The kiwifruit (Actinidia deliciosa) is a large, woody, deciduous vine native to the Yangtze Valley of China. Also known as the ‘Chinese gooseberry’, the fruit was renamed for export and marketing reasons in the 1950s; briefly to ‘melonette’, and then by New Zealand exporters to ‘kiwifruit’. Seeds from China were taken to New Zealand and planted in 1906 and since then production of the fruit has grown significantly. Kiwifruit have an oval shape, typically the size of a large hen’s egg, and a fibrous, dull brown-green skin, and bright green or golden flesh with rows of tiny, black, edible seeds. With the soft texture and a unique flavor of the fruit, today it has become a commercial crop in several countries.

Approximately 700,000 tonnes of kiwifruit enter world trade each year, with the major producers being Italy (35%), New Zealand (32%) and Chile (15%). Kiwifruit is also an important horticultural crop in Australia, where it is produced primarily for the domestic market.

Whenever it is grown, kiwifruit still experiences production problems associated with pollination, resulting in poor fruit set and fruit size/quality (Howpage et al. 2001). Research into alleviating these problems is largely based on the use of managed honey bee pollination services, which has shown significant potential in Australia and abroad.

Kiwifruit production in Australia

Kiwifruit can be grown in most temperate climates with adequate summer heat, commonly grown on sturdy support structures, and producing several tonnes per hectare. Kiwifruit vines require vigorous pruning, similar to that of grapevines. Fruit is borne on one-year-old and older canes, but production declines as each cane ages.

Kiwifruit are produced across Australia; however, the majority of production occurs in Victoria (60%) and New South Wales (20%) (Table 1). The areas of Goulburn, Ovens and Murray in north-eastern and central Victoria are the major kiwifruit producing regions, providing favourable soil and climatic conditions for cultivation (Figure 1). Australia produces kiwifruit exclusively for the domestic market, with imports from New Zealand and Italy making up for shortages in supply.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Kiwifruit production by state across Australia (ABS 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NSW</td>
</tr>
<tr>
<td>Kiwifruit – production (tonnes)</td>
<td>365</td>
</tr>
<tr>
<td>Kiwifruit – total area (ha)</td>
<td>66</td>
</tr>
</tbody>
</table>
Pollination in kiwifruit

A kiwifruit vine produces either male or female flowers. Therefore, the dioecious nature of the crop dictates the need for the planting of both male and female vines in the field for pollination, which entirely depends on vectors such as honey bees and wind. Kiwifruit produces no nectar and requires a high level of pollen transfer to produce a properly sized and shaped fruit. A well-pollinated kiwifruit contains 1,000–1,400 seeds. By contrast, a well-pollinated apple contains 6–7 seeds (Howpage et al. 2001).

The relative importance of honey bees and wind in kiwifruit pollination is unclear, although several researchers have demonstrated the value of honey bee foraging of kiwifruit production. Vaissiere et al. (1996) found that fruits from bee-visited flowers showed a significantly higher number of seeds compared to those from control flowers, and demonstrated that honey bees are effective pollinators of kiwifruit. Furthermore, Howpage et al. (2001) found that vines that had no access to honey bees had significantly lower fruit set compared to those vines open to honey bee foraging (Table 2). Honey bee pollination was also found to significantly increase the mean number of fruit in higher weight classes, resulting in more marketable highly sought-after product for growers (Howpage et al. 2001). These results show that honey bees were responsible for higher fruit set, increased yields, and larger fruit with higher seed numbers in kiwifruit. Honey bee hive densities of 30hives/ha (bee saturation) had no significant effect on kiwifruit production and resulting weights of fruit (Table 2).

While this evidence demonstrates that adequate pollination will help ensure adequate seed formation and reduce the incidence of deformed fruits, 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 (Howpage et al. 2001).

### Table 2 Effect of different honey bee pollination treatment on number of kiwifruit and fruit weights (Howpage et al. 2001)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean number of fruit/vine</th>
<th>Mean number of fruit in each weight group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;50g</td>
</tr>
<tr>
<td>Supplementary pollination (6 hives/ha)</td>
<td>168.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Bee saturation (30 hives/ha)</td>
<td>159.6</td>
<td>3</td>
</tr>
<tr>
<td>No bee pollination</td>
<td>50.3</td>
<td>17.5</td>
</tr>
</tbody>
</table>
Pollination management for kiwifruit 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**

*Vine and blossom density:* A generally used spacing has been vines placed 5.5–6m apart with rows being 4.5 m apart. It is also common to have vines planted in rows, with a 3 x 5m spacing on a T-bar trellis system with a polliniser in every sixth position (i.e. planting ratio of male to female vines of 1:5) (Howpage et al. 2001).

