Almond

This case study is the primary source of information on potential pollination services for the industry. It is based on data provided by industry, the ABS and other relevant sources. Therefore, information in this case study on potential hive requirements may differ to the tables in the Pollination Aware report (RIRDC Pub. No. 10/081) which are based on ABS (2008) *Agricultural Commodities Small Area Data, Australia 2005-06.*

Introduction

Almonds (*Prunus dulcis*) were first found in an area stretching from northern India westwards to Syria, Israel and Turkey. They have since spread along the shores of the Mediterranean into northern Africa and Southern Europe. In more recent times almond cultivation has spread throughout the world, with the USA now being the world's largest producer, followed by Spain, Italy and Greece. Almonds are highly sought after worldwide and can be consumed raw, roasted, toasted, whole or sliced, alone, in candy, confections, or prepared dishes. An almond tree may remain in production for 50 years or more (McGregor 1976).

The majority of commercial almond cultivars are self-incompatible, meaning that without cross-pollination a viable crop is highly unlikely. As the commercial part of the fruit is the kernel, pollination and ovule fertilisation are of critical importance to obtain optimal yields, and typically require the joint planting of at least two inter-compatible and simultaneously blooming cultivars, and the presence of pollinating insects for pollen transfer (Socias i Company et al. 2005). Fruit setting and pollination have been described as the most influential limiting factors for almond production (Hill et al. 1985). Honey bees are recognised as the most efficient and practicable pollinating insects of almond blossom and are in huge demand worldwide for their pollination service (Socias i Company et al. 2005; Somerville 2007; Thomson and Goodell 2001; Hill et al. 1985).

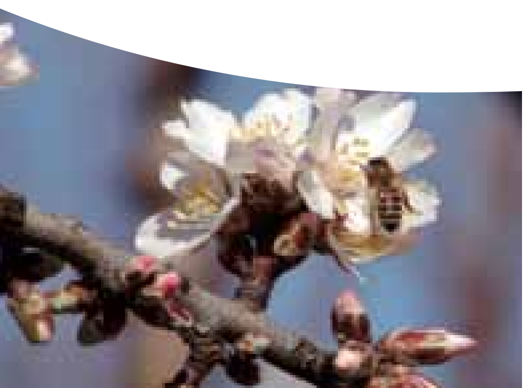
Almond production in Australia

The original plantings and beginning of the almond industry in Australia occurred in the Adelaide Hills of South Australia. The industry expanded into the South Australian Riverland in the 1960s and then along the Murray River in the 1970s. Currently the single biggest location of almond trees planted is around Robinvale, New South Wales, with some 7,200 hectares planted in mid -2005 (Somerville 2007).

In 2008, Victoria produced 65% of Australia's almonds with South Australia and New South Wales producing 32% and 3% respectively. Australia is a relatively small player in the global almond market, however, the industry has great potential and has been growing strongly for more than two decades. Total production of Australian almonds reached 26,060 tonnes in 2008 with the most widely cultivated varieties being Nonpareil, Carmel and Price (Table 1).

Table 1 Australian almond production (tonnes) by variety from 2006–2008 (ABA 2008)

Variety	2006	2007	2008
Nonpareil	7,989	13,751	13.430
Carmel	4,246	7,383	7,996
Price	903	2,037	2,338
Total	**13,138**	**23,171**	**23,794**



Almonds prosper where summer temperatures are hot and dry, but they require chilling during dormancy (McGregor 1976). These climatic characteristics coupled with suitable land and soil, a highly developed infrastructure, a well-organised and professionally managed industry commitment to best practise production and research make many areas of Australia an ideal place for the production of almonds. Total Australian almond plantings are estimated at 27,315 hectares after a 5% increase on 2007's average of 26,100 hectares (ABA 2008; Somerville 2007) (Table 2 and Figure 1). In 2007/08, Australia's exports were worth a total of $75 million to the Australian economy, with the main export markets being India, Spain, Germany and New Zealand (ABA 2008). The primary driver for exports is now the increasing production, which having satisfied domestic markets must now be exported (AAGA 2000; ABA 2008).

