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Honeybee Pollination Services for the Australian Almond Industry

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Abstract

Almonds *(Prunus dulcis (Mill.) D. A. Webb*) are a high value horticultural crop that rely almost exclusively on European honeybees (*Apis. Mellifera)* to produce nuts. The Australian almond industry is concentrated in the Riverland region of South Australia, the Sunraysia region of Victoria and the Riverina district of New South Wales. The rapid expansion of the industry has created speculation that there is a hive number shortage looming. Australia currently uses some 190,000 hives for almond pollination, which are sourced from all states on the eastern seaboard. Industry forecasts suggest that the demand for hives will increase to 300,000 by 2021 when industry plantings will reach its peak. Currently, there are 372,529 commercial hives registered in Victoria, South Australia and New South Wales. Whilst there are sufficient hives to service future almond pollination demand, there is only 50 per cent participation in pollination from beekeepers.

This article investigates the issues around almond pollination, short-term demand and supply and provides some recommendations to assist in solving the perceived imminent shortfalls in supply. Industry data have been collated from both the honeybee and almond industries to enable analysis of the true supply and demand issues around the provision of honeybees for pollination.

Key words: Honeybee; almond; pollination; *apis. Mellifera*; demand and supply; *Prunus dulcis*

Introduction

Cross-pollination is a requirement for many of the commercially grown fruits, nuts, vegetables, pulses and oilseeds that we eat every day (Degrandi-Hoffman et al., 1992). Cross-pollination can be achieved through many mechanisms including wind or, most commonly, through insects physically moving the pollen from flower to flower. Whilst there are many species that effectively pollinate, like flies, native bees, and ants, the only commercially viable and scalable option available to growers is the use of European honeybees.

Australian growers are in the unique situation of being able to enjoy high levels of 'free' pollination from the 'feral' honeybees due to the absence of significant pest and diseases (Roberts et al., 2017). This free pollination is sufficient for some small growers in areas that can support high levels of feral beehives through areas of natural vegetation. The trend towards large plantings of simultaneously flowering orchards in areas with little surrounding natural vegetation to support feral colonies and other native pollinators means that these growers need to employ managed pollination services (Nicolas et al., 2014).

The pollination of almonds is well understood (Connell, 2000; Klein et al., 2012) and the use of managed European honeybees is standard practice to achieve maximum yield (Phillips, 2014). Little research has been conducted investigating the market forces for the supply of honeybee pollination in Australian almonds. Understanding the pressure points for supply along the chain will help both growers and beekeepers better manage the supply and demand of hives.

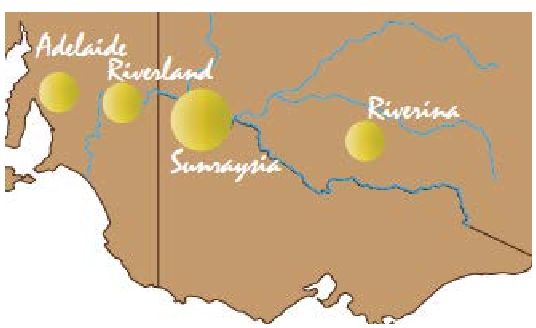
In recent years the price for almonds has been attractive, investments have been made in orchard expansion and the demand for pollination is on the rise (Almond Board of Australia, 2017). In the Horticulture Innovations Strategic Investment Plan 2017-2021 honeybee shortages are cited as a major weakness in the almond industry SWOT analysis (Horticulture Innovation Australia, 2017). In addition, the threat of Varroa mite and the potential impacts on the Australian honeybee industry are real (Roberts et al., 2017).

The Demand for Pollination

Australian almond pollination profile

The Australian almond industry has grown significantly over the last decade to cover 35,000 ha with over 10 million trees (Almond Board of Australia, 2017). The orchards are concentrated mainly around the irrigation areas of North Western Victoria, North Eastern South Australia and Southern New South Wales.

