Apples

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

The apple (*Malus domestica*) tree is one of the most widely cultivated plants in the world with more than 7,500 known cultivars. Most commonly apples are eaten fresh for their sweet soft, yet crisp flesh, while some cultivars are breed more specifically for cooking and making cider. The tree originated from central Asia where its wild ancestor is still found today. China is by far the largest producer of apples, with approximately 40% of worldwide production in 2008, followed by the USA, Iran and Turkey.

Most of the known apple cultivars are self-incompatible to some degree (Delaney and Tarpy 2008) meaning that in the highly self-incompatible varieties, fertilisation of the seed does not proceed and no fruit is set when self-pollination occurs, in other varieties self-pollination results in varying proportions of the full potential crop being set under otherwise favourable conditions (Somerville and White 2005).

Cross-pollination is therefore required in all varieties in order for apples trees to bear an optimal crop. Of the ten available ovules in a particular fruit, the greater the number that are fertilised, the greater the likelihood that 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.

Cross-pollination occurs when pollen is moved from the flowers of one variety to the flowers of another variety. This means apple trees require the involvement of a pollinator, such as a honey bee, and a polliniser (which could be either an apple or crab apple variety that produces viable and compatible pollen). This movement of pollen across varieties most often happens when insects forage for nectar and pollen and fly from one tree to another. Research by Somerville & White (2005) in orchards in New South Wales suggests that more than 97% of the insects that visit apple blossoms are honey bees.

Apple production in Australia

There are more than 15 varieties of apple produced commercially in Australia. The four most common varieties are shown in below (Table 1). Victoria and Western Australia are the largest producers of the 'Pink Lady', 'Granny Smith' and 'Sundowner' varieties, while Victoria, New South Wales and Queensland produced the majority of the 'Gala' variety.

Table 1 Production of most common apple varieties in Australia (ABS 2008)

Production of fruit (fresh weight) ('000 t)	2005-06	2006-07	2007-08
'Pink Lady' ('Cripps Pink')	56.5	55.9	60.5
'Granny Smith'	58.9	65.1	58.5
'Gala'	37.5	37	39.5
'Sundowner' ('Cripps Red')	18.1	20.1	19.9
Total production	**171.0**	**178.1**	**178.4**

Most locally produced apples are sold and consumed as fresh fruit. About 15% of the total Australian production is processed for juice/cider, dried fruit, frozen fruit, fresh apple slices and canning (Table 2).

In 2001/02 the apple industry was worth $348 million to the Australia economy, with a total of over 1,300 growers distributed throughout the southern half of the country (HAL 2006) (see also Figures 1 and 2). The Australian apple industry is strongly oriented toward the domestic market. Around 93% of production in 2002 was consumed in Australia. There is in addition, a growing export trade in fresh fruit (HAL 2006). Significant export markets in 2001-2003 included the United Kingdom, Malaysia, India, Singapore and Sri Lanka (HAL 2006).

Table 2 **Industry at a glance: fresh and processed fruit (HAL 2006)**

Production of fruit (fresh weight) ('000 t)	2005-06	2006-07	2007-08
Fresh wt ('000 t)	276.4	270.5	265.5
Processing wt ('000 t)	45.1	42.5	34.4
% Fresh/Processing	84/16	84/16	87/13

