermelon, rockmelon, and honeydew
Joanna Embry	Biosecurity Officer, Melons Australia
Kane Younghusband	Melon grower – watermelon
Pumpkin	
Patrick Fox	Pumpkin grower – Fox Farms
Melanie Gray	Pumpkin grower – Ceres Farm
Rob Hinrichsen	Pumpkin packer – Kalfresh
Jamie Jurgens	Pumpkin grower
Andrew Moon	Pumpkin grower – Moonrocks
Bradley Qualischefshi	Pumpkin grower
Mike Rieck	Pumpkin grower
Lynley Van Latham	Pumpkin grower/marketer - Rugby Farms
Kees Versteeg	Pumpkin packer – Qualipac
Beekeepers and Pollination Brokers	
Murray Arkadieff	Beekeeper and pollination service provider, QLD
Peter Barnes	Beekeeper and pollination service provider, QLD
Chloe Bidner	Beekeeper and pollination service provider, QLD
Neil Bingley	Beekeeper and pollination service provider, NSW
Casey Cooper	Beekeeper and pollination service provider, NSW
Steve Fuller	Beekeeper and pollination service provider, NSW
Danny Le Feuvre	Beekeeper and pollination service provider, SA
Stephen Fewster	Beekeeper and pollination service provider, WA
Shawn Hinves	Beekeeper and pollination service provider, Kangaroo Island, SA
Ben Hooper	Beekeeper and pollination service provider, SA
Therese and Laurie Kershaw	Beekeeper and pollination service provider, NSW
Craig Klingner	Beekeeper and pollination service provider, NSW
Jon Lockwood	Beekeeper and pollination service provider, NSW
Kevin MacGibbon	Beekeeper and pollination service provider, VIC
Tim Malfroy	Beekeeper and pollination service provider, NSW
Rob Manning	Beekeeper, queen bee breeder, bee researcher, WA
Jo Martin	QLD Beekeepers Association (forwarded survey to QLD beekeepers)
Peter McDonald	Beekeeper and pollination service provider, VIC
Trevor Monson	Pollination broker, VIC
Courtney Nobbs	Beekeeper and pollination service provider, QLD

Lachlan Rasmussan	Beekeeper and pollination service provider, QLD
Harold Saxvik	Pollination broker, NSW
Dr Doug Somerville	Beekeeper and pollination service provider, NSW
Steve Targett	AHBIC Chair and beekeeper
Trevor Weatherhead	Beekeeper and pollination service provider, QLD
Brian Woolfe	Beekeeper and pollination service provider, NSW
Ian Zadow	Beekeeper and pollination service provider, SA

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Abbreviations

ABA	Almond Board of Australia
ABS	Australian Bureau of Statistics
AFB	American Foulbrood
AMS	Australian Macadamia Society
APAL	Apple and Pear Australia Limited
APVMA	Australian Pesticides and Veterinary Medicines Authority
CEO	Chief Executive Officer
CRC	Cooperative Research Centre
DAFF	Department of Agriculture, Fisheries and Forestry (Australian Government)
DAFWA	Department of Agriculture Western Australia
DPI	Department of Primary Industries
EFB	European Foulbrood
IDM	Industry Development Manager
KPI	Key Performance Indicator
NSW	New South Wales
NT	Northern Territory
NZ	New Zealand
PIBs	Peak Industry Bodies
PHA	Plant Health Australia
PRG	Project Reference Group
QDAF	Queensland Department of Agriculture and Fisheries
QLD	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
RND4P	Rural R&D for Profit Program (Australian Government)
RIRDC	Rural Industries R&D Corporation (now trading as AgriFutures)
SA	South Australia
SIP	Strategic Investment Plan
TAS	Tasmania
UNE AARSC	University of New England Applied Agricultural Remote Sensing Centre
USDA	United States Department of Agriculture
VIC	Victoria
WA	Western Australia
WBF	Wheen Bee Foundation
WSU	Western Sydney University

Grower Pollination Survey

hort frontiers Strategic partnership initiative | POLLINATION FUND

APPLE POLLINATION SURVEY

Dear Grower,

Honey bee and native stingless bee pollination is needed for many crops. Growth in horticulture, limited honey bee supply, and potentially the loss of wild honey bees to Varroa, will add to demand for paid pollination services.

To ensure we have an adequate supply of pollinators, we seek your help with the collection of pollination service statistics. The data will provide a better understanding of current and future hive requirements. Analysis will highlight hive resource gaps, facilitate industry planning and prioritisation of research.

This work is part of project HA21005 'Australian Pollination Service Statistics' funded through Hort Innovation, delivered by AgEconPlus. Information provided will be aggregated to inform a final report. Individual survey responses will be held on a secure server and not shared with any individual or organisation. Hort Innovation's privacy policy is at www.horticulture.com.au/privacy-policy.

I would appreciate if you could take a moment to complete this short survey.