Figure 1. Almond growing regions in Australia



Source: (Almond Board of Australia, 2017)

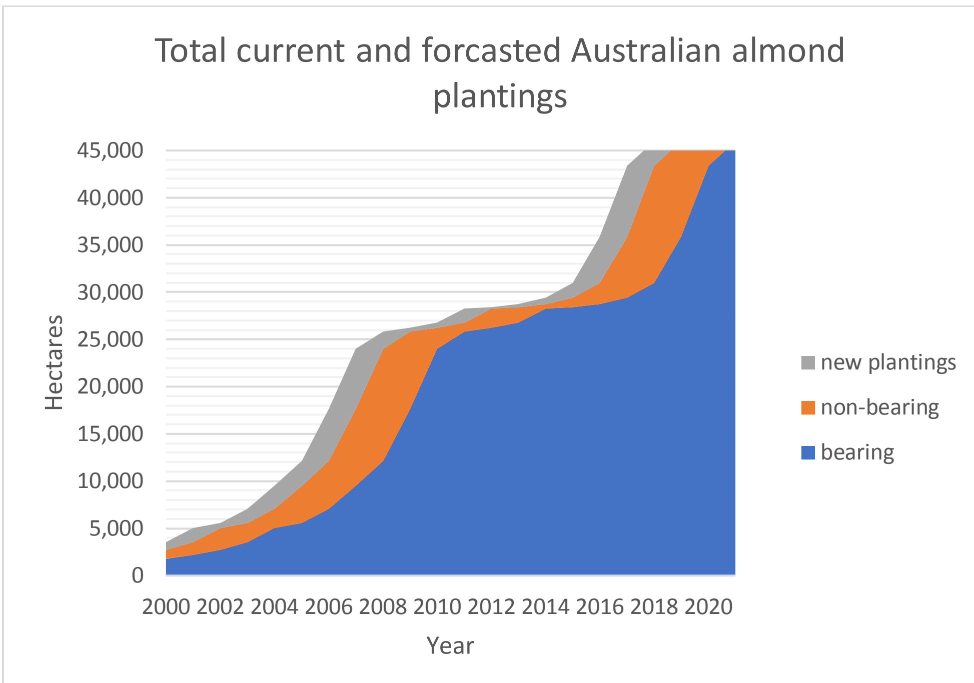
Almond trees take 3-4 years to reach a fruit bearing age during which time they do not require managed pollination (Tombesi et al., 2017). Once reaching fruit bearing age, managed bee hives are introduced and the resulting fruit set is harvested from the trees for the first time. Flowering occurs during August and the fruit develops through to harvest in March. Harvest is done by mechanical harvesters that shake the trees to dislodge the fruit.

The main cultivar grown in Australia is Nonperial with 16,899 hectares planted nationally (Almond Board of Australia, 2017). Due to the cultivar's reliance on cross-pollination for fruit set (Connell, 2000), growers plant additional compatible cultivars on alternate rows to provide pollen movement by pollinators.

Carmel is the most common pollinating cultivar followed by Price at 10,063 ha and 3,750 ha respectively (Almond Board of Australia, 2017).

It is estimated that the total footprint from the almond industry will reach 45,000 ha (pers. comm. B. Brown) in fruit-bearing trees by 2021. If this is realised, this will result in an increase of 15,000 ha in fruit-bearing trees compared to 2017 (Almond Board of Australia, 2017). At the current stocking rate of 6.7 hives per hectare (Cunningham et al., 2016) an additional 100,500 hives will be needed. Currently there are approximately 190,000 hives brought into the almond-growing regions from South Australia, Victoria, New South Wales and as far as Queensland (Almond Board of Australia, 2017).

Figure 2. The total area planted to almonds nationally including the new plantings, non-fruit bearing area and the fruit bearing area which requires pollination



Source: adapted from (Almond Board of Australia, 2017)

If the current spike in new orchard development slows as expected, the peak hive demand will occur in 2021 as the last new plantings reach early maturity. Figures adapted from industry and peers' comments suggest that there will be demand for 300,000 hives migrating to the almond growing regions each August.

Further, Cunningham and colleagues have shown that the current stocking rate is not providing maximum pollination outcomes and recommends an increase to 8 hives per hectare (Cunningham et al., 2017). If industry were to adopt this recommendation, the total hives required by 2021 would increase to 367,000.

Pollination substitutes

Currently there is no adequate alternative to using beehives for pollination. Research has been carried out in other countries to investigate the viability of alternative native pollinators to no avail (Artz et al., 2013). In current research, Cunningham (2017 unpublished) has investigated the potential for spraying compatible pollen onto the trees to artificially pollinate. This initial work has shown improved pollination outcomes; however, there is no plan for commercialisation as there are technical issues in servicing large areas that need to be overcome.

