

Soybean

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 soybean (*Glycine max*) is a species of legume native to East Asia. The plant is classed as an oilseed and is an annual plant that has been used in China for over 5,000 years as a food and a component of pharmaceuticals. Upon crushing the seed there are two primary products, oil and meal. Soybean oil is primarily consumed as table oil, or processed further into products like margarine and mayonnaise. Similarly it can be used in the preparation of paint, lacquer, soy diesel, ink and soap. Meal is the remains of the crushed seed, accounting for approximately 80% of the seed, and used predominantly in compound feed. Soybean products are now a fundamental component of the diets of over 16% of the global population (PIBA 2001).

The soybean is a bushy, upright, annual, summer legume ranging in height from 0.3 to 1.2m with dense, alternate and usually trifoliate oval leaves, which are 5–10cm across. There are many different cultivars that are bred for production under different environmental conditions and their time till maturity ranges from 75 to 200 days (McGregor 1976). Although soybean is generally considered a self-pollinating species, yield increases of about 10 to 40% have been demonstrated when comparing honey-bee-pollinated vs. self-pollinated plants (Erickson et al. 1978). Further, honey bees can produce substantial honey crops when they visit soybeans flowers (Erickson et al. 1978).

Soybean production in Australia

Soybean production is dominated by the USA, China and Brazil. Australia remains a relatively small player in the market in both production and consumption, yet both are increasing. Oil seed production in Australia is approximately 6% of annual global grain production and of this, production is largely dominated by canola (PIBA 2001). Traditionally, production of soybean was relatively constrained by available area; however, research and plant breeding have enabled production to succeed in areas not typically suited for soybeans with target areas for further growth including northern and southern New South Wales, northern Victoria and southern Queensland (Figure 1).

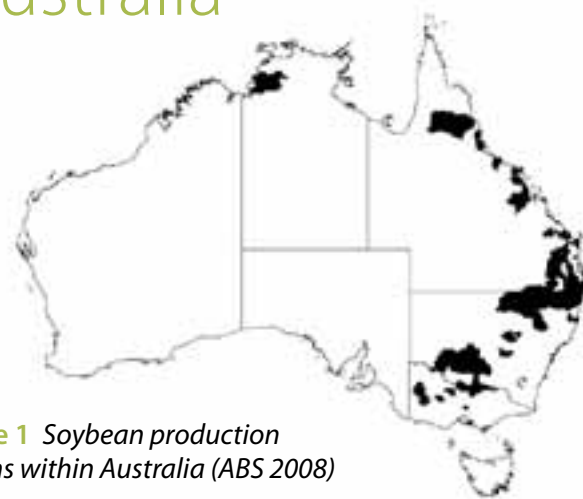


Figure 1 Soybean production regions within Australia (ABS 2008)



Area planted for soybean has risen from 23,700 hectares in 1993/1994 to 53,100 hectares in 1999/2000. During this time yield as a function of season has varied, with the average at 1.88tonnes/ha. Recent data from the Australian Bureau of Statistics shows production for three years ending at 2007/08 (Table 1) (AOF 2009).

Australia remains a net importer of soybeans and soy value-added products. During 1999/2000 the value of imports was estimated to be \$67 million. Taking oil and other products into consideration, the whole market was estimated to be worth over \$100 million per annum which has no doubt grown in subsequent years. Australian producers may be hesitant to move into soybean production due to price differentials for beans for human consumption as opposed to those for

stock feed (PIBA 2001). Key global producers such as the USA are geared towards production of beans for stock feed rather than varieties suitable for human consumption (AOF 2009).

Table 1 Domestic production of soybean per state (AOF 2009)

Production of soybean (tonnes)	2007/08	2006/07	2005/06
QLD	20,000	10,000	15,000
NSW	15,000	20,000	40,000
VIC	0	0	1,000
Total	35,000	30,000	56,000

Pollination in soybeans

The soybean inflorescence may contain 1–35 purple or white florets, 1cm long, on each short raceme or flower cluster. Each plant may have up to 800 florets and each floret is capable of producing a bean pod usually containing four seeds, however only around 13–57% of florets will set. Flowering usually continues for four to six weeks and there may be half a million florets per acre (McGregor 1976).

Soybean has generally been considered to be a self-pollinating species; however, Erickson et al. (1978) comment on how few published data sets are available to support this hypothesis and remark on how bees have been seen to extensively visit certain varieties of soybean. Even though the quantity of nectar produced by each flower is small, the flower density is high and the areas under crop, in the USA at least are generally big, making it a good food

source for bees. Yield increases of between 10% to 40% have been recorded in soybean when comparing honey-bee-pollinated plants against self-pollinated plants (Robacker et al. 1983) whilst cage exclusions trials have shown up to 15% increase in production (Erickson et al. 1978) (Table 2).

Table 2 Honey bee pollination increases soybean yields (Erickson et al. 1978)

	Bees	No bees	Open Field
Threshed beans	664	577	813
Filled pods	332	276**	386
Total beans	782	643**	889

** Statistically significant decrease, $P < 0.01$.



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A more recent study by Chiari et al. (2005) also found that seed production was higher ($P = 0.0001$) in covered areas with honey bee colonies (50.64%) and uncovered areas (57.73%) than in covered areas without honey bee colonies; they concluded that honey bees were responsible for 95.5% of the pollination accomplished by insects (Table 3). The pod number in covered treatment with honey bees was also 61.38% higher ($P = 0.0002$) than in the covered treatment without honey bees (Chiari et al. 2005).