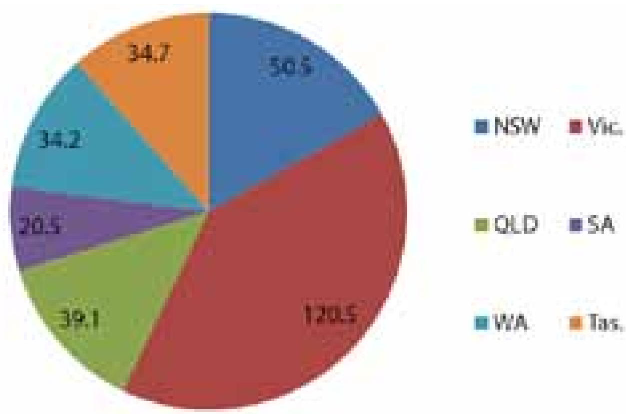


Figure 1 *Apple production by state ('000 tonnes) (ABS 2008)*

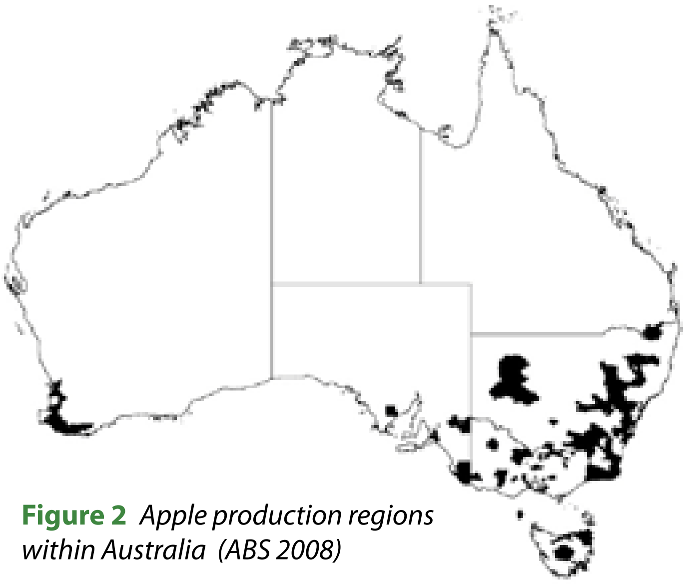
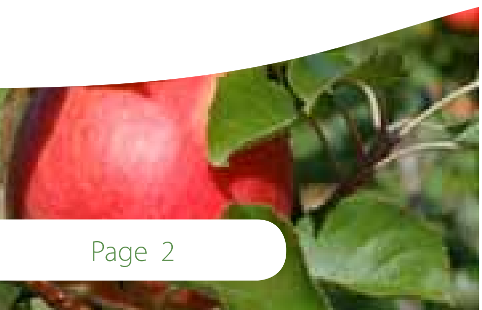


Figure 2 *Apple production regions within Australia (ABS 2008)*



Pollination in apples

Several studies have shown increased fruit set and resultant production when using managed honey bee colonies for pollination services. Langridge and Jenkins (1970) showed that by excluding bees from apple trees significant reductions in fruit set, yield/tree and seed No/fruit could be demonstrated (Table 3). In one orchard trial, three colonies of bees per ha (giving 33 foraging honey bees per 1,000 flowers) resulted in a 32% set and 57kg of fruit per tree (Langridge and Jenkins 1970). Another apple orchard of the same age had only one colony per ha (giving 11 foraging honey bees per 1,000 flowers) resulting in a 15% set and 30kg of fruit per tree. There is also some evidence to suggest that sufficient foraging by honey bees on apple varieties such as 'Pink Lady' and 'Sundowner' can reduce the number of picks for the crop as a result of improved pollination.

Whilst this evidence demonstrates that adequate pollination will help ensure adequate seed formation and reduce the incidence of deformed apples, 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 (Somerville 1999; Vicens and Bosch 2000).

Pollination is among the most critical events in the commercial production of apples. Excessive fruit can be thinned as they set but once flowering has occurred there is no way to put more fruit on to the tree (Delaney and Tarpy 2008; Somerville 1999).

To attain the best fruit set on apple trees, the king blossom (the largest and first one to open) in each flower cluster must be pollinated with pollen from a flower of another variety of apple. To achieve this, the tree providing the pollen (polliniser) must be in bloom when the king blossom of the target apple tree emerges and continue for the period required to service the flowers that follow the king blossom. Therefore, a key aspect of pollination management is the selection and cultivation of pollinising cultivars that flower at the same time as the commercial cultivars in numbers and locations appropriate to ensure timely and adequate coverage of the commercial variety to be pollinated.

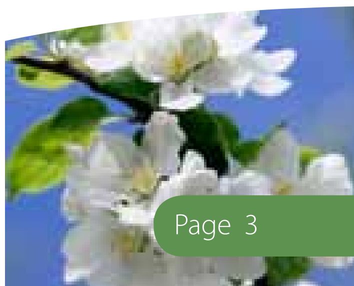
Both yield and quality of fruit are dependent upon the intensity of pollination. Management of this aspect of pollination has two elements. First, there must be sufficient pollination agents (honey bees) present during flowering to ensure that all flowers are adequately covered and, second, density and distribution of the pollinising variety must be sufficient to ensure that the pollen delivered by the bees results in the fertilisation of all available ovules.