Plant breeding has resulted in the development and release of self-fertile varieties, the first of which has been named “Independence”. These cultivars are self-compatible and have the ability to produce some fruit in the absence of cross-pollination (Dicenta et al., 2002). However, it is well recognised that they will set additional fruit when cross-pollination occurs. In some sectors this has been hailed as the saviour to the beehive supply shortage problem; however, the adoption of the new variety has been low with only 200 ha being planted since its release in 2014 (Almond Board of Australia, 2017).

Planting self-fertile varieties will do little to reduce the need for beehives unless the new cultivars are planted in isolation of the self-incompatible cultivars. It is very hard to control the foraging habits of bees and growers will need to maintain the correct hive density across the whole orchard to ensure sufficient pollination occurs.

The Supply of Pollination

The Australian honeybee industry

The Australian honeybee industry is a small but significant primary industry. The primary product from this sector is honey with some by-products including wax, propolis, queens and packaged bees.

The provision of hives for pollination services is a growing income source for beekeeping businesses with 44 per cent of commercial beekeeping businesses Australia-wide conducting some paid pollination services in 2015. In 2015, honey sales accounted for 85 per cent of cash receipts, showing honey is still the focus for most beekeeping enterprises (van Dijk et al., 2016).

The beekeeping industry is made up of some 13,400 registered beekeepers who own some 448,300 hives (van Dijk et al., 2016). Whilst at face value there appear to be sufficient hives to service current pollination requirements, of the 13,400 registered beekeepers there are only 1,280 beekeepers with 50 or more hives and are thus considered commercial beekeepers.

Increased public interest in beekeeping has seen the recreational beekeeping sector explode in popularity. In South Australia alone, registrations have gone from 770 registered beekeepers in 2015 to 1753 in 2017 (pers. comm. M. Steadman). Yet, the number of registered beekeepers with 50 or more hives has remained stable or decreased. This pattern has occurred in all the beekeeping states.

The apiary industry is considered to be a livestock industry and falls under the relevant livestock acts in each state. There is variation in the regulation under which beekeepers in each state operate, but some rules are consistent. Nationally, the industry has advocated a five-zone policy which restricts the movement of hives across some areas. The five-zone policy restricts where hives can be sourced from to service pollination requirements. Hives cannot be moved in or out of each of the zones. In addition, each state has its own defined requirements for hive movement across borders. For example, hives from South Australia that are being moved to almond pollination at Lindsay Point (Victoria) must cross the border and in doing so must have a valid health certificate from the relevant state department. Should the beekeeper stay over the border for more than 90 days, they are required by law to register in that state.

Table 1. The five recognised hive movement zones

Zone	States and Territories covered
1	Western Australia
2	Tasmania
3	Queensland, New South Wales, Victoria and South Australia
4	Northern Territory
5	Kangaroo Island

Therefore, hives can only be sourced from Victoria, South Australia, New South Wales and Queensland to service the eastern state almond pollination needs. Even then, due to the state border restrictions and distance to travel, it is reasonable to assume that hives would only be sourced from Queensland as a last resort.

Generally, only commercial beekeepers service the almond industry with some minor exceptions. This combination reduces the available pool of hives for almond pollination. The data in Table 2 show that, notionally, there are adequate hive numbers to meet demand. However, not all apiarists are willing to service the almond industry.

Table 2. Number of commercial beekeepers in each state available to supply almond pollination services*

State	Commercial hives
SA	61,064
Vic	81,400
NSW	230,065
Total	**372,529**

Source: Primary data sourced from BioSecurity SA, NSW DPI, VIC DPI
* Excludes hives owned by operations with <50 hives. Effective as at October 3, 2017.

The low participation rate in almond pollination is explained in a recent survey (Table 3) to be a result of insufficient remuneration for services (44 per cent), increased biosecurity threat from mass congregations of hives (35 per cent) and the reluctance to travel the long distances required (27 per cent) (van Dijk et al., 2016). These data build the case that the anticipated hive shortage is not a hive 'shortage' but a lack of participation in almond pollination by beekeepers.

Contextual Challenges to Participating in Almond Pollination

The ongoing relationship between apiarists and the almond growers is bound by some contextual challenges which have the potential to diminish the ability for supply to meet demand in the short term. These include the following:

- Remuneration for the pollination services provided or the perceived opportunity cost from missing a honey flow.
- Significant concerns from beekeepers regarding bio-security issues during mass hive congregations for pollination.
- Lack of refuge sites for both the winter pre-pollination hive build-up and the post-pollination hive recovery.

