Buzz-bees and other pollinating insects can increase the yield of strawberry plants

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- Bees and other insects pollinate strawberry flowers and can increase production
- Further research is required to determine their importance across different growing areas in Australia

Summary

Insects and other animals pollinate the flowers of many plants. The importance of insect pollination on the performance of strawberry in 53 studies was reviewed. The yields of plants not exposed to insects and dependent on gravity or wind for pollination were only 0.65 of those exposed to insects under natural conditions (open pollination). In contrast, the yields of plants exposed to additional insects such as beehives were 1.34 times those exposed to insects under natural conditions (open pollination). Insect pollination was better than self-pollination using gravity and wind. Managed hives or additional wild bees were better than open pollination under natural conditions. Further experiments should be conducted to examine the importance of insect pollination in different cultivars and growing conditions. Management of pollination is likely to become more important in the future with the loss of pollinating insects under global warming.

Introduction

Insects and other animals are important for the pollination of many plants. About 75% of the main agricultural crops rely at least to some extent on pollination for growth, quality or seed production. Crops vary in their dependence upon animal pollinators. Some crops can only be pollinated by animals, whereas others can be partly self- or wind pollinated. Pollinators are responsible for 5% of crop yields in developed countries and 8% in developing countries.

Most pollinators are wild animals, including 20,000 species of bees. Bees are the most important pollinators in agriculture and visit 90% of the top 107 crops globally. About 12 managed pollinator species (all bees, including honeybees, bumble bees, solitary bees and stingless bees) are used in crop production. Flies are the second most common visitors to flowers, with over 120,000 species globally. Hover flies (Family Syrphidae with 6000 species) are especially important.

Most modern strawberry cultivars are hermaphrodites which means that they have both female and male parts in each flower. The flowers are also fertile, with the anthers releasing viable pollen. Cultivars are mostly self-compatible and do not require cross-pollination. Individual flowers can be fertilised by pollen released from within the flower through the assistance of gravity and wind. However, the arrangement of the stamens (male parts of the flowers) within the flower (often below the stigmas, female parts of the flowers) and the large number of stigmas in each flower (up to 500 or more per flower) can lead to inadequate fruit growth in the absence of pollinators. The role of pollinating insects in commercial production is unclear, with a range in the methods used across experiments and a range in the responses recorded.

Common pollinators visiting strawberry include the Western or European honeybee (*Apis mellifera*), the Eastern or Asian honeybee (*Apis cerana*), other Apis spp., bumble bees (especially *Bombus terrestris*), stingless bees and hoverflies (Family *Syrphidae*).

Calderone (2012) reported on the value of pollination for strawberry in the United States in 2010. The total value of the industry was US$2.245 billion, with pollination by honeybees contributing US$0.045 billion and pollination by other insects contributing US$0.404 billion. In other words, pollinating insects contributed to about 25% of the value of the industry in the United States. **Wild insects were more important than honeybees.** Lautenbach et al. (2012) indicated that the total value of pollination for strawberry in the top-ten producing countries was US$1.69 billion in 2009. Pollination is likely to become more important in the future with a decline in the abundance and diversity of pollinating insects under global warming and loss of habitats affecting both crop and wild plants.

Agricultural crops vary in their dependence on pollinators for high yields. The dependence on pollinators (pollinator dependence or PD) ranges from zero (independent of pollinators) to one (completely dependent of pollinators). Values of pollination dependence for strawberry range from 0.10 to 0.60 and mostly from 0.20 to 0.30. Most of the cited values are based on a few original reports and many of these do not include data on yield. It can be concluded that the relationship between productivity and pollination in strawberry is unclear. It is not known if values of pollination dependence vary with cultivar, growing location or growing system.

This article reviews the importance of pollination on the performance of strawberry. The main object of the study was to determine the relationship between productivity and insect pollination. The relationship between various indices of fertility and pollination was assessed by examining the performance of strawberry across 53 studies.

Gordon and Davis (2003) examined the importance of honeybee pollination on strawberry production in Australia. They used a pollination dependence value of 0.40 indicating that 40% of total yields were dependent on pollinating insects. The relative importance of managed and wild bees and other insects was not determined.

Terms used in pollination biology

Pollination is the transfer of pollen from the stamens to the stigma, the receptive area of the female reproductive tissues. There are various modes of pollination that apply to strawberry:

Autogamy or self-pollination usually refers to the transfer of pollen from the stamen to the stigma of the same flower. This can occur through the assistance of gravity or wind.

Geitonogamy refers to the transfer of pollen from the stamen of one flower to the stigma of another flower on the same plant. This can occur through the assistance of gravity, wind or insects.

Anemophily refers to pollination by wind.
Plants can be partially or exclusively anemophilous.

