Pollination Aware

Citrus

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

Citrus is a common term and genus of flowering plants in the family Rutaceae, which originated in the world's tropical and subtropical regions, with many species thought to be native to China. The most well-known examples are the oranges (*C. sinensis*), mandarins (*C. reticulata*), grapefruit (*C. paradisi*), lemons (*C. limon*), Limes (*C. aurantifolia*), cumquats (*C. fortunella*) and tangelo (mandarin x grapefruit). These species most commonly form large shrubs or small trees, reaching 5 to15m tall, with spiny shoots and alternately arranged evergreen leaves with an entire margin. All varieties ripen slowly and can be stored on the tree to be harvested over months.

Many citrus fruits, such as oranges, tangerines, and grapefruits, are generally eaten fresh. They are typically peeled and can be easily split into segments. Grapefruit is more commonly halved and eaten out of the skin with a spoon. Orange and grapefruit juices are also very popular breakfast beverages. More astringent citrus, such as lemons and limes, are generally not eaten on their own, and are mainly used in cooking, beverages, and served with numerous dishes.

Over the last five decades, considerable research has improved production practices, resulting in ever-increasing yields and quality (Sanford 2003). All too often forgotten, however, has been study of the effects of pollination and pollination practices on citrus crops (Sanford 2003). Though many studies have tackled the issue of pollination in citrus crops, and there is good information available for growers, there remains much controversy surrounding the pollination potential of bees and management strategies required to ensure adequate pollination (Sanford 2003).

Citrus production in Australia

Citrus trees thrive in a consistently sunny, humid environment with fertile soil and adequate rainfall or irrigation. Australia's citrus growing industry is situated primarily along the Murrumbidgee and Murray Rivers, with over 90% of plantings in the Riverina, Sunraysia and Riverland irrigation areas of New South Wales, Victoria and South Australia, and the Central Burnett area of Queensland. There are also smaller plantings in Western Australia and the Northern Territory (CIAC 2002) (see also Figure 1). Total production of citrus reached almost 650,000 tonnes with New South Wales (40%) and South Australia (28%) making up the majority of national production (Table 1).

Table 1 Production of citrus (ABS 2008)

	NSW	NT	QLD	SA	VIC	WA	Total
Total citrus – production (t)	264,315	230	86,061	184,998	101,213	11,151	**647,969**
Total citrus – (ha)	5,296	51	1,845	2,617	1,791	476	**12,076**

*Total hectares of citrus trees calculated from total tree numbers data, at a rate of 1,000trees/ha.

Oranges (78%) and mandarins (12%) are the main citrus fruit grown in Australia with smaller areas of lemons, grapefruit and limes (Table 2).

Most fruit is grown for the fresh fruit market but a percentage of the orange crop is used for juice production. The Australian citrus industry is the largest fresh fruit exporter in the Australian horticultural industry (CA 2009). In 2002/03, record exports of 167,000 tonnes were achieved, with an estimated gross value production of $201 million (CA 2009). Australia can export high quality fresh navel oranges and mandarins when they are out of season in the northern hemisphere. This includes Asian markets where Australia also has a natural advantage of proximity (CA 2009).

Table 2 Percentage of different citrus produced in Australia (ABS 2008)

Fruit	Production (tonnes)	% of total production
Grapefruit	12,576	2
Lemons and limes	26,833	4
Mandarins	75,135	12
Oranges	507,232	78
Other citrus	**26,192**	**4**
Total citrus	**647,968**	**100**