Table 3. Participation of beekeepers in paid pollination and the percentage that service almonds

State	Participation in paid pollination (%)	Participants that go to almonds (%)
SA	78	65
Vic	55	94
NSW	40	79

Source: (van Dijk, 2016)

Opportunity cost

Almond pollination generally commences in the first week of August and, depending on weather, will last for 3-4 weeks. Determining the amount of honey that can be produced during the same time depends greatly on the location of the hives and the weather conditions. The current pollination price for almond hives is $104.00/hive and the current honey bulk price is $5.30/kg. Therefore, a hive must produce 20kg of honey over the same period as almond pollination to break even. Through personal experience and comments from peers, I judge that a beekeeper would need an exceptional honey flow to exceed this, and, even if it did occur, this could not be repeated yearly.

Potential impacts of bio-security

Honeybees are susceptible to a number of diseases and pests. Endemic diseases include American foulbrood, European foulbrood, chalkbrood, sacbrood, nosema, small hive beetle, and wax moth (Roberts et al., 2017). If not managed appropriately, these endemic diseases can have significant impacts on the quality of hives produced for pollination.

The mass hive movement from the eastern seaboard to the almond growing regions has been described as the largest movement of livestock in the country. This movement occurs each year at the end of July and services the almond bloom during August. Due to the sheer number of hives required, growers often need to employ the services of several different beekeepers to meet their demand. Issues arise from having many enterprises and a large number of hives all mixing together. Disease transfer during this pollination event is a credible concern to beekeepers and is a barrier to conducting pollination (Gordon et al., 2014).

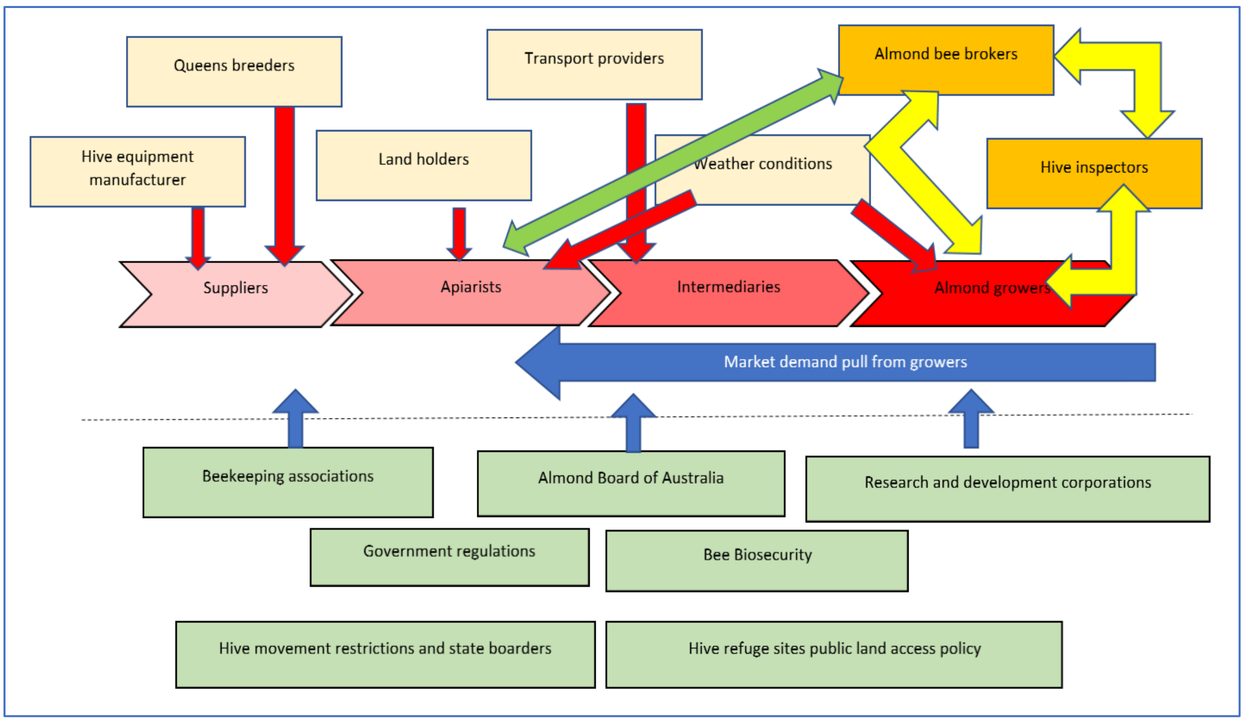
Australia is currently free from some of the most significant pests that occur elsewhere in the world, notably the Varroa mite (*Varroa destructor and V. jacobsoni*), Tropilaelaps mite (*Tropilaelaps clareae* and *T. mercedesae*) and Tracheal mite (*Acarapis woodi*) (Roberts et al., 2017). If Varroa mite were to establish in Australia it would have significant impacts on the ability of the honeybee industry to meet pollination demands. Overseas experiences, most recently in New Zealand, demonstrated that once the mite is established there is a dramatic decline in the number of feral bees in the landscape and a large reduction in commercial hives as the industry adjusts to a change in management. The spread of both the endemic and exotic pest diseases can be expedited significantly during the almond pollination event (Gordon et al., 2014).