Table 3 — **Apples: fruit set with and without honey bees (Langridge and Jenkins 1970)**

Variable	Open Trees	Caged trees
Fruit set/tree	1,862	51**
Flower clusters/tree	794	631
Fruit set/100 cluster	240	8**
Yield/tree (kg)	125	8.6**
Seeds/fruit*	7.1	1.9**

*Samples of 20 fruit per tree. ** Statically significant reduction, P<0.01.





Pollination management for apples 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: In older-style orchards, trees were spaced in 6 x 6m patterns (250trees/ha) and took about 25 years to reach maximum production. The more recent trend using dwarf rootstock can result in as many as 2,000 trees/ha, very high flower numbers per hectare and maximum production can be reached within six years. Under circumstances of higher tree and blossom densities the density and condition of hives must also increase to ensure optimal pollination.
- 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

All varieties of apples should be cross-pollinated with another apple or crab-apple variety (polliniser) (Lacey and Antione 2006). To attain the best fruit set on apple trees, the king blossom (the largest and first one to open) in the flower cluster must be pollinated. Orchardists must ensure there are sufficient polliniser varieties throughout the orchard and that the bloom periods of the polliniser and the king blossom of the apple tree overlap (Lacey and Antione 2006). This will help to gain maximum fruit set.

Density of bees

The apple flower cluster is made up of about six flowers and is produced on any aged woody shoot 15mm to 50mm long called a spur (Somerville 1999). Apple blossoms have five petals and numerous stamens; the ovary consists of five carpels, each of which contains two ovules (Somerville and White 2005).

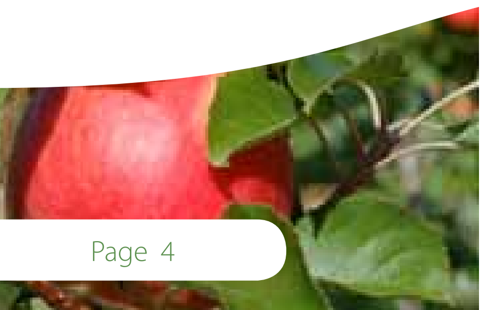
For adequate pollination to occur, most of these ovules need to be fertilised. Failure to fertilise even one ovule per carpel will result in misshapen fruit or smaller fruit or in some cases, the tree will shed these developing fruits completely. Some suggest that more than 97% of insects that visit apple fruit blossoms are honey bees.

The optimal number of hives/ha for apples has been researched since the mid 1970s, with recommendations of 1–12 hives/ha (Delaney and Tarpy 2008). The average rate of hive stocking across the scientific literature is 2-4 hives/ha although recommendations for particular orchards may be highly dependent on environmental and landscape factors.

Three to five colonies of bees per hectare should be used in orchards with high density planting as there are more flowers per hectare. Honey bees are more likely to move between trees of different varieties when bee density is high, and food resources are limited. Hence, cross-pollinations from tree to tree occur in the later foraging hours each day and early and late in the flowering season.

Arrangement of hives

Hive placement within the orchard is a very important factor to consider. It has been shown that bees prefer to forage within 100m of their hives. Many different placement scenarios have been proposed depending upon the layout of the orchard but it has been generally recommended that groups of 4–8 hives be placed at intervals of 150m throughout the orchard. In order to allow the bees to take full advantage of the early morning



bloom time, it is also important to place hives in the sunlight (Somerville and White 2005). The selection of good hive sites and the use of hive stands will ultimately increase flight and help to insure foraging activity under marginal weather conditions. Hives should also be elevated slightly off the ground. Hives should be placed in sunny locations that are protected from the wind; they should not be set in low-lying areas where moisture or moisture-laden air will settle (Somerville and White 2005).

Timing

The primary or king bud on any flower cluster opens first and if properly fertilised usually produces the choicest, largest fruit. Apple trees will bloom over a number of weeks but it is the first 9–10 days that are the most important to set the king blossom. To maximise the likelihood that bees will forage on the apple flowers, and thus transfer pollen, hives should be in the orchard when roughly 5–10% of the apple flowers have blossomed. Such a delay will encourage bees to focus on the target trees rather than learn to visit competing plants (Lacey and Antione 2006).