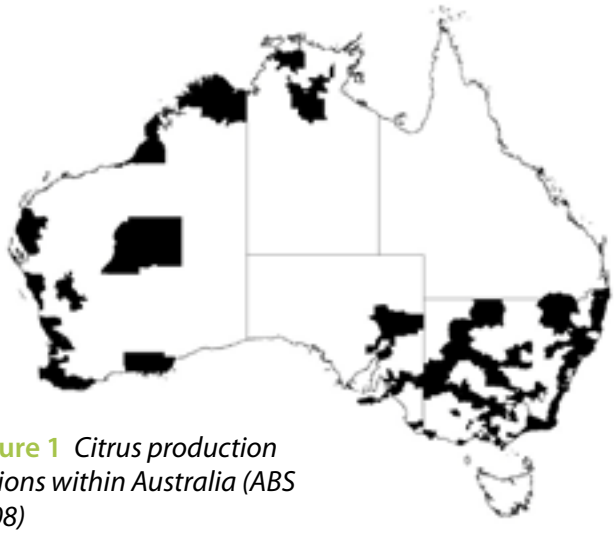
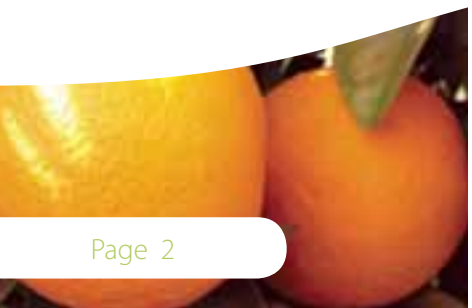


Figure 1 *Citrus production regions within Australia (ABS 2008)*



Pollination in citrus

The pollination requirements for citrus are quite diverse (Sanford 2003; McGregor 1976), ranging from self-fertile (Valencia oranges) to almost complete self-sterile (mandarin and mandarin-hybrid complex**)**. Pollen must be transferred to these self-sterile or partially self-sterile flowers from those of another compatible type for maximum fruit production (Sanford 2003). In others (Washington navel oranges), the plant is benefited if pollen is moved from flower to flower within the cultivar or within the species (Sanford 2003), and finally others such as lemons, have no known benefit from transfer of foreign pollen to the stigma (Sanford 2003; McGregor 1976).

The literature contains conflicting reports on the need for bees in some citrus varieties and therefore it is difficult to make generalisations regarding the responsiveness of citrus crops to honey bee pollination. Factors such as the variety, conditions at the site and honey bee pollination may all contribute or alternatively, have no effect in increasing yields, fruit size and seed number. Some have suggested as citrus flowers have both male and female parts on the same flower (complete or perfect flowers) that they will generally pollinate themselves and produce fruit (i.e. they are self-compatible and self-fruitful). There are, however, a few special cases with tangelo and tangerines where a pollinator is required for good fruit set. Citrus trees produce an abundance of flowers. Citrus has a natural tendency to drop its fruit, and most of the fruit set at bloom will not hold on until maturity. A good crop may be borne if only 3–7% of the flowers that are set yield mature fruit.

Several studies have shown increased fruit set and resultant production when using managed honey bee colonies for pollination services (Sanford 2003). Butcher (1960) found that honey bee foraging on Minneola tangelo increased fruit set, with optimal fruit set occurring at 60–90m from a group of honey bee colonies (Table 3).

Some growers of seedless cultivars readily discourage honey bee pollination as seedless fruits are often more sought-after, demanding higher retail prices in comparison to seeded varieties. Conflicting situations can occur when beekeepers (who prize orange blossom honey) and citrus growers (who blame the bees for causing otherwise seedless mandarins and oranges to develop pips) are operating in close proximity (CA 2009; McGregor 1976).

It is difficult to issue hard and fast recommendations about citrus pollination for a number of reasons. There exist a number of citrus varieties and more are being developed all the time. Each has its own characteristics that must be addressed in order to assure adequate pollination. Recommendations for grapefruit will differ from limes which will differ from oranges. In addition, a good many variables exist under field conditions which often do not mirror those of controlled experiments (Sanford 2003).