Value Chain Map

The value chain for the provision of honeybee hives for pollination is relatively simple compared to something like mapping the process of honey to market. Although simple it is important to identify all the inputs, influence and participants to fully understand the issues in the chain. All too often actors in the chain are focused on their role and are blind to the other roles along the chain.

Figure 2 depicts the interactions of the different components along the chain. At the hive input level queen breeders play a very important role. Every hive must have an active queen and the most efficient way of sourcing/producing one is to purchase direct from a queen breeder. Importantly, queen breeders are subject to the same restrictions as hive movements described earlier. Therefore, there is a limit to the number of queens that beekeepers can source at any given time. Natural events such as floods and drought can also adversely affect queen supply.

Figure 2. The value chain map representing all the influences in producing and providing pollination hives for almonds



Source: Authors Compilation

Landholders, both public and private, also significantly influence the number of hives that can be produced. Hives must be placed somewhere pre- and post-pollination; this is traditionally done on land that is not owned by the beekeeper, but on land that is sometimes rented with payment being in honey. The supply of quality refuge sites is identified as a barrier to participation and expansion (van Dijk et al., 2016).

Adverse weather conditions can significantly affect the hives during the pre-pollination period. Winter weather conditions dictate the strength of hives delivered to almonds. Conversely, the weather during pollination can dictate the amount of flying time the bees have to pollinate and achieve fruit set.

The relationship between the almond pollination broker, apiarist, hive inspector and almond grower is dynamic. The broker often plays an intermediary role and coordinates the delivery, inspection and removal of the hives. Brokers are usually only employed by the bigger corporate-style operations; most smaller private orchards circumvent the broker to save costs. The inspector can either be organised by the broker as part of their service or be independent. Their role is to inspect the hives to ensure that they meet the minimum requirements for a pollination hive.

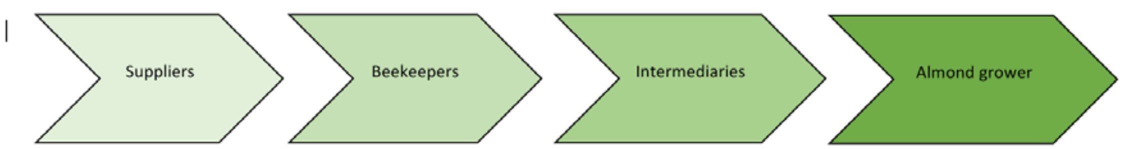
At a higher level a number of organisations and groups influence the chain. These include research and development outcomes like hive standards and hive densities or placement information. Government regulations play a role in terms of hive movement restriction, as explained earlier. Government policy in relation to land management also can play a significant role.

In this value chain the market demand is coming from the almond growers who need hives for pollination, a key component in the almond value chain. This market pull demand determines the dynamics of the relationship between the main actors as the grower has no substitute for the service and is fully reliant on the service for fruit set. This dynamic gives the beekeeper negotiating power as the beekeeper has a substitute for income in honey production. This ability of the apiarist to substitute their income during the same period explains, somewhat, the low participation rate.

Assessing the Performance of the Value Chain

There are few actors in the value chain for providing pollination hives in almonds. However, the actors that do exist are incredibly important. This short chain results in a high level of responsiveness and efficiency in providing the services.