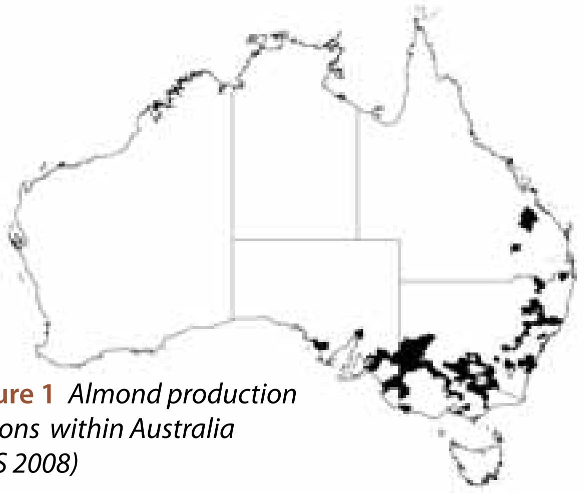


Figure 1 *Almond production regions within Australia (ABS 2008)*

Table 2 **Almond planting areas* (ABA 2008)**

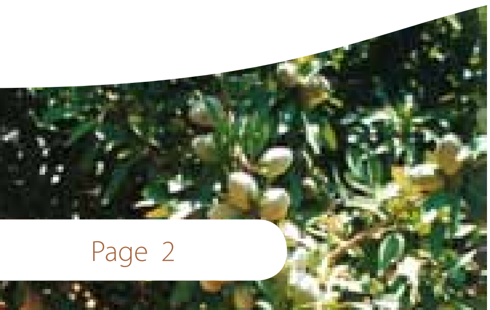
State	Bearing (ha)	Non-bearing (ha)	Area (ha) total
VIC	8,095	10,568	18,663
NSW	759	2,404	3,163
SA	4,426	1,062	5,488
Total	**13,280**	**14,034**	**27,314**

* Almond bearing trees in Queensland are estimated to be less than 50, but grow over a wide region, and so do not appear in Table 2.

Pollination in almonds

The need for insects to pollinate almond blossom is not a question, neither is the use of honey bees for this purpose (Sommerville 2007; McGregor 1976; Somerville 2007). Generally the almond flower is self- incompatible. A pollen tube will not grow down the style of a flower of the same tree, the same cultivar, and sometimes of certain other cultivars (McGregor 1976). Therefore, there is a need for the pollen of one cultivar to be transferred to the stigma of another cultivar (Somerville 2007). Only bees that carry pollen from one cultivar to another receptive flower contribute to fruit set. There are at least two ways in which honey bees might acquire pollen from different cultivars. They can move between trees of different cultivars, or they can acquire pollen in the hive from contacting nest-mates who have been foraging on different cultivars. Not all flowers set, thus, to obtain a maximum crop of almonds, essentially 100% of the flowers must be cross-pollinated (McGregor 1976).

Under weather conditions favourable for honey bee foraging, the individual flower is most receptive to cross-pollination the day following opening and remains decreasingly receptive over the next three or four days with flowers not pollinated being shed in about a month (McGregor 1976). A profitable almond crop depends upon the cross-pollination of practically all flowers. In general almond growers aim for the heaviest possible set of almonds, as unlike some other species (e.g. apples, peaches) there are no problems with fruit thinning and nuts with small kernels are in greatest demand (McGregor 1976). The bee populations should therefore be sufficiently dense that repeated



visits to every flower occur and the bees must 'shop around'; that is, they should not only visit many flowers on the one tree but also must visit between cultivars to obtain their loads of nectar and pollen (McGregor 1976; Degrandi-Hoffman et al. 1992). During flowering, fair weather with daytime temperatures above 12°C is essential to permit flight of pollinating insects with flight of honey bees maximised above 19°C (Somerville 2007; McGregor 1976).

Honey bees have been found to be the most efficient pollinators of almond blossom by many authors (Degrandi-Hoffman et al. 1992; Somerville 2007). Several studies have shown increased fruit set and resultant increased production when using managed honey bee colonies for pollination services. With very few exceptions, cross-pollination is essential for fruit set in almonds and honey bees have been recognised as the most efficient pollinators time and time again.

