Strawberries

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

Strawberries (*Fragaria ananassa*) were first grown in Brittany and France around 1740 via a cross of *Fragaria virginiana* from eastern North America, which was noted for its flavour and *Fragaria chiloensis* from Chile which was noted for its large size. Strawberries are now widely cultivated across the world and in addition to being consumed fresh, can be frozen, made into preserves, as well as dried and used in confectionary. Strawberries are also a popular addition to dairy products, while strawberry pigment extract can be used as a natural acid/base indicator due to the different color of the conjugate acid and conjugate base of the pigment.

The strawberry plant is a stemless, low-creeping, and usually perennial herb that may live for many years although it is sometimes grown annually. Some cultivars are evergreen and others tend to be deciduous, depending on the area in which they are grown. The trifoliate leaves form a blanket cover of the ground and range from 0.1 to 0.8m deep which shelters the fruit. The creeping runners occasionally produce roots and inflorescences at the leaf bases. The ripe fruit is 2.5–5cm long and light to dark red when ripe (McGregor 1976).

The weight of the strawberry fruit is roughly proportional to the number of fertilised ovules around the receptacle (Nitsch 1952, as cited in Goodman and Oldroyd 1988). Several studies of the pollination requirements of strawberries have been conducted outside Australia, both in the USA (Hughes 1961; Moore 1969; Conner and Martin 1973; all as cited in Goodman and Oldroyd 1988) and in Great Britain (Free 1968, as cited in Goodman and Oldroyd 1988). These studies have generally shown that fruit quality (as assessed by individual fruit weight and shape) rather than numbers of fruit harvested, are improved by insect pollination (Goodman and Oldroyd 1988).

Strawberry production in Australia

Strawberries can be grown all year round in Australia and most states have strawberry producing industries (Table 1). Traditionally, production has been concentrated in the warmer months (October to May); however, growing seasons can be extended in temperate climates through the use of different varieties and planting techniques. The diversity of the Australian climate also enables June to September production in warmer or subtropical climates such as areas of Queensland and Western Australia. Production is concentrated in coastal regions, namely the Sunshine Coast area of Queensland, the Camden region of New South Wales, the Yarra Valley region in Victoria, the Adelaide Hills in South Australia, and Wanneroo and Albany in Western Australia (SAI 2009) (see also Figure 1).
The short-term fruiting cycle of strawberries allows some growers to grow strawberry crops intermittently with other short-term crops, such as vegetables. For example, in Queensland there is a core group of 250 known regular growers, while 60–100 growers enter and leave the industry over short periods. On the world scale, Australia was the 28th largest strawberry producer by volume in 2002, with the USA, Spain and Japan the top three respectively. However, Australia ranks higher (17th) in production efficiency, producing an estimated 21t/ha in 2002. World leaders in production efficiency are the USA, Israel and Spain, with 46, 42.5 and 42t/ha estimated for 2002 respectively. The Australian strawberry industry as a whole is focused on the domestic fresh fruit market; however, exports do occur on a largely opportunistic basis. Imports of fresh fruit have declined to almost negligible levels in recent years, although there are significant imports of processed strawberry products (SAI 2009).

Table 1  Production of strawberries by state (ABS 2008)

<table>
<thead>
<tr>
<th></th>
<th>NSW</th>
<th>QLD</th>
<th>SA</th>
<th>TAS</th>
<th>VIC</th>
<th>WA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production per state (tonnes)</td>
<td>320</td>
<td>12,670</td>
<td>1,340</td>
<td>327</td>
<td>6,788</td>
<td>3,001</td>
<td>24,446</td>
</tr>
<tr>
<td>Percentage production per state (%)</td>
<td>1.3</td>
<td>51.7</td>
<td>5.5</td>
<td>1.3</td>
<td>27.7</td>
<td>12.5</td>
<td>100</td>
</tr>
</tbody>
</table>
Pollination in strawberries

The strawberry unlike many other fruits is an aggregate of achenes that accumulates sugars and vitamins and ripens like a true, fleshy fruit (McGregor 1976). The strawberry has the peculiarity of producing flowers with different potentials depending upon their rank in the floral hierarchy. This hierarchy allows the prediction of the chronological sequence of flowering, the number of pistils per flower and thus the relative size of the strawberries. The primary flower bears about 350 stigmata, the secondary ones about 260, and the tertiary ones about 180. Nitsch (1950, as cited in McGregor 1976) showed that the weight of a berry is directly proportional to the number of fertilised achenes. These achenes, resulting from fertilised ovules, are large and surrounded by well-developed fleshy tissue, whereas the achenes resulting from unfertilised ovules are less voluminous and closer together (Chagnon et al. 1989).