Figure 3. Map of the value chain actors in the provision of hives for almond pollination



Actors	Queen breeders Hive hardware	Individual enterprises	Pollination brokers Transport operators Private Landholders Public lands	Small individual growers Corporate growers
Activities	Produce queens Supply bee boxes	Produce and manage hives	Facilitate hive placement Match growers to beekeepers Deliver hives Provide refuge for hives pre and post pollination	Consumers of service

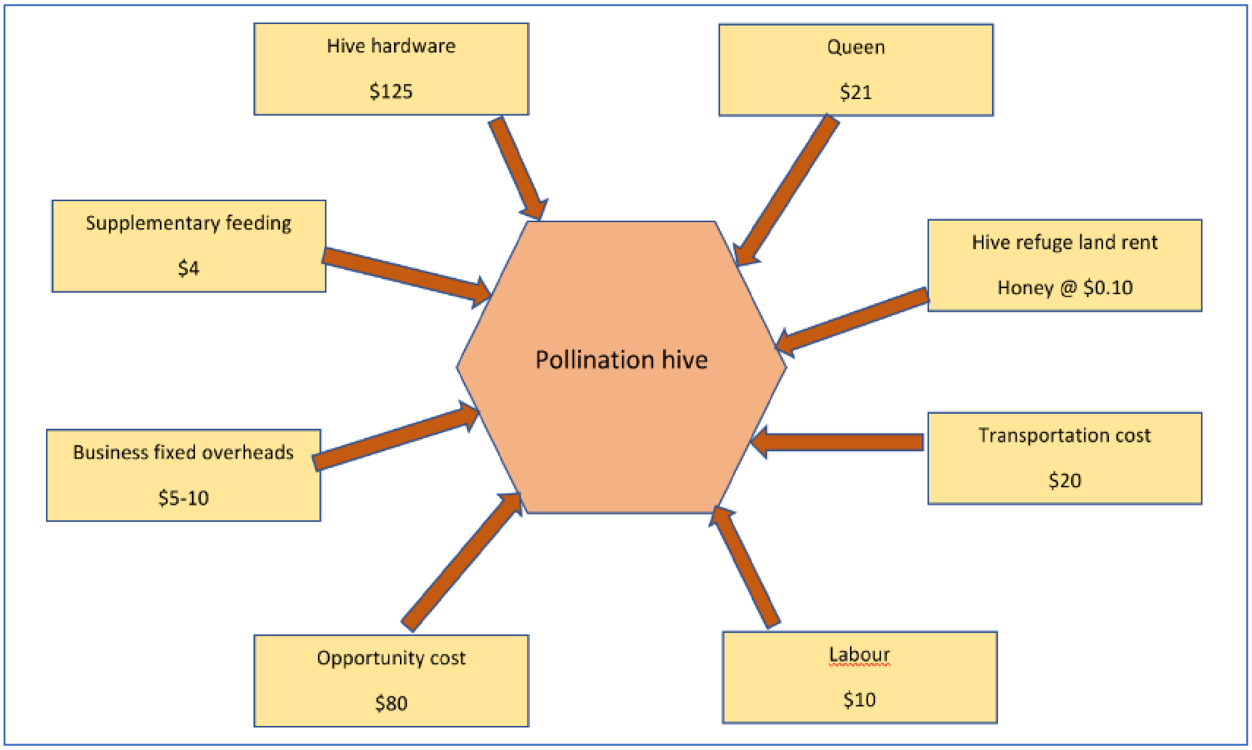
Source: Authors Compilation

To effectively measure the efficiency of the pollination value chain we need to investigate the relative cost of supplying a pollination hive and the value that is placed on the service.

Production costs

The cost to produce an individual pollination hive varies significantly between beekeeping enterprises. Figure 4 shows the relative costs of each of the major inputs at a hive level to create the pollination service.

Figure 4. Relative input costs per hive to produce an individual pollination hive



Source: primary data collected by the author

Price received

The price paid to beekeepers for their pollination services in almonds has increased significantly, from $65/hive in 2008 to $104/hive in 2017. This reflects higher demand due to the significant increase in area planted. It is not clear if this upward trend will continue; however, as discussed, there is a large short-term increase in demand which will significantly stretch supply at current participation rates. Therefore, increasing prices would be expected to continue until the new plantings plateau and the market finds its equilibrium.