Yours sincerely

Danny Le Feuvre
On behalf of Hort Innovation

Your Enterprise

1. Your property location (nearest town) ________________________________ **State:**__________

2. Area of apple production (ha) ____

3. Production system used (mark 'X'):

Traditional, low density - uncovered	
Medium and high density – uncovered	
Medium and high density – netted for birds and hail	
Other (please state)	

Pollination Services

4. Where does pollination of your crop come from:

	Percentage (%)
Managed honey bees – hives supplied by a beekeeper	
Managed native stingless bees – hives supplied by a beekeeper	
Unmanaged honey bees – living wild near your crop	
Unmanaged other insects – living wild near your crop (native bees, beetles, flies)	

5. Managed honey bee requirements (hives per hectare)

Production System	hives/ha
Traditional, low density - uncovered	
Medium and high density – uncovered	
Medium and high density – netted for birds and hail	
Other (please state)	

6. What is the typical current cost to rent hives from beekeepers for pollination ($/hive)?

	$/hive	Weeks in Crop
Not applicable		
Honey bees		
Native stingless bees		

7. Typically, when are hives required for the pollination of your crop (week/month)?

	Week/Month
In (e.g., week 3, August)	
Out (e.g., week 2, September)	

8. What are the major issues you experience with hives supplied for pollination (number 1 to 3)?

No issues, the service provided is appropriate	
Quality – hives are not strong enough to do the job (limited auditing)	
Can't secure enough hives when I need them (supply)	
Hives arrive late and miss the peak flowering window	
Beekeeper management when on site e.g., hives not dropped right locations	
Cost – price demanded by beekeepers is not reasonable	
Pests and disease – fear of pests and diseases is keeping beekeepers away	
Beekeeper/bee needs are not consistent with the management of my orchard (e.g., cannot use production sprays)	
A biosecurity incursion and closure of state borders	
Other (please state)	

9. Which of the following climate variations/events is most likely to impact pollination of your crop (mark 'X')?

Extreme heat (heatwaves)	
Extreme dry (drought)	
Extreme cold (frost)	
Extreme rainfall (floods)	
Extreme wind (cyclones)	
Catastrophic wildfire (pollinator habitat/bee nutrition)	
Other (please state)	
Other (please state)	

10. Have you noticed changes in seasonal patterns that impact the supply of pollination services (e.g., winter flowering before insects are active)?

____

11. What is the highest priority for pollination research (mark 'X')?

Honey bee management and efficiency	
Native pollinators to fill honey bee pollination gap	
Pollination in protected cropping systems	
Managing multiple species for efficient pollination	
Alternatives to insect pollination (mechanical, new crop varieties)	
Understanding supply and demand balances including future costs	
Other (please state)	
Other (please state)	

12. Other comments in relation to crop pollination ____

____

____

____

Thank you for completing this form. Please return via email to: dannybees38@gmail.com

Pollination Service Provider Survey

BEEKEEPER POLLINATION SERVICE ADVICE

Dear Beekeeper,

Honey bee pollination is needed for many crops. Growth in horticulture, limited honey bee supply, and potentially the loss of wild honey bees to Varroa, will add to demand for paid pollination services.

To ensure we have an adequate supply of pollinators, we seek your help with the collection of pollination service statistics. The data will provide a better understanding of current and future hive requirements and changes needed to ensure beekeepers continue to supply pollination services.

This work is part of project HA21005 'Australian Pollination Service Statistics' funded through Hort Innovation, delivered by AgEconPlus. Information provided will be aggregated to inform a final report. Individual survey responses will be held on a secure server and not shared with any individual or organisation. Hort Innovation's privacy policy is at www.horticulture.com.au/privacy-policy.

I would appreciate if you could take a moment to complete this short survey.

Yours sincerely
Michael Clarke

1. In which state are you based (state) ____________________

2. How many hives does your business manage (hives) ____________________

3. What percentage of suitable hives do you send to crop pollination (%) ____________________

4. In which states/territories do you provide pollination services (state) ____________________

____

5. Typically which crops do you provide hives to pollination, when (mark 'X'):

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Almond												
Apple												
Avocado												
Blackberry												
Blueberry												
Canola												
Cherry												
Citrus												
Faba beans												
Macadamia												
Mango												
Melon												
Pear												
Pumpkin												
Raspberries												
Stone fruit												
Sunflower												

6. What, if any, barriers do you see in supplying hives for pollination:

	Mark Top 3 with 'X'
No barriers, pollination is a valuable source of income	
I can make more money from honey	
Price is not enough for the risk of American Foulbrood (AFB)	
Too stressful in getting hives up to standard	
Pesticide sprays harming my bees	
Pollination is too hard on the bees and me	
Distance and transport difficulties	
Farmer infrastructure and expectations e.g., site access, bee placement in orchard	
A biosecurity incident and closure of state borders	
Contracts needed with the farmer	
Other	
Other	
Other	

7. What is your biggest cost in supplying hives for pollination:

	Mark Top 3 with 'X'
Labour for hive manipulation prior to pollination	
Supplementary feeding – sugar and pollen purchase	
Transport and diesel to supply hives to the crop	
Other	
Other	
Other	

8. What are your intentions for the supply of hives for pollination in 5 years' time (mark 'X' and '%')?

	Intention ('X')	Percentage (%)
Increase		
Decrease		
No change		

9. Which of the following climate variations/events is most likely to impact the supply of hives for pollination (mark 'X')?

Extreme heat (heatwaves)	
Extreme dry (drought)	
Extreme cold (frost)	
Extreme rainfall (floods)	
Extreme wind (cyclones)	
Catastrophic wildfire (pollinator habitat/bee nutrition)	
Other (please state)	
Other (please state)	

10. Have you noticed changes in seasonal patterns that impact your ability to supply hives for pollination (e.g., winter flowering before bees are active)?

____

11. What is the highest priority for pollination research (mark 'X')?

Pesticide strategies to prevent damage to pollinating honey bees	
Systems to better detect/manage disease (e.g., AFB) during pollination	
Research on bee "forage" near crops to maintain bee health when pollinating	
Pollination in protected cropping systems	
Grower education on the importance of managed/paying for pollination	
Understanding supply and demand balances including future costs	
Native pollinators to fill honey bee pollination gap	

Alternatives to insect pollination (mechanical, new crop varieties)	
Other (please state)	
Other (please state)	

Other comments in relation to crop pollination ____

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Thank you for completing this form. Please return via email to: Clarke@AgEconPlus.com.au