Soybean flowers, however, are not always attractive to honey bees, leading to the hypothesis that environmental conditions during growth and flowering of plants affect the development of flower characteristics (Robacker et al. 1983). In general, plants that grow in higher temperatures produce more nectar and are more attractive than those grown in cooler climates up to a maximum of

29°C. Erickson et al (1978) also observed that it was necessary to consider that the attraction of the soybean to honey bees was not the same for all varieties.

Table 3

Production of soybean with and without honey bee pollination (Chiari et al. 2005)

Treatment	Production/ ha (kg) \pm s.e.	Significance (P = 0.05)*
Uncovered area	3777.00 (\pm 141.43)	A
Covered area with honey bees	3607.17 (\pm 111.17)	A
Covered area without honey bees	2394.58 (\pm 65.00)	B

*Averages followed by different letters, in the same column, are different by Tukey's test ($P < 0.05$)

Pollination management for soybeans in Australia

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

row spacing, all-weather vehicle access may not be possible which may mean apiaries will need to be placed on the outside of the crop.

Crop layout

- *Row spacing and blossom density:* A single soybean plant may bear up to 800 florets. The crop is laid out in rows. For narrow rows (18–36cm), the optimum plant population is between 250,000 and 400,000 plants per hectare and for wider rows (75cm), 280,000 to 320,000 plants per hectare is optimal (NSW.DPI 2004).
- *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. Depending on

Density of bees

Soybean plants are mostly self-pollinating, however, insects (namely the honey bee) working the flowers has been shown to increase pod set in some cultivars (Erickson et al. 1978; Robacker et al. 1983; Chiari et al. 2005). There are limitations in the literature specifying the amount of hives per hectare required to achieve maximum yield of a soybean crop given that soybeans can have up to 800 florets on one plant alone. However, recommendations by the Department of Agriculture and Food in Western Australia (2005) suggest a hive density of 3–5 hives per hectare.



Timing

Flowering can last from four to six weeks; however, with the florets of soybeans the anthers dehisce before the flower opens so that the stigma is in contact with and receptive to the pollen on the anthers. Pollination and fertilisation can be accomplished before the flower opens. Bees should therefore be introduced with the onset of flowering to ensure the benefit of increased yield from the bees is realised (McGregor 1976).

Attractiveness, nutritional value of pollen and nectar

Soybean flowers possess many entomophilous characteristics, which depending on the cultivar and climatic conditions during growth and flowering will attract honey bees to varying degrees (Robacker et al. 1983).

Honey bees may produce substantial honey crops when visiting soybean flowers. Measurements taken by the Department of Agriculture and Food in Western Australia (2005) describe the nectar as watery and white with a mild to unpleasant taste and the pollen as a grey-brown colour. Measurements taken for a single variety showed total sugar content per flower was 50% and nectar production was 0.048 microlitres/flower/24hour period. Nectar has been shown to have 35–53% sucrose content (average 43.6%) (DAF 2005).

Availability of honey bees for pollination

Commercial beekeepers may profit from setting hives near monoculture soybean fields. In Tennessee, USA, for example, it has been reported that large quantities of surplus honey crops have been produced by bees working soybean fields (Sheriden and Collison 2005). As a marketable commodity, soybean honey ranks high among the nectar crops. Soybean honey is desirable in both taste and nutrition, and its high antioxidant content makes it an ideal preservative for use in the food industry. To the hobbyist beekeeper, soybean is a readily available and abundant source of nectar and pollen for their bees. It seems likely that it would be in the interest to both the growers and beekeepers to have hives in and surrounding a soybean crop.

Feral bees

Soybean growers relying on feral bees for part or all of their pollination services should be aware that pollination may be insufficient to obtain a maximum yield. However as soybean plants are mostly self-fertilising and pollination by bees has not been unequivocally shown to increase yield, most growers may see bringing in hives as unnecessary and costly. The benefits of honey bee pollination services should be publicised more readily, to inform growers of the potential yield increases resulting in higher profits.

Risks

Pesticides: Placing hives well back from the crop also may help the grower. If a crop needs spraying with pesticide the location of the hives is crucial. The further the beehives are placed away from the crop the better. If spraying is necessary, then this should be conducted in late afternoon or evening when foraging bees have ceased their foraging activities. One of the biggest dangers of placing bees near any agricultural crop is the possibility of colonies or field bees being sprayed by pesticides.

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.



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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, 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 37°C. 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 a direct bearing on the amount of nectar secreted. It has also been found that nectar is the most concentrated in old flowers about to wither, but nectar concentration fluctuates widely in accordance with the relative humidity throughout the day. The number of honey bees that visit the blossom has been directly correlated with the amount and concentration of nectar produced.

Alternatives/opportunities for improvement

Improved seed-set: Early studies from the 1920's noted how three crops in the USA when in flower were very fragrant and were more attractive to bees. This information indicates that cultivars might be selected with aroma or attractiveness that when incorporated in a hybrid seed program might efficiently attract pollinating insects. Because of the potential value of hybrid soybeans, the breeders might watch for selections that show attractiveness to bees (McGregor 1976).



Potential pollination service requirement for soybeans in Australia

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

Table 4 Potential pollination service requirement for soybeans in Australia

State	Peak month	Area (ha) total	Average hive density (h/ha)*	Estimated number of hives required
NSW	December	15,456	4	61,824
QLD	January	7,793	4	31,172
VIC	December	570	4	2,280
Total	-	23,819	-	95,276

Notes: Area sourced (ABS 2008), flowering times from AOF (2009) and average hive density from DAF (2005)

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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Notes





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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.

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