Preparation of bees

For a hive to be able to adequately pollinate fruit blossom, it must be above certain strength in bee numbers. To achieve this, honey bees are managed by beekeepers to ensure that hives go into the winter in good condition and are not stressed over winter. Some degree of stimulation may be required before hives are placed in the orchards. This may require either artificial stimulation by feeding pollen supplements or substitutes, or by moving the apiary onto early flowering conditions before moving into the orchard. A hive of 4–6 frames of brood is sufficient to go onto apples. With an expanding brood nest, the bees have greater need for pollen to feed their larvae, thus showing greater enthusiasm in flying even during less-than-favorable conditions.

Attractiveness, nutritional value of pollen and nectar

Honey bees collect nectar and pollen from apple blossoms and find this group of plant moderately attractive for both their nectar and pollen (Lacey and Antione 2006; Vicens and Bosch 2000). The amount of nectar and pollen varies among cultivars so that honey bees show preferences for some cultivars over others. Removing all weeds and other non-target plants is also imperative to minimise the risk that the honey bees will be distracted from target trees. Where there are more attractive sources of foraging than apple blossom, beekeepers may have to place hives in small numbers around orchards rather than in fewer larger groupings. Canola crops, for instance, are far more attractive to bees than apples.

Availability of bees for pollination

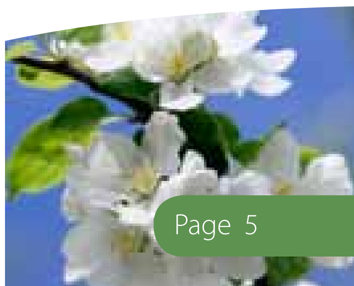
On the face of it, the apple blossom season coinciding as it does with a period when beekeepers with a prime focus on honey production may be looking for floral resources to build up the condition of their hives prior to the main spring and summer honey flows, should mean that the beekeeper and the orchardist have interests that are highly complementary. It is important however that orchardists understand that when considered in detail these interests may in fact be competitive.

To achieve the improvement in colony strength that a beekeeper seeks, optimal hive densities may be only one per hectare or lower whilst the density required to ensure optimal pollination may be two to three hives per hectare or higher. At such a high stocking rates bees are unlikely to store any excess honey. A financial incentive may therefore necessary to induce beekeepers to put hives in orchards.

Rates of $25 per hive (Tasmania, 1989); $64 per hive (WA, 1993); $64 per hive (WA, 1994) have been seen. The Western Australian prices quoted were for several varieties of apple flowering over an extended period or running into the flowering periods of other fruits such as cherries whilst that for Tasmania the price was for a period of a few weeks to cover the flowering of a single apple variety.

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 apples 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.



Risks

Pesticides: 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

Temperature and rainfall have a marked effect on honey bee activity. Bee activity is very limited below temperatures of 13oC, with activity increasing up to around 19oC, 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. Under rainy conditions bees fly between showers but only usually for very short distances. Wind, particularly strong wind, tends to reduce the ground speed of bees and hence reduces the number of flights per day.

Colony strength will also have a direct bearing on the temperature at which honey bees will leave the hive. Only strong colonies will fly at lower temperatures. Bees need to keep their brood nests within their hives at a constant temperature of 37oC. The cooler the external temperature, the more the bees are required within the hive to maintain that temperature. Hence if the colony is strong in numbers the surplus bees not required for maintaining hive temperature are available for foraging duties.

Environmental factors have been shown to have a direct bearing on the amount of nectar secreted by flowers. Concentration of nectar can fluctuate widely in accordance with the relative humidity throughout the day. As honey bees are attracted to nectar, number of honey bees that visit the blossom may vary throughout the day. Bees may have a preference for old flowers about to wither as nectar has been found to be most concentrated in these flowers.