Table 3 Effect of bee pollination on Minneola tangelo fruit set (Butcher 1960)

Distance from hives (metres)	Number of trees in zone	Average number fruit per tree	Number of trees with 10 or more fruit
0–30	25	4.1	3
30–60	59	7.8	20
60–90	46	12.3	21
90–120	50	9.5	17
120–150	47	5.9	9

Pollination management for citrus 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*: The standard spacing for citrus is 7.3m between the rows and 5.5m between the trees in the row (QLD.DPI 2009). For oranges, lemons, grapefruit and Ellendale mandarins, tree spacing within the rows can be reduced to 3.6m but alternate trees will have to be removed later (QLD.DPI 2009). A close-planting alternative for high-density planting is the double-row system (QLD.DPI 2009). This has double rows planted 2.4m apart with 7.3m between the centres of each double row (centre of double row to centre of double row) (QLD.DPI 2009).
- *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

The pollination requirements for citrus are quite diverse (Sanford 2003; McGregor 1976), ranging from self-fertile (Valencia oranges) to almost complete self-sterile (mandarin and mandarin-hybrid complex**)**. Thus in orchards containing these self-sterile species it is vital that sufficient numbers of pollinisers are incorporated into the orchard's layout in order to gain optimal cross-pollination and thus fruit set.

Density of bees

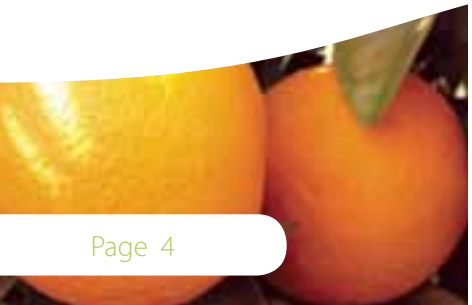
It is difficult to issue hard and fast recommendations about citrus pollination for a number of reasons. A large number of citrus varieties already exist and even more are being developed all the time. Each has its own characteristics that must be addressed in order to assure adequate pollination. Recommendations for grapefruit will differ from limes which will differ from oranges. So too will recommendations for the number of hives per hectare needed for efficient pollination of flowers. As such, a conservative estimate of one hive per hectare has been applied in this case when predicting the demand for honey bee pollination services in Australia, although recommendations may more commonly be 1–4 hives/ha (McGregor 1976).

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

To maximise the likelihood that bees will forage on the citrus flowers, and thus transfer pollen, hives should be in the orchard when roughly 5–10% of the flowers have blossomed. Such a delay will encourage bees to focus on the target trees rather than learn to visit competing plants.



Citrus

Preparation of bees

For a hive to be able to adequately pollinate fruit blossom, it must be above certain strength in bee numbers. Strong colonies should go into citrus to maximise pollination efficiency, although considering the flowers are a good source of carbohydrate for bees, the bloom may also be used to 'build up' honey bee colonies.

Attractiveness, nutritional value of pollen and nectar

Honey bees collect both pollen (if it is produced) and nectar from citrus. The flower is so constructed that if the bee has visited a previous pollen-producing flower, some pollen is likely to be transferred to the next stigma visited (CA 2009; Sanford 2003).

In the USA, the nectar flow of citrus is more abundant than that from any other source and is actually considered a nuisance to grove workers in California. Over 25% of California's honey production is attributed to the citrus flow thus there is considerable effort to time pest-control spraying to avoid adverse effects on honey bees during the period of nectar gathering.

Availability of bees for pollination

Beekeepers readily place their colonies near citrus groves for the delicious honey the bees store and citrus specialists frequently intimate that an ample supply of bees is always in the groves. Citrus nectar is eagerly sought by honey bees and the delicious, light-coloured honey is widely favoured, though it darkens and granulates within a few months. Thus beekeepers and citrus growers may have a mutually beneficial situation as sufficient honey is produced as a result of honey bee foraging, resulting in increased cross-pollination between trees, resulting in increased fruit set, hence increased revenue.

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 citrus 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 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.

Potential pollination service requirement for citrus in Australia

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

Table 4 Potential pollination service requirement for citrus in Australia

State	Peak month	Area (ha)	Average hive density (h/ha)	Estimated number of hives required
NSW	November	5,296	1	5,296
NT	November	51	1	51
QLD	November	1,845	1	1,845
SA	November	2,617	1	2,617
VIC	November	1,791	1	1,791
WA	November	476	1	476
Total		**12,076**		**12,076**

Notes: Area sourced from ABS (2008) *Agricultural Commodities Small Area Data, Australia 2005-06*flowering times and average hive density estimated from 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.

Australian Government

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Know-how for Horticulture™

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.

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