Entomophily refers to pollination by insects, such as bees, wasps and occasionally ants (*Hymenoptera*), beetles (*Coleoptera*), moths and butterflies (*Lepidoptera*), and flies (*Diptera*).

Connor and Martin (1973) examined the effect of different modes of pollination on fruit development in strawberry in Michigan in the United States. The results of their experiment indicate the importance of gravity, wind and insects on fertility. They found that self- and bee-pollination, self-, wind- and bee-pollination, and self-, wind- and all insect-pollination gave heavier fruit than self-pollination (gravity only) and self- and wind-pollination (Table 1). Wind, bees and other insects all increased achene (seed) development compared with self-pollination.

Table 1. Effect of pollination on average fruit weight and achene (seed) development in strawberry in Michigan. Means in a column followed by a common letter are not significantly different by the Fisher's least significant test at 5% level of significance. Data from Connor & Martin (1973).

Treatment	Fruit weight (g)	Percentage of achenes that were fully developed
Self-pollination (plastic screen)	5.5 a	51 a
Self + wind pollination (netted cages)	5.8 a	62 b
Self + insect pollination (plastic screen + bees)	7.2 b	68 c
Self + wind + bee pollination (netted cages + bees)	7.2 b	71 c
Open pollination (other insects + bees)	7.3 b	80 d

Strawberry flower components. Photo credit: Roman Samokhin

Strawberry flowers are attractive to bees and other pollinating insects. Photo credit: Christopher Menzel, QDAF

High levels of pollination are required to produce acceptable fruit quality and marketable yields. Photo credit: Jane Richter

Role of insects in the pollination of strawberry flowers

The importance of insect pollination on strawberry was assessed from the literature. Various indices of fertility were used to examine the importance of different modes of pollination, including yield, average fruit weight and the percentage of misshapen fruit.

In the first analysis, yields achieved with self-pollination were compared with those achieved when the flowers were exposed to pollinating insects under natural conditions (open pollination).

In the second analysis, yields achieved with additional insects such as beehives were compared with those achieved under open natural pollination.

In the first set of experiments, the flowers were bagged to exclude insects, or the plants were grown under insect-proof cages or greenhouses. Two types of bags were used across the different experiments. Paper bags prevented pollination by insects and the wind. Netted bags prevented pollination by insects but allowed pollination by the wind.

In the second set of experiments, the flowers were exposed to pollinators under natural open conditions or supplementary insects introduced into the greenhouses, tunnels or field plots.

Two-sided t-tests were used determine if the ratio of yield, etc. (self-pollination/open-pollination and additional insects/open-pollination) was significantly ($P < 0.05$) lower or higher than one. This would mean that self-pollination had lower or higher yields than open pollination. It would also mean that plants given additional pollinators had lower or higher yields than those exposed to natural open pollination.

The results showed that insect pollination was better than self-pollination (gravity and wind). Additional insects were better than open pollination under natural conditions.

The yields of plants not exposed to insects were 0.65 ± 0.25 (SD or standard deviation, $N = 47$) of those exposed to insects ($P < 0.001$). Average fruit weight was 0.71 ± 0.22 ($N = 53$, $P < 0.001$), while the incidence of misshapen fruit was 3.27 ± 1.90 higher in the plants not exposed to insects ($N = 38$, $P < 0.001$).

These results indicate that insect pollination was generally better than pollination due to gravity or wind.

Differences in the response across experiments are probably due to differences in the morphology of the flowers, with self-pollination more successful if most of the stamens (male parts of the flowers) are above the pistils (female parts of the flowers).

The yields of the plants exposed to additional insects such as beehives were higher than those exposed to pollinators under natural conditions ($\times 1.34 \pm 0.25$, $N = 19$, $P < 0.001$). Average fruit weight was also higher ($\times 1.11 \pm 0.22$, $N = 23$, $P = 0.031$), while the incidence of misshapen fruit ($\times 1.12 \pm 0.64$, $N = 10$, $P = 0.584$) was similar in the two groups of plants.

It is apparent that managed hives or the addition of wild bees or other insects can improve the productivity of commercial fields.

Implications for commercial strawberry production

- The results of this study show that the yields of strawberry were higher when the flowers were exposed to pollinating insects (open pollination) than when they were dependent on wind or gravity (self-pollination).
- Exposing the flowers to additional insects such as beehives, etc. also increased yields compared with those exposed to pollinators under natural conditions.
- The benefits of insect pollination vary with the cultivar, growing system and environment.
- Supplementary pollinators are often beneficial when plants are grown under tunnels or in greenhouses.
- Further experiments are required to determine the role of pollinating insects and bee management on the productivity of strawberry in different growing areas in Australia.

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