*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**

Distribution of male flowers is an important part of plantation management. For small, single-row plantings, one male vine to every five females is necessary. In commercial plantings, 10–12% of the vines must be males, that is, about one male for every eight or nine female vines, and the males should be staggered evenly throughout the block plantations (Vaissiere et al. 1996). Up to 13% of the orchard canopy in commercial blocks in New Zealand may consist of unfruitful males vines, necessary as pollinisers (McNeilage and Steinhagen 1998).

**Density of bees**

It has been demonstrated that a stocking rate of six hives per hectare gives sufficient pollination of kiwifruit, resulting in significant increase in revenue for the grower (Howpage et al. 2001). A saturation treatment (30 hives/ha) used by Howpage et al. (2001) showed no significant improvement on fruit set, or resulting fruit weight when compared to a stocking rate of six hives/ha.

**Arrangement of hives**

To maximise the pollinating potential of honey bees while they are in the crop, the placement of hives is a very important factor to consider. For example, it has been shown that bees prefer to forage within 100m of their hives and so hives should not be placed greater than this distance apart. In addition, hives should be placed off the ground and in sunny locations away from the wind whenever possible and kept away from moisture-laden low lying areas. These measures will help to ensure that honey bee foraging is maximised for the best pollination outcome (Somerville 2007).

**Timing**

The overlap of male and female flowering times is important for ensuring sufficient pollination leading to fruit set. The time of flowering must be ascertained so that the flowering of male and female plants will coincide. It is recommended that there be eight hives per hectare when 10–15% of the flowers are open to ensure honey bees are foraging on the target bloom and thus maximising pollination services for the grower.

**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 colder months 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 substrates, 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 kiwifruit. 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
Kiwifruit flowers have no nectar to attract honey bees although both female and male flowers have pollen which is attractive to foraging honey bees (Goodwin 1987). Supplementation of colonies in a kiwifruit orchard doubled the amount of kiwifruit pollen collected when they were fed sugar syrup (Goodwin 1987). This resulted from an increase in the number of foragers visiting kiwifruit flowers rather than an increase in the length of time the flowers were visited during the day (Goodwin 1987).

Availability of bees for pollination
The kiwifruit blossom season coinciding as it does with a period when beekeepers have a prime focus on honey production should mean that the beekeeper and the orchardist may have interests that are highly conflicting. The beekeeper will be looking for floral resources to build up the condition of their hives prior to the main spring and summer honey flows, and therefore a financial incentive would be necessary to encourage beekeepers to put hives in kiwifruit orchards.

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 kiwifruit flowers 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.

Alternatives
In anticipation of a shortage of hives for expanding culture, work was begun in New Zealand about 1980 to perfect means of collecting and drying pollen and preparing a suspension for spraying onto the blooming vines by tractor-drawn equipment. Pollen is commercially available in California also for artificial pollination.
Potential pollination service requirement for kiwifruit in Australia

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

### Table 3: Potential pollination service requirement for kiwifruit in Australia (ABA 2008)

<table>
<thead>
<tr>
<th>State</th>
<th>Peak month</th>
<th>Area (ha) total</th>
<th>Average hive density (h/ha)*</th>
<th>Estimated number of hives required</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIC</td>
<td>October</td>
<td>183</td>
<td>6</td>
<td>1,098</td>
</tr>
<tr>
<td>NSW</td>
<td>October</td>
<td>66</td>
<td>6</td>
<td>396</td>
</tr>
<tr>
<td>QLD</td>
<td>October</td>
<td>37</td>
<td>6</td>
<td>222</td>
</tr>
<tr>
<td>WA</td>
<td>October</td>
<td>15</td>
<td>6</td>
<td>90</td>
</tr>
<tr>
<td>SA</td>
<td>October</td>
<td>8</td>
<td>6</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>309</td>
<td></td>
<td>1,854</td>
</tr>
</tbody>
</table>

Notes: *Area sourced from ABS 2008 Agricultural Commodities Small Area Data, Australia 2005-06, flowering times DAF (2005) and average hive density from Howpage et al. (2001).
References


GOODWIN, R.M. 1987. Ecology of honey bee (Apis mellifera L.) pollination of kiwifruit (Actinida deliciosa (A. Chev.)). PhD, University of Auckland


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.
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.