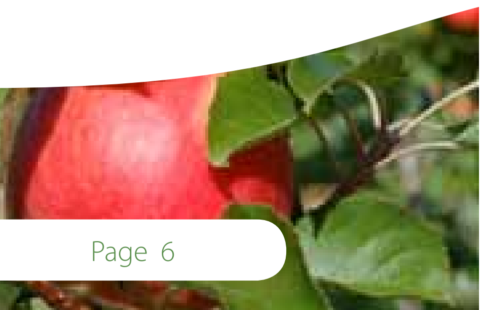
Alternatives

The relatively extensive nature of apple production, the highly seasonal nature of the flowering of apples and the intensity of pollination required to ensure optimal commercial outputs mean that there is no realistic alternative to pollination by honey bees, whether biological or mechanical, available to the apple industry in Australia.

Opportunities for improvement

As with so many aspects of agricultural and horticultural production in Australia the two key opportunities for improvement in managing pollination in apple orchards lie in:

- improved awareness of the importance and the mechanics of pollination in commercial apple production to allow management decisions that might affect pollination outcomes to be made on an informed basis. To be most effective this improved awareness should extend to all those involved in the management and conduct of the pollination process including the orchardist, the beekeeper and their employees.
- the application of modern technologies such as computer-modelling and global positioning systems to assist in the more precise and timely implementation, monitoring and review of informed management decisions.



Potential pollination service requirement for apples in Australia

Optimal use of managed pollination services in all apple orchards in Australia would require a service capacity as indicated in Table 4 below.

Table 4 **Potential pollination service requirement for apples in Australia**

State	Month (flowering)	Area (ha)	Average hive density (h/ha)*	Estimated number of hives required
VIC	October	4,279	3	12,837
NSW	October	2,455	3	7,365
QLD	September	1,571	3	4,713
WA	October	1,423	3	4,269
TAS	November	1,224	3	3,672
SA	October	1,306	3	3,918
Total		**12,258**		**36,774**

* Notes: Area sourced from ABS (2008), flowering times from Apple and Pear Australia Limited (2008) and average hive density from Somerville (1999)

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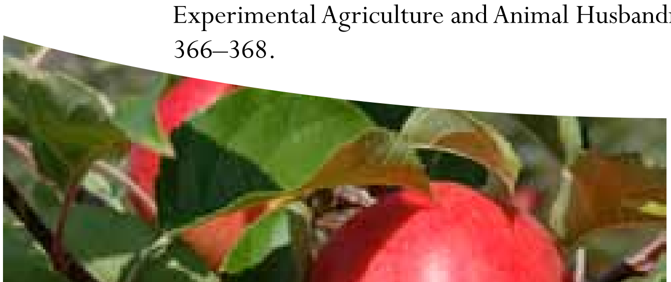
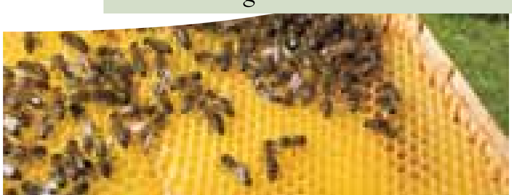
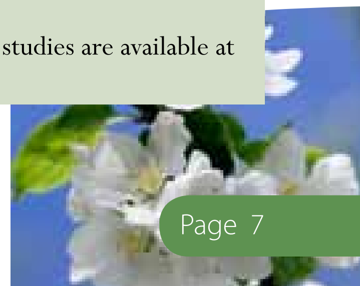
This case study was prepared as part of *Pollination Aware – The Real Value of Pollination in Australia*, by RC Keogh, APW Robinson and IJ Mullins, which consolidates the available information on pollination in Australia at a number of different levels: commodity/industry; regional/state; and national. 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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This project is part of the Pollination Program – a jointly funded partnership with the Rural Industries Research and Development Corporation (RIRDC), Horticulture Australia Limited (HAL) and the Australian Government Department of Agriculture, Fisheries and Forestry. The Pollination Program is managed by RIRDC and aims to secure the pollination of Australia's horticultural and agricultural crops into the future on a sustainable and profitable basis. Research and development in this program is conducted to raise awareness that will help protect pollination in Australia.

RIRDC funds for the program are provided by the Honeybee Research and Development Program, with industry levies matched by funds provided by the Australian Government. Funding from HAL for the program is from the apple and pear, almond, avocado, cherry, vegetable and summerfruit levies and voluntary contributions from the dried prune and melon industries, with matched funds from the Australian Government.

RIRDC Publication No 10/109

ISBN 978-1-74254-079-5