Whilst this evidence demonstrates that adequate pollination will help ensure adequate fruit set, which in turn results in better outcomes for the grower, it has been suggested that management to ensure good pollination often may not be given sufficient attention, especially during the busy spring season (Degrandi-Hoffman et al. 1992; Somerville 2007).

Pollination management for almonds in Australia

There are a number of factors within the orchard which have a direct bearing on the pollination efficiency of honey bees:

Orchard layout

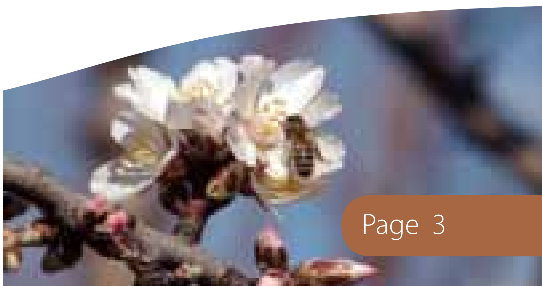
- *Tree and blossom density*: Observations of honey bees foraging on orchard trees indicate that most foraging occurs on a single tree and bees only occasionally move between trees (Degrandi-Hoffman et al. 1992). When honey bees do move from tree to tree, movement is usually to the nearest tree and down a row which is often planted to a single cultivar (Degrandi-Hoffman et al. 1992). Thus it is important for orchardists to place pollinating cultivars at regular intervals throughout the orchard in order to extract the most benefit out of foraging honey bees.
- *Access*: From a beekeeper's point of view, all-weather truck access is highly desirable. Limited access may lead to an increased workload for the beekeeper, uneven placement of hives and thus inefficient pollination. Ensuring the beekeeper has good access will aid in placement of hives and be mutually beneficial to the grower (increased pollination efficiency) and the beekeeper (decreased labour effort).

Pollinisers

It has been recommended that there be either one polliniser row of trees for every three rows of the main variety, or two rows of polliniser trees for each two of the main variety. Whichever recommendation a grower may use, the importance of having a good spread of pollinisers within the orchard will remain essential in gaining optimal yields from season to season.

Density of bees

The hive stocking rate for almonds has been quoted as 4–30 hives per hectare (Somerville 2007). The standard stocking rate in the USA has been five hives per hectare for many years. Several studies indicate that at least 5–7 strong colonies per hectare may be required for maximum production of almonds (Somerville 2007; McGregor 1976). Stocking rates set by Australian Honey bee broker, Trevor Monson, is one hive per acre in two-year-old trees, two hives per acre in three-year-old trees and three hives per acre in established orchards. This equates to around seven hives per hectare in established trees. Somerville (2007) suggest that this rate is high in comparison to USA stocking rates, but yields are also said to be significantly higher in Australia, which could be a result of the higher density of bees (Somerville 2007).



Arrangement of hives

The strategic placement of honey bee hives providing a pollination service is of high importance in order to maximise pollination and thus fruit set. McGregor (1976) suggests that the colonies should be distributed throughout the orchard in small groups 150–200m apart. The apiary location should also consider reducing temperature extremes. The availability of an adequate water source and the provision of shade are important in hot dry climates. In the cooler part of the year the hive should be exposed to the morning sun as radiant heat permits early morning foraging activity (Somerville 2007).

Timing

Honey bee colonies should be in the orchard at the beginning of flowering and should remain until flowering of the main cultivar has ended (McGregor 1976).

Preparation of bees

It is fundamentally difficult to build populations of honey bees during cool conditions, particularly if there are no naturally occurring sources of pollen and nectar. Thus to have healthy bees early in the season, August for almond pollination, the preparation and management of bees should be a major priority during the autumn period. Having good bees in August may not be a major concern for many beekeepers if their first expected honeyflow for the spring is not until October.

Specific moves to 'good' breeding conditions may be warranted in the autumn period, particularly late autumn, to ensure that a populous colony with adequate stored honey and pollen enters the winter period in excellent shape. This will ensure the pollination standard for hive strength and condition is readily met (Somerville 2007).