Strawberry flowers are hermaphroditic (having both male and female reproductive organs) and self-fertile and 80% of fruit production is due to abiotic factors such as gravity and wind; however, pollinating insects play an essential role in obtaining maximum fruit set as well as reducing deformities (Chagnon et al. 1989). Many different types of insects visit strawberry flowers, including flies, beetles, thrips, butterflies and various bees; however, only the bees, especially the honey bee (Apis mellifera L) have been shown to be the most efficient in transferring pollen effectively without injuring flower parts. Free (1968, as cited in McGregor 1976) found that although bees sometimes landed on the petals of a flower and approached the nectary from the side, they nearly always proceeded to walk over the stigmas.

There have been a great number of studies over a long period of time showing the benefits of introducing honey bees to the fruit set and quality of strawberries. Several authors have shown the benefits of honey bee foraging behaviour to strawberry production in greenhouses including Petkov (1963, as cited in McGregor 1976) who found that when flowers were isolated from bees only 31 to 39% developed fruit, as compared with fruit developing on 55 to 60% of flowers open to bees. Furthermore, the isolated flowers developed 60 to 65% culls compared to 14 to 17% culls from flowers visited by bees and the average weight of fruit developed from flowers visited by bees was approximately two-thirds greater than isolated flowers (McGregor 1976). The results of a study conducted by Kakutani et al. (1993) given in Table 2 show a comparison between Trigona minangkabau, a Japanese native stingless bee, and Apis mellifera, the European honey bee, as pollinators of strawberry. This data shows that one visit of the honey bee pollinated 11% of achenes and one visit of the stingless bee pollinated 4.7% on average and that 11 visits of the honey bee or 30 visits of the stingless bee are required per flower to attain normal berries (fertilisation rate, 87%). In this study, the rate of deformed berries in the stingless bee area (73%) was also higher than that of the honey bee area (51%).

Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Native bee (Trigona minangkabau)</th>
<th>Honey bee (Apis mellifera)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of visitations required for normal pollination</td>
<td>30</td>
<td>11</td>
</tr>
<tr>
<td>Pollination efficiency (%)</td>
<td>4.7</td>
<td>11</td>
</tr>
<tr>
<td>Deformed fruit (%)</td>
<td>73</td>
<td>51</td>
</tr>
</tbody>
</table>
Pollination management for strawberries in Australia

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

**Crop layout**

- **Plant and blossom density**: The bulk cultivation of strawberries for commercial uses follows the plasticulture system of cultivation. In this method, strawberries are planted on raised mounts of soil known as beds. The beds prepared to plant strawberries are covered by using black plastic, known as a weed blocker, to prevent weeds and erosion from the farm. Density of plants in Australia will typically be between 40,000 and 45,000 plants per hectare for a good crop (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).

**Density of bees**

Strawberry flowers need 10–16 honey bee visits to be effectively pollinated and if feral bees are not in a high enough concentration then hives need to be brought in from an outside source. Many growers will use what is referred to as 'saturation pollination' where there are a larger number of hives per unit of space. The reason for this is that honey bees show preference for some cultivars over others; however, they are generally not overly attracted to strawberries and may be drawn to pollinate other flora with more attractive nectar and pollen. Overstocking of hives thus removes competing pollen and nectar. From 12 to 25 hives/hectare may be required for a commercial grower who is aiming for the best quality and quantity of strawberries (McGregor 1976).