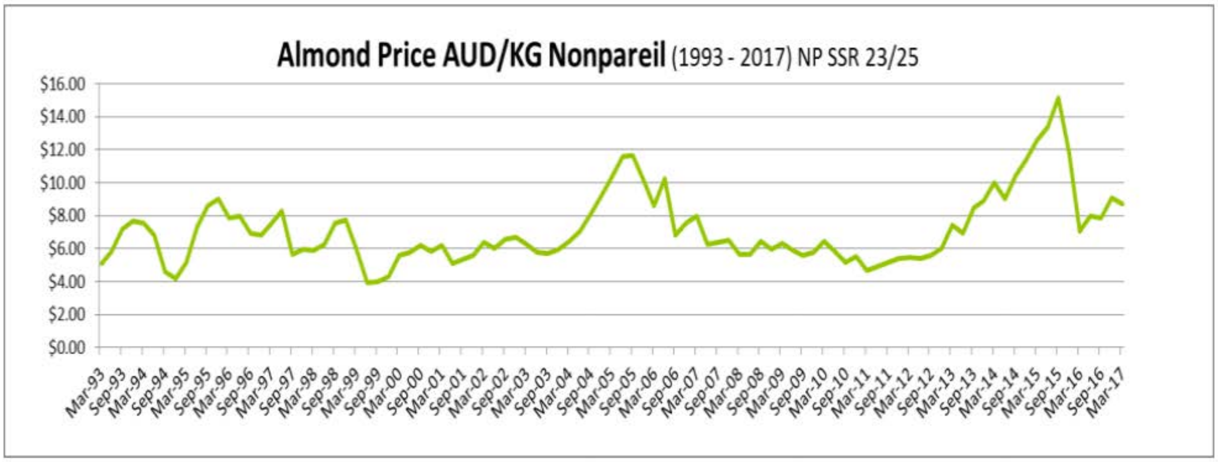
As a comparison, the American almond pollination prices for 2015 were $US170-$200 (Goodrich, 2018). The Californian almond industry, whilst significantly bigger, has been experiencing tight supply issues for many years which may be a sign of things to come for Australian growers.

Drivers of profit

The price paid to the beekeepers is thought to be reflective not just of supply pressure but profitability of the almond industry. Figure 5 shows the price paid for the harvested nuts over time. This shows that the relative profitability of the almond industry is stable and perhaps not a major driver of price paid. The cost per hectare paid for pollination represents only 5 per cent of the cost of production (Thompson, 2017).

The main driver to prices paid for pollination appears to be supply pressure due to a lack of participation in pollination by beekeepers.

Figure 5. Price paid to growers over time



Source: (Thompson, 2017)

Conclusions and Recommendations for Improvement

This analysis has provided some clarity around the sensationalised reports of mass hive shortages for almond pollination. The evidence is clear that there are sufficient hives within the almond-growing states but the participation in almond pollination from the beekeeping sector is low in all three states. This shows that concerted efforts need to be focused on the reduction of barriers to participation, not necessarily encouragement of mass hive production.

The following recommendations are provided to stimulate some discussion around the issues.

Empirical data collection

Survey more deeply the beekeeping industry to identify and explore the specific barriers to participation. Include in the survey what the apiarist sees as potential solutions to their issues. Currently, the ABARES 2016 survey (van Dijk et al., 2016) is the only empirical study to highlight barriers to participation in pollination. This gap in deep understanding of the underlying issues is critical to further understanding the potential supply and demand issues into the future.

The honeybee industry is significantly understudied at a business and decision-making level. Complete knowledge of the factors that drive the decisions of the beekeepers will assist the pollination-dependent industries to secure pollination into the future.

A strong example of this is in America where a deep knowledge of the factors driving participation are understood. Articles in industry publications accurately describe the influencing factors through regular empirical data collection (Goodrich, 2018).

Economic modelling

Modelling to show the true cost of providing pollination services and the opportunity costs in participation would assist in the decision making of beekeepers. This would also assist in modelling the forecasted prices of services into the future, addressing the main barrier to participation identified by van Dijk et al. (2016), that is, price received for services.

Do nothing and allow market forces to work

This is the argument posed by many: simply allow the laws of supply and demand to work. One could argue that the barriers to participation, notably pollination fees, are yet to reach an equilibrium point. As new plantings develop at a faster pace than the expansion of the beekeeping industry the equilibrium point will continue to move. As the equilibrium point moves, and demand increases at a faster rate than supply, the price paid will continue to rise (Sumner and Boriss, 2006). This, in my view, is a simplistic view of a complex industry.

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