Attractiveness, nutritional value of pollen and nectar

Honey bees require nectar and pollen to satisfy their nutritional requirements. The quality of pollen collected by honey bees directly affects the welfare of a colony. Poor quality or low volumes of pollen can equate to shorter-lived bees and a colony that has a greater susceptibility to disease. The principal component on which pollen quality is measured is crude protein. Pollen with crude protein levels above 25% are considered excellent and highly favoured by beekeepers (Somerville 2007). Almond pollen crude protein levels have been reported to range from 23% up to 31%. A combination of high crude proteins levels and given that copious quantities of pollen are produced by almond blossom means the species can be described as an excellent source of nutrients for honey bees.

Availability of bees for pollination

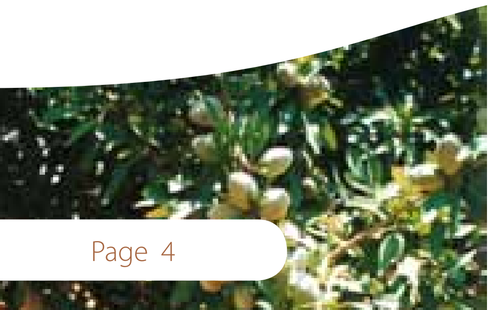
The interest in providing bee hives for almond pollination has been viewed to date by beekeepers in a positive, but cautious light. Prompt payment, limited exposure to chemical damage and the time of year all combine to provide a degree of attraction for many commercial beekeepers (Somerville 2007). Even so, almond blossom still coincides with a number of nectar producing winter flowering eucalypt species that have the potential to provide alternative economic gains for the beekeeper in the form of honey crops (Somerville 2007).

Feral bees

Orchardists relying on feral bees for part or all of their pollination services should be similarly aware first, that feral colonies are unlikely to be at full strength at the time that almonds flower and, second, that even if they were, foraging by these bees is unlikely to be sufficiently intense to achieve the level of pollination required for optimal production especially if there are alternative floral resources available to the bees in the same vicinity (Somerville 2007).

Risks

Pesticides: A serious problem arises when pesticide-induced bee kills occur. Both beekeepers and growers of crops dependent on honey bee pollination services may suffer financial losses. One of the biggest drawbacks of placing bees near any agricultural crop is the possibility of colonies or field bees being affected by pesticides. Pesticides should be kept to a minimum while hives remain on the property. Most poisoning occurs when pesticides are applied to flowering crops, pastures and weeds.



It is strongly recommended that growers take the following steps to prevent or reduce bee losses:

- follow the warnings on pesticide container labels
- select the least harmful insecticide for bees and spray late in the afternoon or at night
- do not spray in conditions where spray might drift onto adjacent fields supporting foraging bees
- dispose of waste chemical or used containers correctly
- always warn nearby beekeepers of your intention to spray in time for steps to be taken to protect the bees; give at least two days' notice
- always advise nearby farmers.

Weather

The radius from the hive a bee will forage is dependent on a range of variables. Temperature and rainfall have a marked effect on honey bee activity. Bee activity is very limited below temperatures of 13°C, with activity increasing up to around 19°C, above which activity tends to remain at a relatively high level. Decreases in both numbers of bees visiting blossoms and the distance from the hive at which bees forage occur with a decrease in temperature.

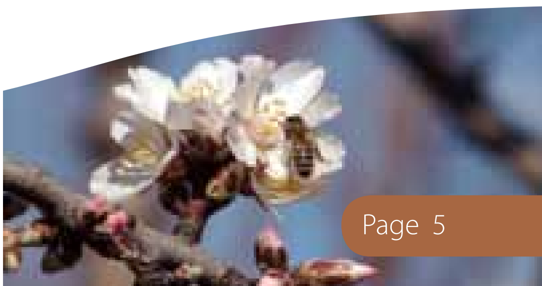
As wind increases the number of foragers decreases in almost a linear relationship (Somerville 2007). For example, when it becomes too windy most foragers stop visiting almond trees, but will continue to work dandelion blossom on the orchard 'floor' even though its nectar may or may not be of poorer quality than the pollination target species.