**Timing**

Strawberry flowers have been noted by Moore (1964, as cited by McGregor 1976) as being receptive to pollination for around seven days after opening, but the number of seeds per berry is reduced in late-pollinated flowers. Conner (1970, as cited in McGregor 1976) reported that many flowers were dried and shrunken on the second day after opening. The best time for pollination seems to be during the first one to four days after opening and the reaction to pollination is rapid, within 24 to 48 hours the petals fall off and the pistils dry up. Skrebtsova (1958, as cited in McGregor 1976) found that flowers pollinated at the most receptive time, the time of fullest development of the reproduction organs, produced berries 13–58% heavier than those pollinated before or after this time.

**Preparation of bees/attraction, nutritional value of pollen and nectar**

The strawberry plant does produce pollen and nectar; however, very little nectar is produced in protected cultures (greenhouses) compared to outdoor cultures. Furthermore the nectar produced by the strawberry flower from protected cultures is not always sufficient for the optimal development of a honey bee population. There is very little information with regard to sugar and protein attributes of strawberry nectar and pollen for honey bees; however, for a hive to be able to adequately pollinate fruit blossom, it must be above certain strength in bee numbers. For this reason it would be wise for the grower to provide sugar water and pollen supplements and substitutes both prior to and during the strawberry pollination campaign.
Strawberries

Availability of bees for pollination
If taken into consideration that strawberries can be grown all year round in Australia and in most states coupled with the high number of hives per hectare required to produce fruit of acceptable standard for the market then it is quite obvious that a significant number of hives are required for each crop cycle. Given that the nectar and pollen of strawberry flowers are not overly attractive to honey bees nor does it produce a marketable honey, it is easy to see that the interests of the grower and beekeepers may be conflicting, and as in many other situations monetary incentive may be the only reason for beekeepers to pollinate strawberry crops.

Feral bees
Relying on feral bees to provide pollination services is probably not feasible if the grower wishes to achieve optimal production quality and quantity. Feral bees may not be at sufficient strength at the time of flowering, and even if they were they would most likely not be at a sufficient density to achieve the level of pollination required especially if there are more attractive nectar and pollen sources nearby.

Risks
Pesticides: One of the biggest drawbacks of placing bees near any 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. Under rainy conditions bees fly between showers but only usually for very short distances. Wind, particularly strong wind, reduces 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 bees will leave the hive. Only strong colonies will leave the hive at low temperatures.

Alternatives
A major problem in using honey bees for pollination of strawberry in greenhouses is that colonies frequently crash due to the death of workers and low foraging efficiency. Foraging range of the honey bee is much larger than the size of most greenhouses and the bees can fly upward to a height of several dozen meters at onset of foraging. Due to these foraging habits, a large portion of the bees can become trapped at a greenhouse ceiling and die. Several other different insects can be used to pollinate strawberries, all with varying success and all which have their own management issues. One alternative could be to use the native Australian stingless bee (Trigona) which may have smaller foraging range suitable for greenhouses. Such an alternative was proven to be successful in Japan in a study conducted by Kakutani et al. (1993). The study found that the native Trigona species was much more suited to greenhouses and farmers could still be profitable.
Potential pollination service requirement for strawberries in Australia

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

<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>February</td>
<td>458</td>
<td>18</td>
<td>8,244</td>
</tr>
<tr>
<td>NSW</td>
<td>January</td>
<td>52</td>
<td>18</td>
<td>936</td>
</tr>
<tr>
<td>QLD</td>
<td>August</td>
<td>695</td>
<td>18</td>
<td>12,510</td>
</tr>
<tr>
<td>WA</td>
<td>September</td>
<td>142</td>
<td>18</td>
<td>2,556</td>
</tr>
<tr>
<td>TAS</td>
<td>January</td>
<td>23</td>
<td>18</td>
<td>414</td>
</tr>
<tr>
<td>SA</td>
<td>January</td>
<td>90</td>
<td>18</td>
<td>1,620</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,460</td>
<td>18</td>
<td>26,280</td>
</tr>
</tbody>
</table>

Notes: Area sourced (ABS 2008), flowering times from SAI (2009) and average hive density from McGregor (1976).

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.
References


Notes
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 10/139