Alternatives

Despite the pre-eminence of honey bees as managed agricultural pollinators, other insects are more effective in certain situations (Thomson and Goodell 2001). Examples include *Megachile rotunda* as a pollinator of alfalfa (*Medicago sativa*) and bumble bees (*Bombus* spp.) for pollination of tomatoes in greenhouses (Thomson and Goodell 2001). Thomson and Goodell (2001) found that honey bees and bumble bees removed and deposited similar amounts of pollen on almond flowers. They suggested that addition of bumble bees may reduce pollen delivery in almond orchards if honey bees already serve as primary pollinators (Thomson and Goodell 2001). Honey bees have advantageous characteristics in providing pollination services for almond blossom and are the most sought out and highly used insect pollinators worldwide.

Opportunities for improvement

- Increased education of beekeepers: encourage the use of 'industry best practise' methods in providing pollination services to almond orchards. As beekeepers are reminded and/or made aware of the ideal management strategies for ensuring a strong populous colony of bees, then the overall condition of hives going on to almonds is likely to improve (Somerville 2007).
- Ensure all parties understand their roles: beekeepers should be provided with a list of conditions which also describes required strength of hives. The importance of payment on time, good access, clear instructions and good communication from the orchardist should also not be underestimated.



Potential pollination service requirement for almonds in Australia

Somerville (2007) asked the question, 'Are there enough bee hives for the areas being planted to almonds in Australia?' The simple answer is yes, but with reservations. As the demand for bee hives increases, so will the fee paid to beekeepers to provide a pollination service for almonds (Somerville 2007)

Estimates of bee hive numbers required for almonds so far equates to approximately half of all managed hives in the eastern states of Australia (Somerville 2007). This is the same scenario which currently exists in the USA with almond pollination. In the USA, almond pollination service fees are currently around US$150 per hive (Somerville 2007).

Optimal use of managed pollination services in all almond orchards in Australia would require a service capacity as indicated in Table 3 below.

Table 3 Potential pollination service requirement for almonds in Australia (ABA 2008)

State	Peak month	Area (ha) total	Average hive density (h/ha)*	Estimated number of hives required
VIC	August	18,663	6	111,978
NSW	August	3,163	6	18,978
SA	August	5,488	6	32,928
Total		**27,314**		**163,884**

Notes: Area sourced from ABA (2008), flowering times from McGregor (1976) and average hive density from Somerville (2007) and McGregor (1976).

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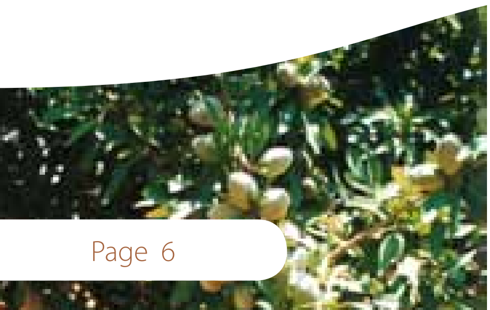
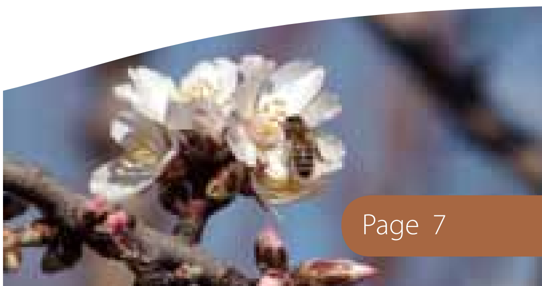


Notes

This case study was prepared as part of *Pollination Aware – The Real Value of Pollination in Australia*, by RC Keogh, APW Robinson and IJ Mullins, which consolidates the available information on pollination in Australia at a number of different levels: commodity/industry; regional/state; and national. Pollination Aware and the accompanying case studies provide a base for more detailed decision making on the management of pollination across a broad range of commodities.

The full report and 35 individual case studies are available at www.rirdc.gov.au.



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